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Sales location among semi-subsistence cassava farmers in Benin: a heteroskedastic double selection model

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Abstract

In much of rural Africa, high transaction costs limit farmers' market participation and thus their potential for income growth. Transaction costs can affect not only whether a farmer sells product but also whether sales occur at the farm gate or at a market. If production behavior is related to a chosen sales location, then analysis of interventions can be improved by explicit consideration of the decision of where to sell. This article develops a double-selection model that explains consumption and production decisions by semi-subsistence farmers who first decide whether to be a seller and then whether to sell at the farm gate or at an off-farm location before deciding on production and consumption. The study tests the validity of this dual-criteria model against a single-criterion model in which a grower first decides to be a seller and then decides production, consumption, and sales location simultaneously. The results suggest that the dual-criteria model provides more information than the single-criterion model using a sample of cassava producer in Benin.

JEL classifications: D23, O12, Q12, Q13

Keywords: Dual-criteria; Transaction costs; Sales location; Agricultural supply response; Cassava, Benin

1. Introduction

Market participation is often considered central to raising incomes among semi-subsistence farmers, but high transaction costs keep many farmers from commercial production. Based largely on transactions costs, farmers self-select to produce for sale or purely for home consumption. If production and consumption decisions are made based on a prior decision of whether or not to market, then producers' response to changes in price or technology will vary systematically with market orientation. Though it is less frequently acknowledged, a farmer may make production and consumption decisions with an intention not to incur the costs associated with travel to market, but still intending to sell surplus from the farm gate. If there are sufficient fixed transactions costs (FTC) distinctly associated for sale at a market place, then short-run response to technology and price changes may vary systematically over farmers who have self-selected to sell off-farm, sell at the farm gate, or not sell at all. Recognition of these three categories of producers could contribute to improved understanding of supply response in Africa and better targeting of interventions.

This article distinguishes two types of sellers: on-farm sellers who sell output at the farm gate, and off-farm sellers who sell either at the market, another home, or an assembly point. Using data for cassava farmers in Benin, this article examines whether growers behave according to a *dual-criteria model* in which there are distinct decisions of whether to sell and where to sell before production and consumption decisions are made or apply a *single-criterion model* in which the sales location decision is made simultaneously with the production and consumption decisions, but after the decision to market. This study compares these models while correcting for heteroskedasticity in the selection equations, as recommended by Lahiri and Song (2000). Although the literature often focuses on sales quantity, this study examines production and consumption quantities to see whether estimated production and consumption relations differ substantively under the two models. When production

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Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article. Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting information supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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and consumption behaviors differ between on-farm and off-farm sellers, supply response to changes in market conditions or technologies may be different from what a single-criterion model would suggest.

Cassava farmers are an appropriate group for analyzing the effect of such sales location decisions for two reasons. First, transportation costs are likely to be relevant for crops like cassava whose bulk to value ratio is high (Takeshima, 2011). Second, although cassava is largely produced for own consumption, the benefits of technologies in the pipeline depend on growers' capacity to sell larger volumes. Our results support use of the dual-criteria model, implying that FTC associated with sales location may lead to different production and consumption responses across on-farm and off-farm sellers, though the difference in estimated coefficients between the single and dual-criteria models is small.

2. Supply response for semi-subsistence producers involving self-selection

Farmers' self-selection concerning whether or not to sell crops has long been studied. Strauss (1984) lays the groundwork for estimating production and consumption decisions for semi-subsistence agricultural households. Goetz (1992) applies the Heckman (1979) sample correction method to analyze how the marketed supply response is affected by the transactions costs involved with market participation. Several studies follow Goetz (1992) to incorporate unobserved transactions costs in estimating marketed supply response by employing the Heckman model (Heltberg and Tarp, 2002) or other methods (Bellemare and Barrett, 2006; Holloway et al., 2005; Key et al., 2000; Renkow et al., 2004).

In contrast to the market participation decision, few studies consider the transactions costs associated with sales off farm versus at the farm gate or that producer behavior might vary by chosen sales outlet. Fafchamps and Hill (2005) identify specific factors that predict whether a coffee grower will travel to market or sell at the farm gate. Those findings suggest the possibility that farm-gate sellers might respond differently to changes in price and other exogenous conditions than farmers that sell off-farm. Such a distinction would imply that production and consumption decisions are made after farmers decide whether to sell and where to sell. Analysis of the influence of transactions costs associated with sales location will be inconsistent if it ignores the role of costs associated with participation in the market at all. Comparison of the dual-criteria model against the single-criterion model can reveal whether there is a separate decision on market location as opposed to market orientation as would emerge if transactions costs associated with location affect production and consumption behaviors.

The dual-criteria model posits that there are different sources of fixed costs at each decision-making stage and thus two potential sources of sample selection bias. Empirical methods accommodating multiple selection criteria are appropriate to capture such characteristics. Such methods were introduced by Catsiapis and Robinson (1982) and Maddala (1983), and have been applied in several studies of issues other than agricultural supply (Vijverberg, 1995). Lahiri and Song (2000) extend a dual-criteria model by using heteroskedastic probit in the selection equations to correct inconsistencies due to heteroskedasticity.

Observed and unobserved FTC can affect farmers' marketing decisions in complex ways. Incorporating such complexity has been a recurrent aspect of the literature (Bellemare and Barrett, 2006; Holloway et al., 2005; Key et al., 2000; Renkow et al., 2004). Many of the methods applied in this literature are, however, infeasible in our data set and in the context of dual-criteria model. The data set in this study does not report the transportation costs for all off-farm sellers as in Bellemare and Barrett (2006) or Renkow et al. (2004), and it does not distinguish between fixed and variable costs as in Bellemare and Barrett (2006). In addition, it seems intractable to combine the dual-criteria structure in this study with methodologies used in Renkow et al. (2004) which estimates FTC as a function of explanatory variables simultaneously with supply and demand. Methods applied in Key et al. (2000) to allow thresholds for participation to vary across households and those developed in Holloway et al. (2005) which employ a Bayesian model to obtain robust estimates of the minimum sales quantity threshold also become intractable in the context of a dual-criteria model.

3. Conceptual framework

The conceptual model developed here posits a semi-subsistence cassava producer who first determines whether to remain autarkic or engage in markets as a buyer or a seller of cassava. This choice defines the farmer's market orientation (denoted M) as buyer, autarky, or seller.[1] These categories are exclusive such that a producer must belong to one and only one market orientation. Farmers that select to sell cassava then make a second decision on sales location (S), either selling from the farm gate (on) or selling off farm (off). An off-farm seller will receive the net revenue determined by the market prices, and variable transactions costs (VTC) incurred in bringing cassava to the sales point, and FTC associated with the off-farm sales location. The farmer selling from the farm gate will receive net revenue determined by the price from the trader to whom he or she sells, and FTC associated with the on-farm sales location. Prices at the farm gate are determined by off-farm market prices and the VTC of traders as well as surcharges for the traders' market power or risk premiums.

In a well-functioning market, a single-criterion model can explain a farmer's behavior as he or she is expected to sell on-farm if his or her VTC is higher than those of a trader, and change his or her sales location (S) depending on market conditions during the production period while adjusting production

[1] As in Key et al. (2000), this study simplifies the analysis by ignoring the case in which a cassava farmer both sells and buys.

and consumption to maximize utility. In an underdeveloped market, high FTC can arise when switching from selling on-farm to selling off-farm requiring a farmer to commit to a sales location in advance. If obtaining information about conditions in a sales outlet implies high FTC, farmers may try to optimize production, consumption, and sales based on conditions in only one outlet. In such cases, production levels based on a pre-determined sales location could rule out selling at the other location even if market conditions changed. Farmers' decisions on sales location (S) may be irreversible and thus lead to behavior which can be better explained by dual-criteria model.

In the dual-criteria model, a producer determines market orientation (M = autarky, buyer, or seller) at time $t = 0$; Sales location (S = on or off) is selected at time $t = 1$; and the quantity produced and consumed given M and S (q) is chosen at time $t = 2$. Periods $t = 0$ and $t = 1$ are defined to impose sequential decision making. Period $t = 0$ begins just prior to any production activity and lasts only as long as required to make the marketing decision. Similarly, $t = 1$ is of short duration and is completed before resources for production are allocated. Period $t = 2$ consists of the full production cycle and all consumption up to the moment just before another production cycle begins.

Utility is maximized over three periods based on the consumption of liquid wealth including cassava stock from previous harvest, and other goods at $t = 0$ and $t = 1$, and consumption of liquid wealth and cassava from the new harvest at $t = 2$. In Benin, cassava production may take up to six to nine months, and harvested cassava may be consumed well into the next production season past the planting time. We can however assume that old stocks of cassava for consumption have been exhausted by the time new cassava is harvested. We model farmers' decisions on cassava consumption from the new harvest at $t = 2$, while treating cassava consumption from previous harvest at $t = 0$ through $t = 2$ prior to the new harvest as part of liquid wealth.[2]

Building on Bellemare and Barrett (2006) and Key et al. (2000), a cassava producing and consuming household's utility maximization problem in a dual-criteria model is

$$\max_{I^M, I^S, q, c, x, c_w} u(C_0; C_1; C_2; \Xi) \tag{1}$$

subject to

$$R\left(p^{\text{off}}, \tau_v^{\text{off}}, m\right) \cdot I^{\text{off}} + \left[p^{\text{on}} I^{\text{on}} + p^{\text{buyer}} I^{\text{buyer}}\right] m + W_2 + T_2 - c_{w2} - \xi \geq 0, \tag{2}$$

$$W_1 = W_0 + T_0 - \sum_{M \in \{\text{seller, autarky, buyer}\}} \tau_f^M I^M - c_{w0} \geq 0, \tag{3}$$

$$W_2 = W_1 + T_1 - \sum_{S \in \{\text{off, on}\}} \tau_f^S I^S - c_{w1} \geq 0, \tag{4}$$

$$q - m - x - c \geq 0, \tag{5}$$

$$G(q,\ x,\ \xi) = 0, \tag{6}$$

$$c, x, q \geq 0, c_{wt} \geq 0\ (t = 0, \ldots, 2). \tag{7}$$

The measurement of utility u (C_t; Ξ) is a function of the vector of quantities of cassava and liquid wealth consumed in each period (C_t) and a vector Ξ of other determinants of utility. $C_t = (0, c_{wt})^\top$ at $t = 0, 1$, and $C_t = (c, c_{wt})^\top$ at $t = 2$ in which c_{wt} is the liquid wealth including cassava from previous harvest that are consumed in period t, and c is cassava consumed from current production cycle which is nonzero only in $t = 2$ ($\top$ denotes transpose). I^M and I^S equal to 1 to identify a producer's market orientation (M) and sales location (S). The variable I^M is the vector of all market regimes so that, $I^M = (I^{\text{seller}}, I^{\text{autarky}}, I^{\text{buyer}})^\top$. I^S is the vector of sales locations so that $I^S = (I^{\text{off}}, I^{\text{on}})^\top$ where $I^{\text{seller}}, I^{\text{autarky}}, I^{\text{buyer}}, I^{\text{off}}$, and $I^{\text{on}} \in \{0, 1\}$, $I^{\text{seller}} + I^{\text{autarky}} + I^{\text{buyer}} = 1$, and $I^{\text{on}} + I^{\text{off}} = I^{\text{seller}}$. $I^{\text{off}} = 1$ for farmers selling off farm and zero for buyers, autarkic growers, and farmers selling from on farm. The value of I^M is determined at $t = 0$, the value of I^S is determined at $t = 1$ and cassava production, inputs, and consumption (q, x, and c, respectively) are all determined at $t = 2$ given M and S.

Equation (2) states that at $t = 2$, revenues from cassava sales, liquid wealth, and other income must cover consumption c_{w2} and expenditures on cassava purchases as well as inputs for cassava production. For an off-farm seller ($I^{\text{off}} = 1$), income includes the revenue R from net marketed supply of cassava (m, negative if there are purchases), the off-farm sales price (p^{off}) and the VTC that the farmer incurs by taking cassava to the off-farm location (τ_v^{off}). For on-farm sellers ($I^{\text{on}} = 1$), income from cassava will equal the farm-gate price p^{on} times the sales volume m. For buyers, m will be negative and the unit costs on purchasing (p^{buyer}) will be determined by price at the purchase location and associated VTC. W_t is liquid wealth in the beginning of period t. T_t is exogenous transfers and other income at period t. Finally, ξ signifies the expenditure on inputs for cassava production other than seed cassava retained from previous harvest.

Equation (3) states that at $t = 0$, the farmer must have enough liquid wealth and other income to cover the FTC associated with the specific market orientation M (τ_f^M) and consumption c_{w0}, and the liquid wealth in the beginning of $t = 1$ (W_1) is the liquid wealth in the beginning of $t = 0$ (W_0) net $\sum_{M \in \{\text{seller, autarky, buyer}\}} \tau_f^M I^M$ and c_{w0}. The cost τ_f^M is incurred regardless of the eventual sales location for activities associated with establishing a household system in which cassava is a commercial crop, rather than a subsistence food source. Setting up such a system may require producing alternative food crops, purchasing food commodities, or searching for labor to market cassava all of which imply transactions costs that are independent of the sales location. Equation (4) sets an analogous constraint on the choice of sales location in period $t =$

[2] This is consistent with our data set in which cassava consumption is measured as the quantity consumed out of the most recent harvest, and does not include the quantity consumed prior to that harvest.

1 and consumption c_{w1}. The FTC associated with sales location, τ_f^S is incurred to cover advance expenses to operate in the market, learn about the expected conditions such as price levels and variability in different markets, learn about the expected transportation costs to distant markets, maintain a vehicle for transporting goods if selling off-farm, or find potential buyers if selling on-farm.

Resource constraint (5) requires that at $t = 2$ consumption (c), net sales (m), and use of inputs (x) must not exceed production q. The function $G(\cdot)$ in (6) represents the production technology that relates inputs with the outputs. Condition (7) specifies the boundaries for consumptions and production quantities.

The values of I^{M*}, I^{S*}, q^*, and c^* from (1) are obtained as reduced forms that are functions of the exogenous variables in (1)–(7). The formulation here can be used to develop empirical models for either a dual-criteria or single-criterion model. Modifying Bellemare and Barrett (2006), a dual-criteria model for cassava production and consumption decisions can be expressed as

$$I^{M*} = I(W_0, T_0, \tau_f^M, E_0) \quad \text{for all } M \text{ in \{Buyer, Autarky, Seller\}} \quad \text{at } t = 0, \tag{8}$$

$$I^{S*} = I(I^{M*}, W_1, T_1, \tau_f^S, E_1) \quad \text{for all } S \text{ in \{on, off\}at } t = 1, \tag{9}$$

$$(q^*, c^*) = Q(I^{M*}, I^{S*}, W_2, T_2, G(\cdot), p^S, \tau_v^{\text{off}}) \quad \text{at } t = 2 \tag{10}$$

in which E_0 represents the farmer's expectation at $t = 0$ on W_1, W_2, T_1, T_2, p^S, τ_f^S, τ_v^{off}, and $G(.)$, while E_1 represents the expectation at $t = 1$ on W_2, T_2, p^S,τ_v^{off}, and $G(.)$.

In contrast to the dual-criteria model, a single-criterion model implies that decisions at $t = 2$ are combined into decisions at $t = 1$ so that

$$I^{M*} = I(W_0, T_0, \tau_f^M, \underline{E}_0) \quad \text{for all } M \text{ in \{Buyer, Autarky, Seller\} at } t = 0, \tag{11}$$

$$(q^*, c^*) = Q(I^{M*}, W_1, T_1, T_2, G(\cdot), p^{\text{on}}, p^{\text{off}}, \tau_v^{\text{off}}, \tau_f^S) \quad \text{at } t = 1 \text{ and } 2 \tag{12}$$

in which $\underline{E}_0$ represents expectation at $t = 0$ on W_1, T_1, T_2, p^{on}, p^{off}, τ_f^S, τ_v^{off}, and $G(.)$. The differences between dual-criteria and single criterion models are that (10) includes I^{S*} but not τ_f^S whereas (12) includes τ_f^S but not I^{S*}. Intuitively, a producer facing a larger fixed costs associated with sales location (τ_f^S) is unlikely to change his sales location S after allocating inputs for q^* and planning c^*, which is better explained by (10). In contrast, a producer facing a smaller τ_f^S may benefit more from being able to switch between possible sales locations and adjust q^* and c^* accordingly, which is better explained by (12). Empirical comparison of (8) thorough (10) with (11) and (12) can determine whether a dual-criteria model better explains the behavior of cassava producers than a single-criterion model.

The dual-criteria model considers distinct transactions costs associated with market orientation and sales location, by assuming that market orientation, sales location, and production decisions are made sequentially. The single criterion model merges the location and production or consumption decisions. A third variation could allow farmers to make market orientation and sales location decisions simultaneously before allocating resources for production. Allowing simultaneous decision-making on market participation and sales location at $t = 0$, followed by production decisions at $t = 1$ implies a *simultaneous model*. Our empirical analysis includes comparison of this simultaneous model with the single-criterion model to see whether the implication of sales location decisions from dual-criteria model is robust.

4. Estimation of the model

4.1. Model specification

This study applies the dual-λ approach suggested by Catsiapis and Robinson (1982) and Maddala (1983) and extended in Lahiri and Song (2000) as it is free from assumptions of independence of irrelevant alternatives required in a conditional logit model and more informative than a nested logit model (Vijverberg, 1995). A heteroskedastic ordered probit is used for the selection Eq. (8) which assigns buyer = 0, autarky = 1, and seller = 2, and a heteroskedastic probit is used to estimate (9) which assigns on-farm seller = 0 and off-farm seller = 1. Following Alvarez and Brehm (1998), the heteroskedastic ordered probit is expressed as

$$\begin{aligned}
\Pr(i = \text{buyer}|\psi_i,\ \pi_i) &= \Phi\left[(\alpha_1 - \psi_i\gamma)/\exp(\pi_i\omega)\right]\\
\Pr(i = \text{autarky}|\psi_i, \pi_i) &= \Phi\left[(\alpha_2 - \psi_i\gamma)/\exp(\pi_i\omega)\right]\\
&\quad - \Phi\left[(\alpha_1 - \psi_i\gamma)/\exp(\pi_i\omega)\right]\\
\Pr(i = \text{seller}|\psi_i, \pi_i) &= 1 - \Phi\left[(\psi_i\gamma - \alpha_2)/\exp(\pi_i\omega)\right]
\end{aligned} \tag{13}$$

and following Alvarez and Brehm (1995) the heteroskedastic probit is represented by

$$\begin{aligned}
\Pr(i = \text{on-farm seller}|\Psi_i, \Pi_i) &= 1 - \Phi\left[(\Psi_i\Gamma)/\exp(\Pi_i\Omega)\right]\\
\Pr(i = \text{off-farm seller}|\Psi_i,\ \Pi_i) &= \Phi\left[(\Psi_i\Gamma)/\exp(\Pi_i\Omega)\right]
\end{aligned} \tag{14}$$

in which probability that a producer belongs to each regime is a function of explanatory variables ψ_i, π_i, Ψ_i, Π_i and estimated coefficients α_1, α_2, γ, ω, Γ, and Ω. The symbol Φ is standard normal distribution function, α_1 is the estimated border between buyer and autarky, and α_2 is the border between autarky and seller. Estimates from (13) are used to calculate the Inverse Mills Ratios (IMRs) $\hat{\lambda}_i$ for farmer's self-selection on market orientation. The probit estimation (14) then includes $\hat{\lambda}_i$ among the regressors Ψ_i. Estimates from (14) are used to calculate another IMR $\hat{\mu}_i$ for the seller's self-selection on sales location.[3]

Once the selection estimates are complete, the production and consumption of cassava can be estimated using (15) and (16) to operationalize (10). More specifically, if $(M, S) =$ (sell, on) then (15) obtains, whereas (16) is relevant if $(M, S) =$ (sell, off), where (15) and (16) are

$$\{q^*, c^*\} = (p^{\text{on}},\ Z,\ \hat{\lambda}_i, \hat{\mu}_i) \text{ for on-farm sellers,} \tag{15}$$

$$\{q^*, c^*\} = (p^{\text{off}},\ Z,\ \tau,\ \hat{\lambda}_i, \hat{\mu}_i) \text{ for off-farm sellers.} \tag{16}$$

Here, Z is a set of exogenous variables that affect production and consumption, and τ is a set of variables that affect the seller's VTC (τ_v^{off}). Equations (15) and (16) are estimated separately using two-stage least squares (2SLS) because income, which is included in Z, is potentially endogenous.

Equations (13)–(16) are based on a premise of dual-criteria decision making. If the single-criterion model is appropriate then (14) is dropped and (15) and (16) are replaced with

$$\{q^*, c^*\} = (p^{\text{off}},\ Z,\ \tau,\ \delta,\ \hat{\lambda}_i). \tag{17}$$

Under the single-criterion model, farmers will act based on p^{on} or p^{off} depending on where they choose to market. Because p^{on} is largely determined by p^{off} and the distance from the farm gate to the sales outlet, (17) posits that production and consumption are consistently estimated as functions of p^{off} which is an instrument for the endogenously chosen price, combined with distance to sales outlet and other household characteristics. In our data, on-farm sellers report only the on-farm price and a distance to sales outlet of zero. We therefore calculate the village average off-farm prices reported by off-farm sellers residing in the same village, as the proxy for p^{off} for the on-farm sellers, while using the actual p^{off} for off-farm sellers. Similarly, we calculate the village average distance to the market for off-farm sales outlet as a proxy for distance to market for on-farm sellers. The set of variables δ are not included in Z, but are expected to affect τ_f^S. These variables include Ψ_i and Π_i in (14) and τ in (16). By construction, Eq. (17) contains τ not only for off-farm sellers but also for on-farm sellers.

These two models are compared using a J-test (Davidson and MacKinnon, 1981) to see which model better explains behavior.[4] This nonnested test is used because each model contains explanatory variables that do not appear in the other. The IMR $\hat{\mu}_i$ in (15) and (16) do not appear in (17). Likewise, variables δ that are in neither (15) nor (16) appear in (17). Consistent confidence intervals of estimated coefficients are obtained through bootstrapping (see Appendix B for details) for (14) through (17) as they contain $\hat{\lambda}_i$ and $\hat{\mu}_i$, which are predicted variables.

4.2. Selection of variables

Table 1 summarizes the variables used in each equation and their expected signs. In a rural African setting, information cost is high and other costs are often determined by farmers' opportunity costs in addition to exogenously determined costs. Most parameters described in (8)–(12) including farmers' expectations E_0, E_1, and $\underline{E}_0$ may be reflected in observable household characteristics. For example, experience or education level may affect the ability to form accurate expectations, while some remote farmers may have vague expectations at best. Many parameters in (8), (9), and (11) are therefore expressed by the set of household characteristics, instead of actual market conditions.

The vector ψ_i (affecting the decision to sell instead of staying autarkic, and become autarkic instead of buying) includes age of household head, dependency ratio,[5] total value of household assets (U.S. dollars), distance in kilometers to cassava plots, cooperative member (yes = 1), size of storage space inside the warehouse (tons), storage space inside the house and attic or rafters (tons), years of education of household head, distance in kilometers to nearest phone service, distance in kilometers to nearest paved road, household size, gender of household head (1 = female), total farm size (ha), access to credit (yes = 1),[6] and regional dummies. Age, assets, and membership in a cooperative may reduce (increase) the probability of being a cassava seller (buyer) instead of being autarkic, as they suggest more capacity to produce commercial crops other than cassava.

Similarly those residing far from the plots may be less (more) likely to sell (buy) cassava than remain autarkic due to high production costs. Distance from a paved road implies isolation from markets which may discourage farmers from selling cassava. However, cassava producers who are more removed from larger markets may be more likely to buy additional cassava products whenever the traders are there or whenever another isolated farmer is in surplus to ensure regular access to food. Distance to mainline phone suggests isolation from market information and may have similar but reverse effects to isolation from markets themselve. Farmers residing close to phone services may have better opportunities to sell higher value commodities than cassava and may find it easier to buy cassava than remain autarkic. Farmers residing further from phone service and having less market information are expected to focus on production for

[3] $\hat{\lambda}_i = \frac{\phi\{-(\psi_i\hat{\gamma}-\hat{\alpha}_2)/\exp(\pi_i\hat{\omega})\}}{\Phi\{-(\psi_i\hat{\gamma}-\hat{\alpha}_2)/\exp(\pi_i\hat{\omega})\}}$ from ordered probit in which φ is standard normal density function. For an off-farm seller, $\hat{\mu}_i = \frac{\phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}{\Phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}$ and for on-farm seller $\hat{\mu}_i = -\frac{\phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}{1-\Phi\{\Psi_i\hat{\Gamma}/\exp(\Pi_i\hat{\omega})\}}$.

[4] As a robustness check, the simultaneous model is also estimated and compared with the other two models using J-test (see Appendix A for details of this estimation).

[5] Dependency ratio is measured as the number of household members younger than 15 years and older than 59 years divided by the number of household members between 15 and 59.

[6] Access to credit is measured by whether at least one household member belongs to rotating credit society.

Table 1
Variables included in each equation and their expected signs

	Heteroskedastic ordered probit		Heteroskedastic probit		Production		Consumption	
					On farm	Off farm	On farm	Off farm
	ψ	π	Ψ	Π				
Age of household head	−							
Dependency ratio	−							
Total asset (U.S. $)	−							
Distance to plot (km)	−							
Cooperative membership (yes = 1)	−							
Storage in warehouse (1,000 t)	+							
Storage inside house (1,000 t)	+		−					
Storage in attic (1,000 t)	+		+					
Household head education (year)	+	?	−	?	+	+	+	+
Distance to paved road (km)	−	?	+	?	+	+	+	+
Distance to phone (km)	−		+		+	+	+	+
Gender of head (female = 1)	−				+	+	+	+
Household size	−				+	+	+	+
Total Farm size (ha)	+				+	+	+	+
Access to credit (yes = 1)	−				−	−	+	+
Own truck/car/motorcycle			+			+		−
Own bicycle			+			+		−
Distance to sales point						−		+
ln (price)					+	+	−	−
Total income					+	+	+	+
λ			?		?	?	?	?
μ					?	?	?	?
Gift							+	+

Note: Regional dummies are not shown.

own consumption and be less likely to buy cassava and remain autarkic, but be more likely to sell cassava when in surplus rather than have higher value products for sale.

Cassava producers with larger households and higher dependency ratios and female heads may be less (more) likely to be sell (buy) cassava than remain autarkic due to their large home consumption. On the other hand, those with more storage space, more educated household heads, and larger farms may be more (less) likely to sell (buy) than remain autarkic due to their higher capacity for cassava production and marketing, and for meeting household cassava consumption.

The decision on market orientation is also likely to be influenced by place of residence. Fig. 1 shows the six administrative regions in Benin as of 1997 and the distribution of population. Although some local markets exist in regions 1 and 3, population and consumer markets in Benin are concentrated in regions 2, 4, and 5. Location in regions 1, 3, and 6 is thus expected to reduce the likelihood of selling cassava due to isolation from markets. Farmers in these regions, however, may be more likely to buy cassava than remaining autarkic due to the purchase driven by the fear of the lack of easy regular access to cassava market, which is similar to the factors mentioned earlier. Meanwhile, regions 2, 4, and 5 have relatively fertile soils (Jagtap, 1995; Manyong et al., 1996) in addition to market access. Location in these regions is expected to raise (lower) the likelihood of selling (buying) cassava rather than remaining autarkic.

The vector Ψ_i (affecting sales location) includes size of storage space inside the house (tons) and in the attic or rafters (tons), education, phone, paved road, ownership of car/truck/motorcycle (1 = yes), ownership of a bicycle (1 = yes), and regional dummies. Off-farm sellers tend to sell dried tuber or flour which are lighter and less bulky than fresh tubers

Fig. 1. Pre-1999 six administrative regions and population densities in Benin (higher density is indicated by darker color).

and can be stored in the attic or rafters. More storage space in the attic may enable sellers to produce for off-farm sale. Those with less education and poor proximity to a paved road or phone service may tend to be off-farm sellers due to reduced chance of contact with a buyer at the farm gate. Those who own means of transportation may be more likely to be off-farm sellers. Regional dummy variables are used to reflect environmental and socioeconomic factors that affect both market orientation and market location but are not otherwise observed in the data.[7]

The vectors π_i and Π_i distinguish differences across farmers regarding sensitivity to idiosyncratic shocks in their decisions on whether and where to sell. Such shocks might include sudden sickness, unanticipated increases in school fees, or unexpected delay or completion of road improvements. Standard ordered probit does not capture differences associated with such idiosyncratic shocks. Here, a more positive $\pi_i\omega$ means the cassava farmer i is less sensitive to idiosyncratic shocks when changing market orientation, as would be expected if the farmer faced higher transactions costs. Similar arguments hold for the choice between seller types in (14). The vectors π_i and Π_i include education and distance to paved road. Greater education may make producers more sensitive to idiosyncratic shocks when choosing their regime because of their knowledge for appropriate responses to such shocks and sufficient resources for a response, or less sensitive if higher education levels indicate higher opportunity costs of time needed to change their regimes. Proximity to a paved road may make farmers more sensitive due to relative ease of identifying potential buyers or sellers, or less sensitive if proximity to paved road indicates stronger ties with a specific buyer (seller).

While some recent studies incorporate monetary fees to account for FTC (Bellemare and Barrett, 2006), our selection equations include only household characteristics. Absence of explicit monetary costs in the selection equations is justifiable because much of τ_f^M and τ_f^S are likely to be nonmonetary opportunity costs of household labor rather than explicit monetary expenses. These FTCs consist mostly of opportunity costs and are determined more by household characteristics than explicit monetary costs.

Production and consumption equations are each affected by the same variables. Production and consumption of off-farm sellers may additionally be affected by their ownership of transportation means and distance to sales point, which affect the VTC. Generally, cassava production and consumption may be higher for producers with higher education, female household heads who tend to engage in food crops than cash crops, larger households with more labor and food consumption, larger farms, and higher incomes which enable the use of better production technologies. Cassava production and consumption may be higher for households residing far from a paved road or mainline phone service since remoteness can depress access to information that could affect production and consumption of more commercial crops or crops with different nutritional benefits than cassava. Better access to credit may also lower production if it encourages production of more profitable crops than cassava. A dummy variable *gift* is included in the consumption equation for households that use cassava as gifts or substitutes for cash payments as it is a common practice and reflects exogenous social structure that affects cassava demand in households. Storage space inside the house and attic are included in Ψ but not in the production and consumption equations in the dual-criteria model; they are included in production and consumption equations in single-criterion model to represent some of the τ_f^S in Eq. (12).

In dual-criteria mode, household characteristics such as age, dependency ratio, assets, distance to plot, cooperative membership, and storage spaces only affect market orientation or sales location and not production or consumption.[8] Distance to plot may not affect production or consumption because once farmers decide to be sellers, they may reallocate household labor to minimize costs of carrying cassava from the plot to the storage facility. Similarly, cooperative membership may not affect production or consumption because cassava production does not require access to fertilizer or other services of cooperatives. Finally, storage space may not affect production or consumption because households have already chosen sales locations appropriate for the space and type of storage they have. Moreover, cassava for home consumption can be stored in the ground and harvested when needed.

Household income is included in the production and consumption equations but may not affect market orientation and sales location decisions. Although market orientation decisions partly reflect a household's need for earning cash income, assets, and age of the household head reflect long-term earning potential and may have more influence on the market participation decisions than current income.

Administrative regional dummies are included to capture other location-specific differences in production and consumption behaviors that may not be captured by other variables. Aforementioned location-specific factors affecting the market participation decisions may also differentiate the production conditions across different administative regions. Importance of cassava in household diet may also differ across each administrative region, thus justifying their inclusions into consumption equation.[9]

[7] Regional dummy variables represent the administrative boundaries rather than agro-ecological zones. Using regional dummy variables therefore may not capture the full characteristics of agro-ecological factors that affect cassava producers' behavior. These administrative regions, however, roughly make up three distinct zones in Benin, namely South (regions 2, 4, and 5), Central (region 6), and North (regions 1 and 3). Regional dummy variables can therefore capture the key differences across agro-ecological zones on their effect on market participation. In addition, regional dummies can capture the differences within the same zones. For example, as indicated in Kherallah et al. (2001b), regions 2 and 5 play different roles as cassava flows predominantly from regions 5 to 2 but not in the reverse direction.

[8] These variables are statistically insignificant when included in the production and consumption equations.

[9] For example, "in Ouémé [region 5], the most important items in the food budget are [. . .] cassava flour. Ouémé leads the other [regions] in its spending on [. . .] cassava flour" (Kherallah et al., 2001a, p. 90).

Poorly served by transportation and communications infrastructure, many smallholder farmers cannot ascertain prices accurately until they become sellers. Thus, this study assumes that in a dual-criteria model, market participation and sales location decisions are made independently of the sales price. Several studies either find no statistically significant effect of sales price on participation decisions (Alene et al., 2008; Goetz, 1992; Heltberg and Tarp, 2002), or do not include the sales price variable in the analyses of decision making at all (Bellemare and Barrett, 2006; Fafchamps and Hill, 2005; Key et al., 2000). These approaches and empirical findings as well as the physical infrastructure in Benin, suggest that the sales price of cassava need not be included in the selection equations in this study. We tested the significance of price in the market orientation and sales location decisions by using the average prices calculated for villages with at least one seller and found that price was statistically insignificant in both cases.[10] Prices are included in the production and consumption models, but given the poor quality of market information the impact of prices is not expected to be robust.

5. Data

5.1. Descriptive statistics

This article uses data from the Benin Small Farmer Survey[11] collected by the International Food Policy Research Institute (IFPRI) and the Laboratoire d'Analyse Regionale et d'Expertise Sociale (LARES). The data set contains information on the economic activities of 899 Benin agricultural households during the 1997 production season. Table 2 summarizes descriptive statistics from the survey. Among 899 households, 559 report the quantity of cassava harvested. Of the 559 cassava-producing households, this study drops households that are both sellers and buyers of cassava, leaving 541 cassava, of which 194 are sellers (125 on-farm sellers and 69 off-farm sellers), 274 are autarkic households and 73 are buyers. Estimation of (15) and (16) is based on a sample of 118 on-farm sellers and 62 off-farm sellers for production and 112 and 61 for consumption. This smaller sample size for (15) and (16) reflects missing data for some households as well as households that report unrealistically large production and consumption quantities given the area planted. Estimation of (17) is based on a sample of 132 for production and 126 for consumption, which are further reduced from the samples for (15) and (16) by keeping only observations for which the data for off-farm price can be obtained.

Contrasts between the characteristics of on-farm and off-farm sellers motivate the comparison of single-criterion and dual-criteria models. These differences could indicate that sellers respond optimally to different conditions in markets with different characteristics, as in single-criterion model. However, the differences could imply that location and distance to infrastructure constrain sellers' capacity to choose optimal sales locations given their production technology or preferences, which is more consistent with dual-criteria model. Most on-farm sellers are closer to more developed infrastructure and mostly sell fresh tubers. Most of off-farm cassava sellers are far from developed infrastructure and sell dried tubers or flour. To make different forms of cassava comparable with each other, 1 kg of dried tuber quantity and 1 kg of flour was converted into 3.3 ($=$ 1/0.3) and 6 kg of fresh-tuber equivalent quantity, respectively, using conversion rate suggested in Zeddies et al. (2001), and price differences between flour and cassava roots reported from Thailand in FAO (2009).[12]

In close proximity to reliable road infrastructure, traders with vehicles are likely to have lower unit costs than less capitalized farmers. This cost advantage is likely to be greater for bulkier products (like fresh cassava) and to diminish in areas farther away from road. Thus, the result that more isolated farmers are less likely to sell on-farm, if they sell, is consistent with the likely differential transactions costs between farmers and traders. Remoteness from a road may thus explain farmers' decision on sales location while their market orientation may only be explained by remoteness from a major market, which is implied by their region.

5.2. VTC in single-criterion model

Although τ_v^{off} in (16) and (17) is unobserved in our model and the estimates may be biased due to omitted variable problems, such bias could be substantially reduced if these variables are correlated with other explanatory variables included in the estimation.

The set of variables representing transactions costs, τ, in (16) are identified by regressing the VTC for each transaction reported by off-farm sellers on a set of potentially related variables as suggested by Vakis et al. (2003) and Henning and Henningsen (2007).[13] Results are shown in Table 3. Distance

[10] We calculated a crude measure of village-average farm gate price (fresh tuber equivalent) for villages where at least one on-farm seller reported farm-gate price. Using the reported price for on-farm sellers and calculated village average price for other producers in each corresponding village, we obtained approximate measurement of farm-gate fresh tuber prices for 212 producers. We then ran a heteroskedastic ordered probit model adding the price variables to the specification in this article. Results showed the price was statistically insignificant with P-value of 0.607. Using a similar approach, we calculated the fresh-tuber cassava price at the off-farm market. Adding the off-farm market price and farm-gate price to the specification in this article, we ran a heteroskedastic probit model for 116 producers for which both prices could be constructed. Both prices were jointly statistically insignificant with P-value of 0.367.

[11] Benin: small farmer survey, 1998. 2004. Washington, DC: International Food Policy Research Institute (IFPRI)(data sets). Available at: http://www.ifpri.org/data/benin01.htm.

[12] Main conclusions of the article and results are robust to slight changes in these conversion rates.

[13] While Vakis et al. (2003) use the predicted value of VTC in the production and consumption equations, this article uses the explanatory variables that affect VTC with statistical significance, but not the predicted VTC itself due to the complexity in obtaining consistent standard errors of Eqs. (8)–(10).

Table 2
Summary statistics of cassava producing households

	Total		On-farm seller		Off-farm seller		Autarky		Buyer	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Production (t/year)										
Fresh tuber	5.3	(8.0)	6.5	(8.8)	2.4	(3.1)	0.4	(0.8)	3.5	
Dried tuber	0.6	(0.7)	1.8	(1.6)	0.9	(0.7)	0.5	(0.6)	0.3	(0.2)
Flour	3.6	(7.2)	0.7	(0.5)	4.9	(8.2)	0.1	(0.1)	0.3	
Consumption (t /year)										
Fresh tuber	0.9	(1.5)	1.0	(1.3)	1.0	(2.4)	0.4	(0.8)	3.5	
Dried tuber	0.5	(0.5)	1.0	(0.9)	0.5	(0.3)	0.5	(0.6)	0.3	(0.2)
Flour	0.5	(0.9)	0.2	(0.1)	0.7	(1.1)	0.1	(0.1)	0.3	
Age	45.9	(13.6)	44.4	(13.9)	46.0	(13.3)	46.0	(13.7)	48.0	(12.9)
Dependency ratio	1.3	(1.0)	1.3	(1.0)	1.1	(0.9)	1.3	(1.0)	1.2	(0.7)
Total asset (U.S.$1,000)	1.0	(2.1)	0.5	(0.7)	0.8	(2.2)	1.2	(2.3)	1.4	(2.8)
Education (year)	1.8	(3.2)	2.9	(3.7)	1.7	(2.9)	1.2	(2.7)	2.2	(4.0)
Household size	9.1	(5.1)	8.0	(4.3)	8.6	(5.3)	9.6	(5.4)	9.7	(4.8)
Female head (%)	4.8		3.8		6.9		4.2		6.8	
Total farm size (ha)	5.2	(5.0)	2.9	(2.8)	3.4	(3.0)	6.7	(5.6)	5.6	(5.4)
Income (U.S.$1,000)	1.4	(1.8)	1.5	(2.0)	1.6	(2.3)	1.4	(1.5)	1.2	(1.5)
Storage capacity (t)										
Inside house	1.6	(3.3)	1.3	(2.8)	1.5	(4.2)	1.8	(3.4)	1.3	(2.5)
Attic	2.6	(5.8)	0.9	(2.4)	3.4	(12.6)	3.2	(4.0)	2.3	(4.4)
Warehouse	3.4	(18.8)	0.3	(1.3)	10.2	(43.1)	3.7	(14.5)	1.3	(33.2)
Distance (km) to										
phone service	19.9	(21.1)	9.7	(8.0)	19.8	(29.2)	25.3	(21.6)	18.0	(18.7)
paved road	24.7	(29.8)	7.3	(7.5)	16.0	(15.4)	31.4	(33.7)	38.5	(33.2)
plot	3.6	(9.7)	4.6	(18.7)	3.3	(5.6)	3.4	(3.4)	2.7	(3.0)
cassava sales point					26.7	(94.4)				
Percentage of household										
credit access	52.9		77.3		66.7		42.8		35.1	
cooperative	59.0		35.6		40.3		70.7		74.3	
own car/truck/motorcycle	28.1		34.4		23.6		28.4		20.3	
own bicycle	70.6		58.3		68.1		76.0		74.3	
Percent of income from cassava sales	16.2	(15.4)	14.1	(12.4)	20.0	(19.5)				
Percent of income from crop sales	60.3	(32.4)	48.4	(28.3)	61.8	(33.4)	65.3	(32.0)	61.2	(34.7)

Note: Age and education are of the household head. Numbers in parentheses are standard deviations.

traveled may be endogenous to the VTC since a cassava seller chooses travel distance to maximize profit, which partly depends on VTC. Table 3 presents results from estimations using OLS and 2SLS instrumenting the distance and squared distance to the sales point.[14] Results from the two approaches are substantively equivalent.

The effect of the distance to sales point on VTC is positive and decreasing in the relevant sample range. The education of household head and proximity to nearest phone service may lower VTC, possibly due to more knowledge of cheapest means for transport or lower cost of finding such means. Based on the results in Table 3, distance to sales point and squared distance to sales point, as well as education and distance to phone service are expected to capture τ in (16) to reflect VTC for all farmers in the sample.

[14] Excluded instrumental variables (IVs) used are distance to paved road, ownership of bicycle, and household assets. Both squared distance to paved road and assets are included to instrument squared distance traveled. Distance to paved road will affect the travel distance, but may not affect the VTC if actual distance traveled is controlled for. Ownership of bicycle may also be good IV. While it affects the distance traveled, it may not affect VTC once distance is controlled for. (On the other hand, ownership of car, truck, or motorcycle is included in the equation so it is not an excluded IV, as it may affect VTC even after the traveled distance is controlled for. For example, different sized cars and trucks can carry substantially different quantities of cassava, so that per unit transaction costs can be quite different.) Household assets may have general effects on the sellers' ability to travel long distances.

6. Results

The primary goal of this article is to empirically test whether the dual-criteria model explains cassava producers' behavior better than a single-criterion model based on results of a *J*-test. This section briefly interprets the results of the dual-criteria and single-criterion models and then discusses the test results and policy implications. The results of simultaneous model are similar to the dual-criteria model and thus only the results of the *J*-test are presented.

Table 3
Estimated log of transportation costs per sales

ln (Transportation costs (U.S. dollars) per kg of sales)	OLS		2SLS	
	Coefficient	Std. err.	Coefficient	Std. err.
Potentially endogenous variables				
Distance to sales point (10 km)	0.276***	(0.083)	0.290**	(0.134)
Distance to sales point (10 km) squared	−0.003***	(0.001)	−0.004**	(0.002)
Exogenous variables				
Cooperative membership (yes = 1)	−0.332	(0.277)	−0.334	(0.289)
Household head education (years)	−0.121***	(0.046)	−0.134***	(0.049)
Distance to phone (km)	0.010*	(0.006)	0.012*	(0.006)
Own truck/car/motorcycle	−0.214	(0.304)	−0.147	(0.358)
λ	0.765	(0.640)	0.889	(0.788)
μ	1.687**	(0.756)	1.622**	(0.898)
Region 2	−0.757	(0.652)	−0.594	(0.684)
Region 4	0.310	(0.592)	0.446	(0.617)
Region 5	−1.300	(0.787)	−1.069	(0.828)
Constant	−6.503	(0.780)	−6.706***	(1.025)
P-value (overall significance)	< 0.0005		< 0.0005	
P-value				
H_0: Underidentified			< 0.0005	
H_0: Not overidentified			0.235	
R^2	0.525		0.500	
No. of observations	54	54		

Significance levels: ***1%, **5%, and *10%, respectively.

6.1. Estimation of market orientation and sales location

The heteroskedastic-ordered probit estimation (13) includes household characteristics and factors that affect access to marketing. Table 4 presents coefficients α, γ (affecting marketing decisions), and ω (reflecting heteroskedasticity) from (13). Results from a standard ordered probit are reported for comparison. Similarly, in Table 5, the coefficients in Γ and Ω from (14) are shown under "heteroskedastic probit," with standard probit results reported for comparison. The test statistics (P-value) in Tables 4 and 5, based on a Lagrange Multiplier test, indicate heteroskedasticity in standard ordered probit model (P-value $<$ 0.0005), which justifies the use of heteroskedastic ordered probit, while homoskedasticity in the probit is not rejected (P-value = 0.425).

The market participation decision by cassava producers seems to be influenced by the region of residence through socioeconomic or environmental characteristics such as soil fertility, as suggested in previous sections. Cassava producers in regions 1, 3, and 6 are less (more) likely to sell (buy) cassava than remain autarkic. Cassava producers in regions 2, 4, and 5 with relatively fertile soil are more (less) likely to sell (buy) cassava than remain autarkic. Coefficients for regions 2, 4, and 5 are also different from each other at P-value < 0.0005 based on Wald test, indicating possible effect of different consumer preferences across these regions on market participation decisions. Greater distance to a mainline phone service seems to increase (reduce) the likelihood of selling (buying) as opposed to being autarkic. Cassava farmers residing closer to the paved road are more (less) likely to be sellers (buyers) than be autarkic, which is also consistent with our expectations. Those who live near the paved road also seem less sensitive to idiosyncratic shocks in changing their market orientation possibly because sellers and buyers have stronger and more stable relationships. Membership in cooperatives seems to lower (raise) the likelihood of being a cassava seller (buyer) than being autarkic as cooperative members may have more opportunity to sell other crops.

Based on Table 5, a seller with higher education may be more likely to be on-farm seller due to higher opportunity costs of traveling to off-farm market for sales. Similarly, results in standard probit indicate that a seller closer to paved road is more likely to be an on-farm seller, possibly due to higher chance of having buyers with vehicles traveling to the farm, although they are statistically insignificant in heteroskedastic probit. A statistically significant λ indicates that idiosyncratic shocks that raise (lower) the likelihood of cassava farmers becoming sellers (buyers) also raise the likelihood that they become off-farm sellers rather than on-farm sellers. Although heteroskedastic error terms were found statistically insignificant, their inclusion improves the consistency of the results.

6.2. Production and consumption decisions

Tables 6–8 present the results of cassava production and consumption Eqs. (15)–(17). Discussion of results is primarily concerned with comparing overall capacity of the two models to explain cassava producers' behavior, but also highlights differences in the implications of the results across the models.

Table 4
Ordered probit results (buyer = 0, autarky = 1, seller = 2)

	Standard ordered probit		Heteroskedastic ordered probit	
	Coefficient gamma (γ)	Std. err.	Coefficient gamma (γ)	Std. err.
Age of household head	0.001	(0.004)	−0.001	(0.004)
Dependency ratio	0.019	(0.057)	0.002	(0.050)
Total asset (U.S.$1,000)	0.007	(0.032)	−0.006	(0.022)
Distance to plot (km)	0.018	(0.015)	0.015	(0.015)
Cooperative membership (yes = 1)	−0.231*	(0.130)	−0.252**	(0.116)
Storage in warehouse (1,000t)	0.009**	(0.004)	0.006	(0.004)
Storage inside house (1,000 t)	0.009	(0.017)	0.002	(0.016)
Storage in attic (1,000 t)	0.014	(0.011)	0.013	(0.010)
Household head education (year)	−0.037**	(0.019)	−0.017	(0.023)
Distance to paved road (km)	−0.006***	(0.002)	−0.004**	(0.002)
Distance to phone (km)	0.009***	(0.003)	0.009***	(0.003)
Gender of head (female = 1)	−0.327	(0.262)	−0.260	(0.190)
Household size	0.004	(0.014)	0.002	(0.012)
Total farm size (1,000 ha)	−0.020	(0.016)	−0.012	(0.015)
Access to credit (yes = 1)	−0.027	(0.128)	−0.069	(0.114)
Region 1	−0.266	(0.232)	−0.293*	(0.173)
Region 2	2.404***	(0.259)	2.194***	(0.260)
Region 3	−0.149	(0.179)	−0.131	(0.157)
Region 4	0.873***	(0.225)	0.878***	(0.227)
Region 5	1.667***	(0.198)	1.431***	(0.178)
a_1	0.974***	(0.310)	0.890***	(.274)
a_2	2.134***	(0.114)	1.814***	(0.156)
Heteroskedasticity specification			Coefficient omega (ω)	Std.err
Household head education (year)			0.028	(0.021)
Distance to paved road (km)			−0.009***	(0.003)
Log-likelihood	−379.090		−370.899	
P-value (overall significance)	<0.0005		<0.0005	
P-value (Homoskedasticity)	<0.0005			
No. of observations	541		541	

Significance levels: ***1%, **5% , and *10%, respectively.

Table 5
Probit results (On-farm seller = 0, off-farm seller = 1)

	Standard probit		Heteroskedastic probit	
	Coefficient GAMMA (Γ)	90% confidence interval (CI)	Coefficient GAMMA (Γ)	90% CI
Storage inside house (1,000 t)	−0.009	[−0.124, 0.066]	−0.006	[−0.207, 0.128]
Storage in attic (1,000 t)	0.014	[−0.027, 0.241]	0.012	[−0.059, 0.850]
Household head education (year)	−0.083*	[−0.192, −0.007]	−0.158*	[−0.566, −0.004]
Distance to paved road (km)	0.051***	[0.030, 0.084]	0.072	[−0.016, 0.156]
Distance to phone (km)	−0.005	[−0.022, 0.009]	−0.007	[−0.186, 0.011]
Own truck/car/motorcycle	−0.153	[−0.698, 0.291]	−0.170	[−1.204, 0.412]
Own bicycle	0.134	[−0.290, 0.507]	0.127	[−0.494, 0.848]
North	−1.328	[−2.896, 0.020]	−1.435	[−5.173, 0.682]
λ	2.137***	[1.096, 4.642]	2.599***	[0.889, 9.977]
Constant	−1.193***	[−1.697, −0.760]	−1.441**	[−2.808, −0.626]
Heteroskedasticity specification			Coefficient OMEGA (Ω)	90% CI
Household head education (year)			0.067	[−0.191, 0.199]
Distance to paved road (km)			0.009	[−0.149, 0.037]
Log-likelihood	−101.554		−100.684	
P-value (overall significance)	<0.0005		<0.0005	
P-value (Homoskedasticity)	0.425			
No. of observations	194		194	

Significance levels: ***1%, **5%, and *10%, respectively.

Table 6
Cassava production with sellers separated

Dependent variable	On farm		Off farm	
ln (harvest (kg))	Coefficient	90% CI	Coefficient	90% CI
Household head education (year)	0.098**	[0.022, 0.158]	0.107	[−0.036, 0.243]
Distance to paved road (km)	−0.014	[−0.038, 0.040]	0.008	[−0.033, 0.095]
Distance to phone (km)	0.009	[−0.006, 0.023]	0.008	[−0.043, 0.035]
Gender of head (female = 1)	−0.024	[−0.786, 0.588]	−0.282	[−1.258, 0.920]
Household size	0.021	[−0.020, 0.065]	0.019	[−0.045, 0.084]
Total farm size (ha)	0.107***	[0.048, 0.164]	0.157	[−0.015, 0.292]
Access to credit (yes = 1)	−0.272	[−0.731, 0.183]	0.488	[−0.369, 1.323]
Own truck/car/motorcycle			0.004	[−.892, 0.795]
Own bicycle			−0.151	[−0.733, 0.615]
Distance to sales point (10 km)			0.014	[−0.036, 0.132]
ln (price)	−0.017	[−0.341, 0.179]	0.006	[−0.671, 0.717]
Total income (1,000 U.S.$)	0.518**	[0.119, 1.242]	0.190	[−0.365, 0.981]
Region 1	0.321	[−3.806, 2.754]	−0.774	[−2.771, 1.994]
Region 2	2.078	[−1.542, 3.739]	0.196	[−3.212, 2.172]
Region 4	0.756	[−2.451, 2.305]	−1.583**	[−3.555, −0.286]
Region 5	0.151	[−2.859, 1.683]	−1.921*	[−4.906, −0.266]
λ	−0.184	[−2.943, 3.064]	−0.429	[−4.349, 1.807]
μ	−0.827	[−1.450, 1.079]	0.091	[−0.942, 1.837]
Constant	6.142***	[4.566, 10.018]	7.684***	[3.796, 12.040]
P-value				
H_0: Overall insignificance	< 0.0005		< 0.0005	
H_0: Not overidentified	0.344			
H_0: Underidentified	< 0.0005			
No. of observations	119		62	

Note: Region 1 for on-farm sellers is dropped due to perfect collinearity with other variables.
Significance levels: ***1%, **5%, and *10%, respectively.

Cassava production by on-farm sellers is positively affected by total income, education, and total farm size (Table 6). In contrast, cassava production by off-farm sellers is mostly determined by the location, but unaffected by education, total income, and total farm size possibly reflecting constraints in marketing capacity. Estimated price elasticities of production are statistically insignificant under both models. Income is treated as endogenous because it includes revenue from cassava sales. 2SLS is therefore used where income is instrumented by all exogenous variables included in each equation, plus total asset value, squared total asset value, and age of household head as excluded variables.

Home consumption of cassava for on-farm sellers is positively affected by farm size and negatively affected by proximity to phone service which reflects general access to communication and transportation infrastructure (Table 7). Access to credit tends to reduce consumption of cassava as farmers with finance can grow more profitable crops that require more inputs and may consume a wider variety of foods. Home consumption of cassava for off-farm sellers is positively affected by total farm size and also statistically significantly low in region 5.

The single-criterion model in Table 8 indicates that most of the signs of statistically significant variables are consistent with economic theory. Education and total farm size raises cassava production while total farm size also raises cassava consumption. Most other variables do not affect the production or consumption of cassava with statistical significance. Variables that are statistically significant in both the dual and single-criterion models are of similar magnitudes. However, the specifications lead to economically significant differences in that the single-criterion model reveals no effect of income on production whereas the dual-criteria model shows a large impact among on-farm sellers.

6.3. Comparison of dual-criteria and single-criterion models

The combined estimation results suggest that both dual-criteria and single-criterion models provide logical explanations of cassava producers' behaviors, but they have different explanatory power. Table 9 summarizes the results of the J-test which compares the explanatory power of these models.[15] A high P-value for particular model indicates that the model is at least as good as the one to which it is being compared. For example, the P-value = 0.406 for production in the dual-criteria model indicates that the dual-criteria model is at least as good as the single-criterion model in explaining cassava production behavior. In contrast, the P-value < 0.0005 for consumption in the single-criterion model indicates that the single-criterion

[15] J-test is based on the samples used in both single-criterion and dual-criteria models, and those used only for the dual-criteria model are dropped as the test requires the use of predicted values from each model.

Table 7
Cassava consumption with sellers separated

Dependent variable	On farm		Off farm	
ln (consumption (kg))	Coefficient	90% CI	Coefficient	90% CI
Household head education (year)	0.021	[−0.083, 0.117]	0.130	[−0.004, 0.300]
Distance to paved road (km)	−0.024	[−0.069, 0.033]	0.011	[−0.072, 0.084]
Distance to phone (km)	0.044***	[0.019, 0.066]	−0.008	[−0.056, 0.037]
Gender of head (female = 1)	−0.447	[−1.525, 0.699]	−0.247	[−1.821, 1.272]
Household size	0.040	[−0.030, 0.104]	0.054	[−0.013, 0.136]
Total farm size (ha)	0.070*	[0.023, 0.139]	0.157*	[0.022, 0.311]
Access to credit	−0.889***	[−1.389, −.337]	0.221	[−0.776, 1.431]
Own truck/car/motorcycle			0.254	[−0.738, 1.109]
Own bicycle			−0.177	[−0.856, 0.610]
Distance to sales point (10 km)			0.030	[−0.061, 0.109]
ln (price)	0.086	[−0.210, 0.434]	0.098	[−1.224, 0.950]
Total income (1,000 U.S.$)	0.625	[−0.106, 1.710]	0.114	[−0.570, 0.866]
Region 1	1.327	[−2.967, 5.015]	−1.393	[−3.414, 1.014]
Region 2	4.054	[−2.778, 7.070]	0.338	[−3.396, 2.608]
Region 4	2.570	[−2.891, 5.505]	−1.244	[−3.635, 0.621]
Region 5	2.196	[−3.792, 4.747]	−2.205*	[−5.453, −0.058]
λ	1.788	[−5.329, 7.173]	0.834	[−3.470, 4.246]
μ	−0.724	[−1.746, 1.126]	0.438	[−1.363, 1.945]
Gift	0.729**	[.386, 1.135]	0.883**	[0.090, 1.439]
Constant	1.826	[−0.752, 8.758]	5.668*	[0.085, 12.877]
P-value				
H_0: Overall insignificance	< 0.0005		< 0.0005	
H_0: Not overidentified	0.248			
H_0: Underidentified	< 0.0005			
No. of observations	113		61	

Note: Region 1 for on-farm sellers is dropped due to perfect collinearity with other variables.
Significance levels: ***1%, **5%, and *10%, respectively.

model is inferior to the dual-criteria model in explaining cassava consumption behavior. Overall, the *J*-test implies that the dual-criteria model provides information regarding both cassava production and consumption behaviors that is not available in the single-criterion model.

A joint test reveals whether the dual-criteria model outperforms the single-criterion model when considering production and consumption jointly. Results from the joint tests support the dual-criteria model over single-criterion model (P-value < 0.0005 for single-criterion model in contrast to 0.396 for dual-criteria model).

The results of *J*-test for the simultaneous model are similar to those for the dual-criteria model (Table 10). The results are inconclusive regarding whether the sequential format of the dual-criteria model or joint decisions of the simultaneous decisions model is preferable. However, although the simultaneous decisions model may provide information not captured in single-criterion model (P-value < 0.0005 in joint test for null hypothesis that single-criterion model is at least as good as simultaneous decisions model), the reverse is also true (P-value = 0.078 in joint test). The dual-criteria model therefore seems to dominate the single-criterion model more clearly than simultaneous decisions model does. These results support the key implication of this article that high FTC can exist in choosing sales location and can force cassava producers to make market orientation and sales location decisions before making production and consumption decisions.

Results of *J*-test need to be interpreted with caution because the information is limited regarding the exact process of farmers' decision making. Nevertheless, they indicate that cassava farmers in Benin face high transactions costs that affect not only their market participation decisions but also their choice of sales locations. Results support the notion that transactions costs lead cassava selling farmers to make decisions based on an intended sales outlet. Once these decisions are made, it appears that farmers cannot easily alter them.

7. Conclusion

This study examines whether cassava producers in Benin decide whether and where to sell production before deciding on target production and consumption levels. Such behavior could be explained by high transactions costs associated with sales locations. The literature suggests that semi-subsistence farmers often make market-participation decisions before production and consumption decisions. If cassava sellers also decide the sales location before making production and consumption decisions, farmers are further constrained by high transactions costs and their potential to benefit from markets is further lim-

Table 8
Cassava production and consumption in single-criterion

Dependent variable	Production		Consumption	
= ln (harvest (kg)), ln (consumption (kg))	Coefficient	90% CI	Coefficient	90% CI
Storage inside house (1,000 t)	−0.009	[−0.054, 0.014]	−0.000	[−0.076, 0.051]
Storage in attic (1,000 t)	−0.004	[−0.055, 0.078]	0.002	[−0.055, 0.107]
Household head education (year)	0.110***	[0.058, 0.171]	0.040	[−0.043, 0.129]
Distance to paved road (km)	0.010	[−0.006, 0.027]	−0.004	[−0.032, 0.020]
Distance to phone (km)	0.006	[−0.009, 0.021]	0.008	[−0.010, 0.030]
Gender of head (female = 1)	−0.013	[−0.552, 0.565]	−0.072	[−1.340, 1.078]
Household size	0.024	[−0.009, 0.060]	0.043	[−0.002, 0.087]
Total farm size (ha)	0.142***	[0.059, 0.212]	0.157***	[0.064, 0.248]
Access to credit (yes = 1)	0.109	[−0.312, 0.529]	−0.159	[−0.719, 0.427]
Own truck/car/motorcycle	0.104	[−0.378, 0.435]	0.185	[−0.316, 0.632]
Own bicycle	−0.139	[−0.438, 0.202]	−0.214	[−0.609, 0.256]
Distance to sales point (10km)	0.015	[−0.024, 0.096]	0.022	[−0.043, 0.114]
ln (price)—off farm	0.106	[−0.157, 0.312]	0.088	[−0.226, 0.362]
Total income (1,000 U.S.$)	0.095	[−0.647, 1.534]	0.090	[−0.892, 1.575]
Region 1	−0.736	[−1.834, 0.709]	−0.986	[−2.415, 0.530]
Region 2	0.314	[−1.618, 2.224]	1.084	[−1.147, 3.183]
Region 4	−1.051	[−2.377, 0.419]	−0.112	[−1.657, 1.641]
Region 5	−1.593	[−3.246, 0.350]	−0.730	[−2.689, 1.597]
Gift			0.840***	[0.443, 1.146]
λ	−0.570	[−2.759, 2.368]	0.983	[−1.831, 4.861]
Constant	7.560***	[5.072, 9.863]	4.819***	[2.151, 7.644]
P-value				
H_0: Overall insignificance	< 0.0005		< 0.0005	
H_0: Not overidentified	0.562		0.479	
H_0: Underidentified	< 0.0005		< 0.0005	
No obs	132		126	

Significance levels: ***1%, **5%, and *10%, respectively.

ited. Such behavior would suggest a value to addressing the specific transactions costs that lead to rigid decisions on sales location.

Results indicate that cassava producers may first decide whether and where to sell cassava and then allocate production resources, rather than deciding the sales location simultaneously with production and consumption levels. A cassava producer may decide where to sell cassava before knowing the market conditions at different outlets, because of the high fixed costs to finding buyers or to discovering prices and price risks in each outlet.

Overall, the results suggest that the policies in African countries to stimulate income growth of semi-subsistence farmers through increased access to markets may need to address the issues of high FTC associated with not only farmers' market participation decisions but also sales location decisions. Our results provide a consistent framework for explaining the complex market participation decision making of cassava producers in Benin. Future studies could build on this framework to assess the economic significance of distinction between dual-criteria and single-criterion models in other contexts. Finally, as a methodological contribution of this study, the findings also indicate that the estimation may be inconsistent even if sample selection bias is corrected using dual-criteria decision-making model if heteroskedasticity of the selection equations is ignored.

Table 9
P-value from *J*-test by Davidson and MacKinnon (1981)

	Dual-criteria model	Single-criterion model
Production	0.406	<0.0005
Consumption	0.321	<0.0005
Joint	0.396	<0.0005

Notes: A small *P*-value indicates stronger evidence that the model is inferior to the other model with statistical significance. Test statistics under the null hypothesis are distributed standard normal distribution for production and consumption in single-criterion model. Test statistics are distributed χ^2 (2) for production and consumption in dual-criteria model as there are on-farm sellers and off-farm sellers, and joint test in single-criterion model as there are production and consumption, and χ^2 (4) for joint test in dual-criteria model as there are production and consumption for both types of sellers.

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Table 10
P-value from J-test comparing simultaneous decisions model with single-criterion model and dual-criteria model

	Simultaneous decisions model and dual-criteria model		Simultaneous decisions model and single-criterion model	
	Simultaneous decisions model	Dual-criteria model	Simultaneous decisions model	Single-criterion model
Production	0.998	0.912	0.767	<0.0005
Consumption	0.490	0.992	0.019	<0.0005
Joint	0.839	0.995	0.078	<0.0005

Notes: A small P-value indicates stronger evidence that the model is inferior to the other model with statistical significance. Test statistics under the null hypothesis are distributed standard normal distribution for production and consumption in single-criterion model. Test statistics are distributed χ^2 (2) for production and consumption in dual-criteria model as there are on-farm sellers and off-farm sellers, and joint test in single-criterion model as there are production and consumption, and χ^2 (4) for joint test in dual-criteria model as there are production and consumption for both types of sellers.

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Appendix A: Simultaneous decisions model

In the simultaneous decisions model, market orientation (M) consists of four regimes, namely buyer, autarky, on-farm seller, and off-farm seller, so that M encompasses sales location S. Using the combination of variables ψ_i, π_i, Ψ_i, Π_i, we ran a multinomial logit model to explain producers' choices among these four regimes. Due to the technical difficulty, we did not run a heteroskedastic multinomial logit. Using multinomial logit is appropriate for sample selection due to polychotomous choices (but not ordered) (Maddala, 1983). The Inverse Mills Ratio for the relevant choice in this case is calculated as $\lambda = \varphi(p)$ / $\Phi(p)$, $p = \Phi^{-1}(\theta)$ in which θ is the predicted probability for each choice calculated based on the results of multinomial logit. Notations φ, Φ and Φ^{-1} are density function, cumulative distribution function (CDF), and inverse CDF of standard normal distribution, respectively. We then conducted J-test comparing the simultaneous decisions model against single-criterion and dual-criteria models.

Appendix B: Bootstrap

A bootstrap of the entire estimation procedure was conducted to obtain consistent confidence intervals of estimated coefficients in the structural equations given that $\hat{\lambda}_i$ and $\hat{\mu}_i$ are estimated variables. Bootstrapping used 200 iterations within which the results became stable. First, empirical samples of $\hat{\lambda}_i$ and $\hat{\mu}_i$ were obtained from bootstrapping in heteroskedastic ordered probit (13) and probit (14) models. Second, standard bootstrapping was conducted on (15) and (16) with each run using different $\hat{\lambda}_i$ and $\hat{\mu}_i$ values obtained from the first step. The bootstrap procedure in this study follows the one suggested by Jeong and Maddala (1993, p. 577); we generated 200 different data sets in which original observations were randomly sampled with replacement, estimated the models using each data set, obtained 200 estimated values for each coefficient and calculated confidence intervals for each coefficient using those values.

We used Limdep for the first and the second-stage discrete choice models, and STATA for the third-stage model. To bootstrap, we first stored 200 combinations of estimated λ and μ values from each sample and programmed STATA to use each λ and μ corresponding to each sample. We used two software programs because heteroskedastic ordered probit is not built in STATA, whereas the two-stage least-square method in Limdep does not provide as many identification tests as in STATA. In some samples, the ordered heteroskedastic probit and heteroskedastic probit do not converge to stable solutions, and the third-stage regressions also fail if excluded IVs do not have enough variation. Following Jeong and Maddala (1993, p. 577), when such results occurred a new random sample was drawn.

In addition, in some samples, $\hat{\lambda}_i$ and $\hat{\mu}_i$ were approximated using

$$\lim_{\eta\to\infty} \frac{\varphi(-\eta)}{\Phi(-\eta)} \approx \frac{\eta + \sqrt{\eta^2+4}}{2},$$

where η estimated as in footnote 3, was beyond the capacity of Limdep. As η reaches infinity, IMR converges to very narrow band set by two limits derived in Gordon (1941) and Birnbaum (1942). Although this approximation above corresponds to Gordon (1941), using Birnbaum (1942) leads to almost identical results from the bootstrap.

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