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Determinants of Marketed Rice Surplus among Smallholders in Benin: Evidence from Two Cross-Sectional Supply Models

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Abstract

Benin's rice sector meets less than half of national demand despite a threefold increase in production over the past decade, yet the commercialization constraints facing smallholders remain poorly understood. This study estimates, using two independent cross-sectional regression models applied to 120 smallholder rice farmers sampled in the Glazoué municipality (Benin), the determinants of the marketed surplus rate and the marketed quantity of rice. A mixed-methods design combines structured surveys with six focus group discussions. Adaptive price expectations are proxied by a three-year, CPI-deflated moving average of local prices within a static, cross-sectional adaptation of the Nerlove framework; heteroskedasticity-robust (HC3) standard errors are used for inference, and an instrumental-variable approach addresses the endogeneity of credit access. Rice selling price is positively and significantly associated with the commercialization rate. Access to credit, farm size, market distance, farming experience, and road accessibility are positively associated with marketed quantity, while self-consumption objectives and formal sales contracts are negatively associated with it. Fertilizer price shows a strong negative association with marketed quantity, indicating acute sensitivity to input costs. A significant gender income gap is also observed (women: USD 85.86 vs. men: USD 143.26/month). The results point to fertilizer voucher schemes, targeted rural road investment, and gender-responsive credit as candidate policy levers for expanding marketed rice supply and strengthening food security in deficit-prone areas, pending further validation.

Keywords: marketed quantity, price elasticity, smallholder rice farming, food security, Benin

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Determinantes del excedente de arroz comercializado entre pequeños productores de Benín: Evidencia de dos modelos de oferta de corte transversal

Resumen

El sector arrocero de Benín cubre menos de la mitad de la demanda nacional pese a triplicar la producción en la última década; con todo, las restricciones a la comercialización de los pequeños productores son poco conocidas. Mediante dos modelos de regresión de corte transversal aplicados a 120 productores de arroz de Glazoué, el estudio estima los determinantes de la tasa de excedente comercializado y de la cantidad comercializada. El diseño de métodos mixtos combina encuestas estructuradas y seis grupos focales. Las expectativas adaptativas de precios se aproximan mediante un promedio móvil trienal de precios locales, deflactado por el IPC, en una adaptación estática de Nerlove, con errores estándar robustos a la heterocedasticidad (HC3) y variables instrumentales para la endogeneidad del acceso crediticio. El precio de venta del arroz está positiva y significativamente asociado con la tasa de comercialización. El acceso al crédito, el tamaño de la explotación, la distancia al mercado, la experiencia agrícola y la accesibilidad vial se asocian positivamente con la cantidad comercializada; el autoconsumo y los contratos formales de venta, negativamente. El precio de los fertilizantes muestra una fuerte asociación negativa, indicando alta sensibilidad a los costos de insumos. Se observa una brecha significativa de ingresos por género (mujeres: USD 85,86; hombres: USD 143,26/mes). Los resultados sugieren que los vales para fertilizantes, la inversión en caminos rurales y el crédito con enfoque de género serían palancas de política para ampliar la oferta comercializada de arroz y fortalecer la seguridad alimentaria en zonas deficitarias, pendiente de validación.

Palabras clave: cantidad comercializada, elasticidad-precio, producción arrocera de pequeña escala, seguridad alimentaria, Benín

Determinantes do excedente de arroz comercializado entre pequenos produtores no Benin: Evidências de dois modelos de oferta de corte transversal

Resumo

O setor arrozeiro do Benin atende a menos da metade da demanda nacional apesar de triplicar a produção na última década, embora as restrições à comercialização dos pequenos produtores sejam pouco conhecidas. Por meio de dois modelos de regressão de corte transversal aplicados a 120 produtores de arroz de Glazoué, o estudo estima os determinantes da taxa de excedente comercializado e da quantidade comercializada. O desenho de métodos mistos combina questionários estruturados e seis grupos focais. As expectativas adaptativas de preços são aproximadas por uma média móvel trienal de preços locais deflacionada pelo IPC, em uma adaptação estática de Nerlove, com erros-padrão robustos à heterocedasticidade (HC3) e variáveis instrumentais para a endogeneidade do acesso ao crédito. O preço de venda do arroz está positiva e significativamente associado à taxa de comercialização. O acesso ao crédito, o tamanho da propriedade, a distância ao mercado, a experiência agrícola e a acessibilidade rodoviária associam-se positivamente à quantidade comercializada; o autoconsumo e os contratos formais de venda, negativamente. O preço dos fertilizantes apresenta forte associação negativa, indicando alta sensibilidade aos custos dos insumos. Observa-se disparidade salarial significativa entre os gêneros (mulheres: USD 85,86; homens: USD 143,26/mês). Os resultados sugerem que vales para fertilizantes, investimentos em estradas rurais e crédito com enfoque de gênero seriam alavancas de política para ampliar a oferta comercializada de arroz e fortalecer a segurança alimentar em áreas deficitárias, pendente de validação.

Palavras-chave: quantidade comercializada, elasticidade-preço, orizicultura de pequena escala, segurança alimentar, Benin

1. Introduction

Rice occupies a central place in global food consumption and holds particular importance in Benin, where rising urbanization and shifting dietary preferences have led to rapidly increasing demand (Bonou et al., 2024; Codjo et al., 2021). This surge in demand presents a major challenge for national food policies across West Africa, requiring a strategic and sustainable response. Historically, rice development strategies in the region have primarily focused on production intensification and, subsequently, on price adjustments in the context of market liberalization frameworks (Loko et al., 2022). In Benin, ensuring rice availability has therefore become a cornerstone of national food security and a key component of an economy largely dependent on agriculture. Sustained growth in domestic rice production is crucial not only to feed the country's growing population but also to foster export opportunities and reduce dependence on imports (Arouna et al., 2021).

Despite concerted government efforts through the Emergency Program for Food Security Support (PUASA) and investments in research and development, domestic rice production has increased threefold over the past decade. Nevertheless, this growth remains insufficient, as national production only meets 47% of the country's total demand (Ministère de l'Agriculture, de l'Élevage et de la Pêche [MAEP], 2017). Rice has become a staple in households and institutional catering due to its ease of preparation and convenience, yet domestic supply struggles to keep pace with increasing consumption (Maertens & Vande Velde, 2017; Totin et al., 2012). To narrow this gap, agricultural policies must aim to gradually substitute rice imports with locally produced alternatives. Such a transition requires farmers not only to achieve self-sufficiency but also to produce marketable surpluses that ensure a steady and sustainable domestic supply. Increasing rice production can be achieved either by expanding cultivated land areas or by improving yields through enhanced agricultural techniques and inputs like adoption of improved varieties (Loko et al., 2022; Rodenburg & Saito, 2022).

In this context, local governments play a pivotal role in this transformation, especially in preserving agricultural land amidst rapid urbanization and infrastructural expansion. As urban development often leads to the conversion of farmland into commercial and industrial zones, local authorities must establish strong land-use planning, monitoring, and knowledge management tools to protect agricultural production areas. In Benin, efforts to strengthen Civil Society Organizations (CSOs) in governance and in monitoring development policies have led to the implementation of the "Project for Supporting CSOs in the Effective Monitoring of Development Policies in Benin" (PASEP/OSC). This initiative facilitates farmers' access to essential agricultural inputs, such as fertilizers, credit, processing equipment, and mechanized tools, and supports the production and distribution of improved seed varieties.

The municipality of Glazoué, which alone accounts for 40.1% of the region's total rice production (Direction de la Statistique Agricole [DSA], 2024), stands out as a key player in supporting the country's rice sector. This region has actively pursued initiatives to bolster local rice production and enhance market participation among smallholder farmers. However, persistent socioeconomic and institutional barriers continue to hinder the efficiency and inclusiveness of rice supply chains.

This study estimates, through two independent cross-sectional regression models applied to the same sample of 120 smallholder rice farmers in Glazoué municipality, the socioeconomic and institutional determinants of rice commercialization. Specifically, it examines (i) the determinants of the marketed surplus rate, defined as the share of harvested rice sold, and (ii) the determinants of the marketed quantity of rice, expressed in physical units. The two equations are estimated separately by ordinary least squares; they are not estimated as a jointly determined simultaneous system, and possible correlation between their disturbances is not modelled. Because the data are cross-sectional and several regressors may be jointly determined with commercialization outcomes, results are interpreted as associations rather than causal effects. The findings are intended to inform locally adapted interventions that can narrow Benin's rice supply deficit and strengthen food security in production zones such as Glazoué.

2. Theoretical Framework: Institutional Economics, Governance, and Agrarian Policy in Rice Systems

This study draws on three complementary analytical frameworks that are institutional economics, rural governance, and agrarian political economy to examine the socioeconomic determinants of rice supply in Glazoué within the context of decentralized agricultural governance.

From the perspective of institutional economics, rice supply outcomes are a function of the formal and informal institutions that shape farmers' access to land, inputs, markets, and information (Sanka & Makhura, 2025; Sossou et al., 2022; Yami & van Asten, 2018). Transaction costs, property rights arrangements, and collective action mechanisms influence the efficiency of supply chains and producers' capacity to respond to demand (Ciliberti et al., 2020). In Benin, decentralization reforms have altered local institutional landscapes, creating opportunities for municipalities and civil society organizations to play a more active role in shaping agricultural markets (Dansou & Carrier, 2023). However, the literature reports mixed outcomes of decentralization in Benin: while it has expanded local participation in some contexts, it has also been associated with increased horizontal inequalities, elite capture of resources, and persistent implementation challenges (Uddin, 2023). These tensions must be acknowledged when evaluating the role of municipalities and CSOs in agricultural market governance.

The rural governance perspective highlights how the distribution of decision-making authority between central and local actors affects agricultural productivity and equity (Kakumba, 2010; Koopmans et al., 2018). Governance quality is reflected in transparency, accountability, and participatory processes. In this study, governance quality is operationalized through indicators such as the presence of functional farmer organizations, access to public extension services, and adherence to transparent input distribution protocols. These dimensions are aligned with the Worldwide Governance Indicators framework (Kaufmann et al., 2011) and are used to assess whether decentralization strengthens or weakens food security objectives (Asare-Nuamah et al., 2023; Harrison & Sayogo, 2014; Seetharam Sridhar et al., 2019). In Glazoué, municipal institutions and CSOs mediate access to production resources, shaping farmers' ability to engage competitively in rice markets.

Finally, agrarian political economy situates rice production within broader political and economic structures, emphasizing the historical legacies of state intervention, market liberalization, and rural class relations (Bernstein, 2016; Nguyen et al., 2020). This framework interrogates power dynamics in resource allocation, the role of agricultural commercialization in smallholder livelihoods, and the uneven benefits of agricultural policy interventions. Critically, commercialization does not automatically translate into improved household welfare: evidence from sub-Saharan Africa documents negative associations between increased market participation and household food consumption scores, driven by market price volatility, post-harvest losses, and intra-household bargaining asymmetries (Bernstein, 2016; Vanlauwe et al., 2014). In Glazoué, these dynamics are questioned in the observed gap between high commercialization intent and actual marketed surplus, reflecting persistent structural constraints. Current scholarly debates emphasize the need to reconcile productivity gains with equitable resource distribution, ensuring that smallholders benefit from intensification strategies (Adolph et al., 2023; Srinatha et al., 2024; Struik & Kuyper, 2017; Vanlauwe et al., 2014).

By combining these three frameworks –institutional economics, rural governance, and agrarian political economy– the study bridges micro-level institutional analyses with macro-level political economy perspectives, providing a multidimensional understanding of rice supply determinants. Operationally, institutional economics informs the choice of supply-side variables (credit, contracts, input prices); rural governance frames the role of decentralized structures and CSOs; and agrarian political economy contextualizes gender and class-based disparities in commercialization outcomes. This integration addresses ongoing debates about whether decentralization and market reforms, when embedded in inclusive governance, can sustain agricultural growth and local food security in West African contexts (Onyeaka et al., 2024).

3. Materials and Methods

3.1 Study Area

This research was conducted in Benin, a West African nation where agriculture supports over 70% of the population and accounts for approximately 25.4% of GDP (MAEP, 2020; World Bank, n.d.b). The agricultural landscape is dominated by smallholder subsistence farming, with crops such as cassava, yams, and maize, as well as export commodities like cotton and cashews. The rice sector, vital for food security, is expanding, particularly through smallholder farmers and cooperatives. Despite challenges like limited mechanization and climate vulnerability, rice production, especially parboiled varieties, is expanding, bolstered by initiatives like the West Africa Agricultural Productivity Program. Compared to maize and cassava, rice exhibits a significantly higher market orientation and stronger integration into urban food systems (Codjo et al., 2021). Yet national rice production meets only 47% of domestic demand (MAEP, 2017), with average paddy yields of approximately 2.5 t/ha remaining well below the potential ceiling of 6-8 t/ha achievable with improved varieties and inputs (Loko et al., 2022; Rodenburg & Saito, 2022). This persistent yield gap underscores the strategic importance of the rice sector despite its relatively smaller cultivated area compared to maize (Bonou et al., 2024). In central Benin, the municipality of Glazoué stands out as a key hub for rice cultivation and processing (Hinnou et al., 2022).

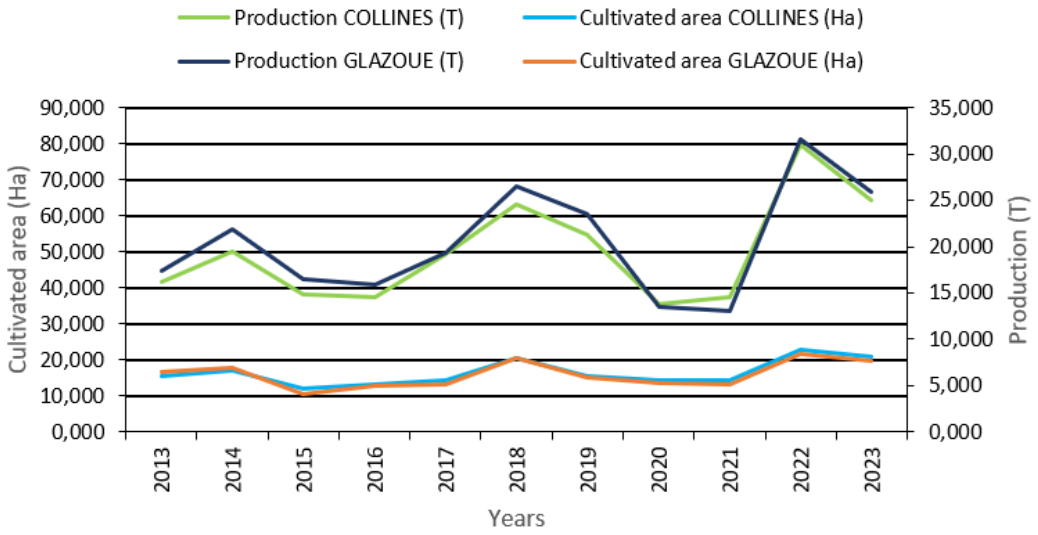

Figure 1. Evolution of rice areas and production from 2013 to 2023

The selection of Glazoué, a municipality located in the Collines department, as the study site was based on several criteria. While other rice-producing municipalities, notably Malanville, Karimama, Grand-Popo, etc., were considered, Glazoué was selected over these alternatives because it uniquely combines the highest departmental rice production share (40.1% of regional output; DSA, 2024), the presence of AfricaRice and INRAB research infrastructure, and the largest post-harvest processing capacity in central Benin. The Collines department is Benin's second traditional rice-producing hub, accounting for 20,889 hectares of rice cultivation (DSA, 2024) (Figure 1). This region plays a crucial role in national rice production, making it a strategic area for examining the factors influencing supply. The region has benefited from the introduction of a diverse range of rice varieties due to the presence of major agricultural research institutions. Specifically, the National Institute of Agricultural Research of Benin (INRAB) and AfricaRice have established research sites in the area, fostering innovation and improved rice production techniques. This scientific infrastructure has contributed to the dissemination of high-yield and climate-resilient rice varieties, significantly impacting local agricultural practices. Post-harvest processing infrastructure in Glazoué enhances its strategic importance in the rice value chain. The region is home to a large rice milling facility with a processing capacity of approximately 100 tons per day. Additionally, two mini rice mills contribute to post-harvest activities: the PDRN mini rice mill (Nerica Rice

Dissemination Program), with a processing capacity of 15 tons per day, and the UNIRIZ-C mini rice mill (Regional Union of Rice Farmers in Zou-Collines), capable of processing 20 tons per day.

These attributes position Glazoué as an ideal context for examining the socioeconomic determinants of rice supply, as they provide a unique combination of high production levels, research-driven innovations, and well-established post-harvest processing infrastructure.

3.2 Sampling and Data Collection

Out of Glazoué's ten administrative districts (arrondissements), six were purposively selected for mixed qualitative and quantitative data collection. The selected districts were Thio, Sokponta, Ouèdèmè, Gomé, Magoumi, and Kpakpaza. These areas were chosen based on their significant involvement in rice production and market supply, accounting for at least 20% of the total agricultural area according to the extension records, and having an active rice marketing point or cooperative presence. The sampling unit was the rural rice-farming household, stratified by both farm size (<1 ha, 1-3 ha, >3 ha) and productivity level, based on local extension records. Villages and households were proportionally sampled to ensure representation across ecological gradients (upland, lowland). The distribution of the sampled farmers across the study area is presented in Table 1.

Table 1. Distribution of the sample in the study area

ARRONDISSEMENTS	VILLAGES	NUMBER OF RESPONDENTS	PERCENTAGE (%)
Ouèdèmè	Kpota, Yagbo	30	25
Kpakpaza	Kpakpaza, Sowe, Yawa	36	30
Thio	Abèssou. Ayo, Missèbo, Sogbadji	6	5
Gomé	Gomé	15	12.5
Sokponta	Sokponta	20	16.67
Magoumi	Aidjesso, Cintille, Masso	13	10.83
Total		120	100

The sampling frame was constructed from the National Agricultural Census (RNA), which recorded 11,181 rice producers in the Collines department, of whom approximately 13% (1,454 producers) resided in the municipality of Glazoué. Applying Yamane's (1967) formula, $n = N / (1 + N \cdot e^2)$, with a precision level of $e = 8\%$, yielded a target sample size of approximately 141 farmers. The final analytical sample comprises 120 farmers: the difference between the target and the achieved sample reflects the unavailability of some selected producers despite repeated follow-up visits, the exclusion of a small number of observations flagged as outliers during data cleaning, and a residual number of refusals to participate.

Data collection involved focus group discussions at the village level (six FGDs, one per arrondissement, comprising 8-12 participants each, purposively selected to include men, women, and youth farmers) as well as individual surveys with rice farmers (n = 120), randomly selected from a sampling frame of registered producers in the six arrondissements, proportional to their production share as shown in Table 1. These interviews provided valuable insights from various actors on rice production management and the sector's contribution to local economic development. The survey instrument was pre-tested with 15 farmers and revised for clarity. Internal consistency (Cronbach's $\alpha = 0.78$) confirmed reliability for Likert-scale items on market access perceptions. The information gathered covered a wide range of topics, including:

- The interactions among stakeholders throughout the rice value chain, from production to consumption, including processing, storage, and commercialization.

- Access to key production factors, such as land, agricultural inputs, financial capital, equipment, and labor.
- Organizational structures related to rice production and the incentives for farmers to form cooperative groups.
- Harvest yields, contractual agreements for sales, and access to credit.
- Procurement and distribution systems, including modes of purchasing inputs and the distribution of harvested rice (e.g., sales, self-consumption, seed preservation, and gifting).
- Cultivated land area, household size, and socio-demographic characteristics of farmers.

Qualitative data were gathered through semi-structured interview guides customized for distinct stakeholder groups. For rice farmers, the guide covered: production objectives and constraints, input access and costs, marketing channels, credit and contract use, and perceptions of price and road accessibility. For cooperative leaders and extension agents, questions addressed governance structures, input distribution mechanisms, and market linkage programmes. For local government officers, the guide focused on land-use planning, decentralization policy implementation, and support for the rice value chain. These data were enriched by field visits and observations of rice processing units, providing deeper insights into the local social dynamics surrounding rice production and its contribution to regional development. For the quantitative component, a structured questionnaire was developed as a standardized instrument to collect responses from individual rice producers.

The collected data underwent thematic analysis to uncover the underlying social dynamics shaping the rice sector in Glazoué, as well as the diverse strategies producers employ to manage local rice production. The analysis followed the six-phase procedure of Braun and Clarke (2006): (1) familiarization with transcripts and field notes through repeated reading; (2) systematic generation of initial codes across all data sources; (3) searching for themes by collating codes into candidate thematic categories; (4) reviewing and refining themes against the full dataset; (5) defining and naming each theme with clear boundaries; and (6) producing the final analytical report integrating illustrative extracts with interpretive commentary. This qualitative analysis was complemented by descriptive statistics and non-parametric tests applied to the quantitative data, ensuring a robust and comprehensive evaluation of the findings.

3.3 Data Analysis

The quantitative analyses were conducted using SPSS (Statistical Package for the Social Sciences) version 20.0 and Excel 2013. SPSS was selected because it was the platform available in the institutional research infrastructure at the time of data analysis and is widely used in agricultural surveys across Francophone West Africa. Excel was used solely for data organization and descriptive tabulations. We acknowledge that more advanced econometric packages (e.g., Stata, R) offer advantages for robust standard error estimation and instrumental variable diagnostics. However, the core Cobb-Douglas OLS regressions, heteroskedasticity-consistent (HC3) standard-error correction, and variance-inflation-factor diagnostics used in this study are fully implementable in SPSS. Two econometric models were employed to investigate key aspects of local rice production in Glazoué. The first model aimed to analyze the determinants of local rice supply, while the second focused on factors influencing production management, particularly through an examination of market dynamics and an analysis of the determinants of the commercialization rate.

Among the functional forms commonly used to estimate agricultural supply relationships, the Cobb-Douglas specification was retained for this study rather than the Constant Elasticity of Substitution (CES) or Translog alternatives, primarily on grounds of interpretability and established precedent in smallholder agricultural economics (Okorie, 2017; Sadoulet & de Janvry, 1995). Its logarithmic linearity yields elasticities that are directly

interpretable and comparable with prior supply-response studies, which is particularly useful for policy-relevant parameters such as the fertilizer-price elasticity discussed below. A formal statistical comparison against CES and Translog specifications was not performed in this study; this is acknowledged as a limitation in Section 5.6, and re-estimation under alternative functional forms is recommended as a direction for future research. Its logarithmic linearity simplifies the interpretation of elasticities, which is critical for policymakers targeting specific inputs (e.g., fertilizer subsidies). Nevertheless, the Cobb-Douglas form carries well-documented limitations: it imposes a unit elasticity of substitution between inputs, constrains returns to scale to be constant by default, and may not capture non-linear input-output relationships. This is particularly relevant when examining fertilizer use under subsidy regimes where responses may be threshold-dependent (Arrow et al., 1961; Heyer et al., 2004). These restrictions should be borne in mind when interpreting the fertilizer price elasticity reported in this study. Among them, the Cobb-Douglas, Constant Elasticity of Substitution (CES), and Translog production functions are widely utilized to analyze supply functions in the agricultural sector (Arrow et al., 1961; Okorie, 2017; Sadoulet & de Janvry, 1995). These models primarily differ in their structural assumptions about output elasticity with respect to inputs, returns to scale, and elasticities of substitution between inputs. These three parameters are fundamental in characterizing any production technology (Heyer et al., 2004).

Although these functional forms –Cobb-Douglas, CES, and Translog– are not highly data-intensive, they have certain limitations. Notably, they fail to account for partial adjustments and adaptive expectations, as highlighted by the Nerlove model (Sadoulet & de Janvry, 1995).

Price expectations, p_t^e, were modeled using a 3-year moving average of local market prices, consistent with adaptive expectations theory (Nerlove, 1958b). Prices were deflated using the national CPI (base year 2015; World Bank, n.d.a) prior to computing the moving average, to remove the influence of general inflation. Years associated with international price spikes (2008 and 2011) fall within the three-year windows used to construct the moving-average price-expectation proxy for the corresponding survey periods. By construction, a three-year moving average attenuates the weight of any single anomalous year relative to a model using contemporaneous prices alone, which limits, without fully eliminating, the influence of these spikes on the price-expectation variable. Given the 3-year window, the first two observations in the price series are excluded from the regression sample, reducing the effective estimation window; this limitation is acknowledged as a minor constraint on statistical power. “Modern technology” was operationalized as the use of certified seeds, mechanized tools, or drip irrigation, verified through farmer self-reports and field observations. The generalized Nerlove model can be expressed in terms of yields, cultivated area, production quantities, and other relevant variables. It is formulated as follows:

$$q_t^d = \alpha_1 + \alpha_2 p_t^e + \alpha_1 z_t + u_t$$

q_t^d represents the desired cultivated area in period *t*; p_t^e denotes the anticipated price, which may more broadly encompass a vector of prices, including the price of the crop itself, the prices of competing products, and the prices of production inputs; z_t represents a set of exogenous factors, primarily consisting of fixed public and private factors, as well as other truly exogenous variables such as climatic conditions; u_t accounts for all unobserved random factors affecting the cultivated area and has an expected value of 0; and the parameters α_i (or elasticities, if the variables are expressed in logarithmic form) capture the relationships between these variables.

According to Koffi-Tessio (1997), the Nerlove model is the most efficient and widely used framework; though it should be noted that alternatives such as the Error Correction Model (ECM) and panel data approaches have gained ground in recent agricultural supply literature by better addressing non-stationarity and farm heterogeneity (Sadoulet & de Janvry, 1995) for estimating the supply function (in the economic sense) within the agricultural sector. This model is particularly valuable as it integrates adaptive expectations and partial adjustment dynamics, providing a more realistic representation of decision-making processes in agricultural production.

Because retrospective, farm-level panel data are not available, this study follows the static adaptation of the Nerlove framework used in prior applications to smallholder rice systems (Yabi et al., 2012), in which the dependent variable is the quantity actually marketed by the farmer rather than a desired or lagged supply level. Adaptive price expectations are captured only through the 3-year, CPI-deflated moving average of local prices described above; no adjustment coefficient, lagged dependent variable, or long-run elasticity is estimated. The specification is:

$$ln(Q_0) = \beta_0 + \sum \beta_i ln(p_i) + \sum Y_k Z_k + e$$

where Q_0 is the quantity of rice sold, p is a vector of price variables (selling price, fertilizer price, imported-rice price, expected price), Z is a vector of socioeconomic, demographic, and institutional variables, and e is the error term. The selling price entered is the price actually received by each farmer for the rice sold during the survey period, self-reported and recorded at the point of sale; it therefore varies across respondents according to their local market (arrondissement), the timing of sale, and the buyer type, rather than representing a single municipality-wide value common to all farmers.

Table 2. Definition, measurement, and expected signs of the study variables

VARIABLE	MEASUREMENT	CODING / REFERENCE CATEGORY	EXPECTED SIGN
DEPENDENT VARIABLES			
Commercialization rate	Continuous; share of harvested rice sold on the market	Percentage, 0-100	−
Marketed quantity	Continuous (log-transformed); quantity of rice sold by the farmer	ln(Q_0)	−
EXPLANATORY VARIABLES - CONTINUOUS			
Rice selling price	Continuous	FCFA	+
Fertilizer purchase price	Continuous	FCFA	−
Imported rice price	Continuous	FCFA	+
Labor cost	Continuous	FCFA, unit cost	−
Household size	Continuous	Number of members	−
Monthly income	Continuous	FCFA	+/−
Rice cultivated area	Continuous	Hectares	+
Distance from farm to market	Continuous	Kilometres	+
Experience in agricultural production	Continuous	Years	+
EXPLANATORY VARIABLES - CATEGORICAL			
Gender	Categorical	Male = 1; Female = 0 (ref.)	+/−
Rice farming training	Categorical	Yes = 1; No = 0 (ref.)	+
Type of ecology	Categorical	Lowland (ref.); Plateau; Both	+/−
Production objective	Categorical	Sale (ref.); Self-Consumption; Sale and Self-Consumption	+/−
Credit	Categorical	Yes = 1; No = 0 (ref.)	+
Sales contract	Categorical	Yes = 1; No = 0 (ref.)	+
Accessibility	Categorical	Paved road (ref.); Carriageway; Non carriageway	+
Production technology *	Categorical	Modern (ref.); Semi-modern; Less-modern; Traditional; Conservative	+/−

No farmer in the sample reported a marketed quantity of zero; the logarithmic transformation of the dependent variable is therefore well-defined for the full analytical sample (n = 120), and no exclusion or constant-adjustment procedure was required.

Multicollinearity was assessed using Variance Inflation Factors (VIFs), with all variables having VIF < 5, indicating minimal multicollinearity. To address endogeneity in credit access, an instrumental variable (IV) approach was used, with proximity to microfinance institutions as the instrument (Wooldridge, 2015). The instrument satisfies the relevance condition: first-stage results show a statistically significant association between proximity to microfinance institutions and credit uptake (F-statistic = 18.4, $p < 0.01$), exceeding the conventional weak-instrument threshold of 10 (Stock & Yogo, 2005). On exogeneity, we argue that the geographic placement of microfinance institutions in the Collines department was historically determined by donor program targeting criteria (proximity to regional urban centers and road infrastructure) rather than by individual farm productivity or household income, thus satisfying the exclusion restriction conditional on the controls included in the model. We acknowledge, however, that self-selection into proximity to such institutions cannot be fully ruled out, and this limitation is noted as a caveat on the IV estimates. The instrumental-variable correction for credit-access endogeneity, described below, is applied to this supply model; the credit-access variable in the commercialization-rate model is estimated by ordinary least squares without IV correction (Table 2).

4. Results

4.1 Socio-Demographic and Economic Characteristics of Respondents

The quantitative variables related to the socio-demographic and economic characteristics of rice producers in the municipality of Glazoué are presented in Table 3 in two distinct formats. First, the mean values are broken down by gender and for the entire sample. Second, categorical classifications derived from these variables are expressed in proportions, also disaggregated by gender and for the overall sample. An analysis of this table reveals that the average age of rice producers is 45.49 years, with no statistically significant difference between the average ages of women (45.02 years) and men (45.75 years). Moreover, a substantial majority (93%) of the farmers are married.

Household size is another notable factor, with an average household size of approximately seven members. More specifically, households led by women have an average of seven members, while those headed by men tend to be slightly larger, with an average of eight members.

Regarding educational attainment, approximately 43% of the sampled rice producers (n = 120; mean age 45.49 years, SD = 10.47) have never attended school, 32% have completed primary education, and less than 1% have attained a university-level education. However, these overall figures mask significant gender disparities. Among the 43% of producers with no formal education, about 67% are women, compared to 30% for men. As education level increases, the proportion of women decreases, reaching 0% at the university level, whereas approximately 1% of men have attained this level. Despite these disparities, most producers (approximately 79%) have received training in rice farming, and 68% are members of a farmers' association.

In terms of occupational engagement, nearly 94% of producers identify agriculture as their primary occupation, followed by trade (2.5%). Notably, a greater proportion of men (96%) are engaged in agriculture than women (91%), while more women (5%) are involved in trade than men (1%). These primary occupations, when combined with secondary activities, generate an average monthly income of $122.70. However, a Student's t-test reveals a highly significant difference between the average monthly income of women ($85.86) and that of men ($143.26) ($t(118) = -4.21$, $p < 0.001$; Levene's test confirmed equal variances). The t-test assumes normality of the income distribution and independence of observations, both of which are reasonable given the random sampling procedure. It should be noted that this bivariate comparison does not control for confounding variables such as cultivated land area, access to credit, or household labor supply, which likely mediate part of the

observed gender income gap. Multivariate analysis in Section 4 partially addresses these interactions through the supply function estimates.

Table 3. Socio-demographic and economic characteristics

Variables	Gender		Total
	Female	Male	
Age	45.02 (10.54)	45.75 (10.49)	45.49 (10.47)
Main activity			
Agriculture	90.7	96.1	94.17
Livestock	0	1.3	0.83
Marketing	4.65	1.3	2.5
Civil servant	0	1.3	0.83
Rice processing	2.33	0	0.83
Other	2.33	0	0.83
Education level			
No formal education	67.44	29.87	43.33
Primary	20.93	37.66	31.67
Secondary	11.63	31.17	24.17
University	0	1,3	0.83
Rice farmers training	81.4	77,92	79.17
Household size	7.09 (2.66)	7.72 (3.00)	7.5 (2.89)
Monthly income	48081 (23532)	80205 (51826)	68694*** (46369)
Farmer organisation membership			
Member	81.4	61.04	68.33
Former member	6.98	16.88	13.33
Never a member	11.63	22.08	18.33
Marital status			
Single	0	1.3	0.83
Married	86.05	97.4	93.33
Widowed	11.63	1.3	5
Divorced	2.33	0	0.83

***Significant at 1% ($p<0.01$).

4.2 Production and Management Strategies for Local Rice Production

4.2.1 Production Objectives

Among the 120 surveyed rice farmers in Glazoué, 86.67% identified sale as their primary production objective, with only a minority orienting their output predominantly toward self-consumption (Figure 2). This distribution indicates that commercialization is the dominant production rationale in this municipality, which functions as an active rice market hub.

The gender breakdown sharpens this finding considerably. Female rice farmers show a markedly higher commercialization orientation than their male counterparts: 95.35% of women declared sale as their sole production objective, against 81.82% of men. Conversely, 11.69% of men targeted both sale and self-consumption simultaneously, compared to 4.65% of women. This divergence is consistent with the observed difference in household size between male and female farmers. Men support households averaging 8.3 members against 5.1 for women. This difference mechanically raises domestic consumption requirements and moderates the share of output directed to market. This household size differential was not, however, submitted to multivariate testing within the present study, so the relationship remains indicative rather than formally established.

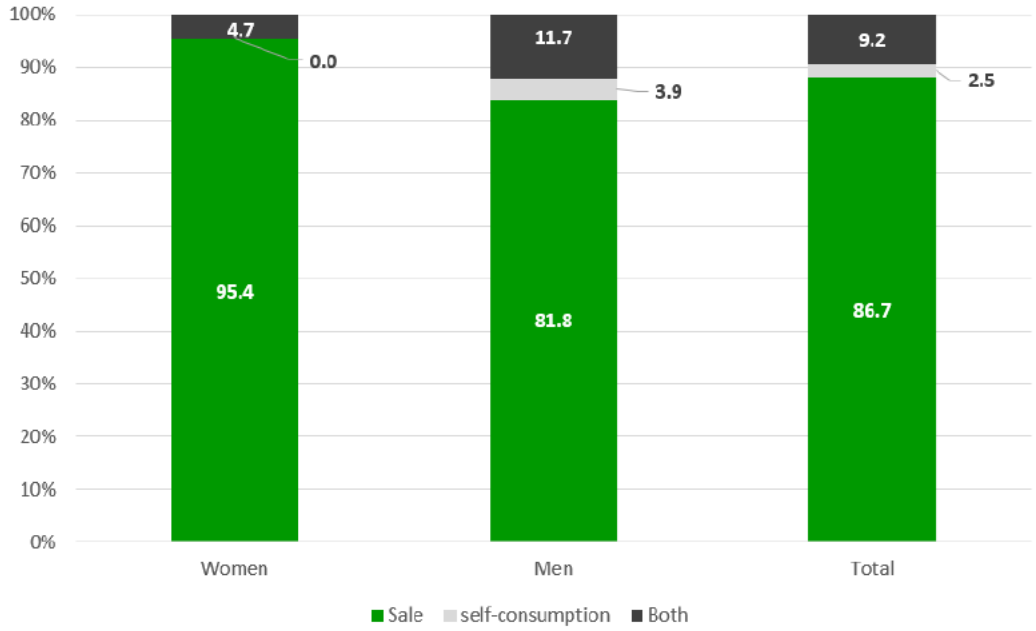

Figure 2. Production objectives of rice farmers in Glazoué, disaggregated by gender

4.2.2 Production Destination

Analyzing the destination of production helps determine whether the actual use of the harvest aligns with the objectives set by farmers at the beginning of the season. Table 4 presents the distribution of production utilization by gender. Findings indicate that 65.91% of the total production is sold, 24.29% is used for self-consumption, and 10.07% is given away. A gender-based analysis reveals that men sell a slightly higher proportion of their production (68.00%) than women (62.54%), although this difference is not statistically significant. However, a significant difference at the 5% level is observed in the proportion of production allocated to self-consumption: female-led farms consume 28.31% of their production. Male-led farms consume only 21.78%. This is because women are more involved in rice parboiling and processing, allowing them to have ready-to-consume rice. In contrast, men, who are less engaged in these activities, must exert additional effort to obtain consumable rice.

Table 4. Average use of production by gender (%)

VARIABLES	FEMALE	MALE	TOTAL
Share of production sold	62.54 (2.04)	68.00 (1.81)	65.91 (1.39)
Share of production consumed	28.31 (2.79)	21.78 (2.19)	24.29 (1.81)**
Share of production given away	9.14 (0.31)	10.22 (0.41)	10.07 (0.30)

** Significant at 5%, ($p<0.05$) Standard deviation

4.3 Local Rice Supply in the Municipality of Glazoué

4.3.1 Determinants of Local Rice Marketing

The sale of locally produced rice is influenced by various factors that either facilitate or hinder its commercialization. Key determinants include: i) the presence of local markets within the village (defined as a designated trading point operating at least once per week, confirmed through field observation), ii) the distance between the farm and the nearest rice market (measured in kilometres by GPS or road atlas, self-reported and verified against commune maps), iii) the accessibility of the village (operationalized as a binary indicator: 1 if the village is reachable by motorized vehicle year-round, 0 if seasonal road closure affects access for at least two months per year), and iv) marketing strategies, including the use of sales contracts (defined as a pre-harvest written or verbal agreement specifying price, quantity, and delivery date with an identified buyer, coded as a binary variable: 1 = contract, 0 = spot sale).

Estimating the commercialization rate function provides insights into the key factors that influence it. According to Table 5, the regression model is highly significant at the 1% level (P-value < 0.001), and the standard errors are robust to heteroscedasticity confirmed by the Breusch-Pagan test ($\chi^2 = 14.7$, $p = 0.04$), which indicated heteroscedasticity in the initial OLS residuals; heteroscedasticity-consistent (HC3) standard errors were therefore applied following the procedure of MacKinnon and White (1985). HC3 adjusts the estimated covariance matrix to obtain valid inference in the presence of heteroskedasticity; it does not make the residual variance constant. Pairwise correlations among explanatory variables were below 0.5, and variance inflation factors were below the conventional threshold of 5, suggesting no severe collinearity; pairwise correlations alone, however, cannot rule out collinearity involving linear combinations of several regressors, and this is noted as a limitation in Section 5.6. The coefficient of determination (R^2) of 60.33% indicates that the independent variables account for 60.33% of the variation in the commercialization rate. The key determinants influencing the commercialization rate include selling price, cultivated land area, distance to market, type of agricultural ecology, production objectives, access to credit, sales contracts, and village accessibility.

Table 5. Determinants of marketing rate

Explanatory Variables	Coefficient	Robust Standard Error
Rice selling price	0.691***	0.181
Labor cost	−0.021	0.040
Fertilizer purchase price	−0.305	0.505
Imported rice price	−0.305	0.237
Household size	0.044	0.127
Monthly income	0.088	0.076
Rice cultivated area	0.128*	0.067
Distance from farm to market	0.554***	0.187
Experience in agricultural production	0.082	0.093
Gender	0.119	0.090
Rice farming training	−0.004	0.136
Type of ecology		
Lowland	-	
Plateau	0.406***	0.113
Both	0.034	0.105
Production objective		
Sale	-	
Self-consumption	−1.474***	0.262
Sale and self-consumption	−0.444**	0.219
Credit	0.209**	0.099
Sales contract	−0.216**	0.095
Accessibility		
Paved road	-	
Carriageway	−0.290*	0.172
Non carriageway	−0.051	0.091
Constant	0.442	3.536
R2	60.33%	
F-statistic	7.66***	

***Significant at the 1% level (p<0.01). **Significant at the 5% level (p<0.05). *Significant at the 10% level (p<0.10).

The selling price is positively and significantly associated (1% level) with the commercialization rate. A 1% increase in the selling price leads to a 0.69% increase in the commercialization rate (HC3 SE = 0.18; 95% CI [0.34, 1.04]). This can be explained by the fact that higher prices incentivize producers to sell more rice to maximize profits. Selling at low prices does not generate sufficient revenue to cover the investments in production, including materials, labor, and financial resources (Kiki & Agli, 2007). The coefficients associated with cultivated land area and village accessibility are positive and significant at the 10% level. A 1% increase in cultivated land area results in a 0.128% increase in the proportion of production sold. Farmers in villages with paved roads have a higher rate of commercialization than those in villages accessible only via dirt roads.

The distance between the farm and the rice market has a positive and significant effect, with a greater impact on farms farther from markets since these farms tend to be more productive. The type of agricultural ecology also significantly influences the commercialization rate. Farmers cultivating in upland areas exhibit higher rates of commercialization than those working in lowland areas. The intended use of production significantly affects the commercialization rate. Compared to those aiming for sales, farmers prioritizing self-consumption exhibit a 1.47% lower commercialization rate, a statistically significant difference ($P < 0.01$). Similarly, access to agricultural credit is associated with a 0.21-percentage-point increase in the proportion of production sold. Interestingly, farmers engaged in formal sales contracts tend to exhibit lower commercialization rates, which could be attributed to contract-related disputes or increased household consumption of their own production.

4.3.2 Determinants of Local Rice Supply

The supply model is globally significant at the 1% threshold, with an R^2 of 74.41%, indicating that nearly three-quarters of the variation in marketed rice quantity is explained by the variables included in the model (Table 6 & 7). The selling price exerts a positive and highly significant effect on supply. A 1% increase in price leads to a 1.70% increase in the quantity marketed, indicating an elastic response. This elasticity applies specifically to the marketed surplus, which is the residual of total production after household consumption and post-harvest losses are deducted. Even a modest price increase is sufficient to redirect a proportionally larger share of output from domestic use to the market, which explains why this coefficient exceeds unity. Fertilizer price has a negative and highly significant association with marketed quantity. A 1% increase in fertilizer price is associated with a 3.86% reduction in marketed quantity. The magnitude of this coefficient reflects the high fertilizer intensity of irrigated lowland cultivation in Glazoué and indicates that movements in input costs are a primary driver of marketed volume. Cultivated area and market distance both show positive and highly significant effects. A 1% increase in cultivated area raises supply by 0.88%. Farmers located farther from markets supply more rice, not less. This result is consistent with the pattern whereby remote producers tend to cultivate larger plots, sell in bulk to itinerant traders rather than bearing transport costs themselves, and exhibit lower own-consumption rates, so a higher share of their output reaches commercial channels regardless of distance.

Farming experience also contributes positively: a 1% increase in experience is associated with a 0.6% rise in marketed quantity, reflecting accumulated technical and commercial knowledge. Access to agricultural credit is positively associated with marketed supply. Farmers who received at least one formal or semi-formal loan for inputs in the 12 months preceding the survey supplied 0.706 times as much rice as those without credit, confirming that liquidity constraints restrict market participation. The presence of a sales contract, by contrast, is associated with lower marketed quantities. This negative association may reflect contractual disputes, reported by 22% of contracted farmers, or delayed payment arrangements that discourage active market engagement.

Farmers whose primary production objective is self-consumption supply approximately 4.97% less rice than those oriented toward sale. Farmers combining self-consumption and sale objectives also supply less than purely market-oriented producers, confirming that the production objective directly conditions the volume

reaching the market. Road accessibility conditions supply in the expected direction: farmers in areas with unpaved or poorly accessible roads market less rice than those with paved road access. Ecological context matters as well. Producers operating in plateau ecosystems supply 0.667 times as much rice as those cultivating in lowland areas, suggesting that agro-ecological conditions influence both yields and the share directed to the market. Finally, adoption of modern production technologies is positively associated with marketed quantity. Farmers using modern techniques supply significantly more rice than those relying on traditional practices.

Table 6. Determinants of local rice supply

Explanatory Variables	Coefficient	Robust Standard Error
Rice selling price	1.701**	0.785
Imported rice price	0.543	0.812
Fertilizer purchase price	−3.861**	1.729
Labor cost	−0.117	0.148
Household size	0.348	0.458
Monthly income	0.192	0.296
Rice cultivated area	0.886***	0.169
Distance from farm to market	2.168***	0.560
Experience in agricultural production	0.614*	0.339
Gender	0.473	0.295
Rice farming training	0.271	0.319
Type of ecology		
Lowland	-	
Plateau	0.667*	0.370
Both	0.134	0.339
Production objective		
Sale	-	
Self-consumption	−4.968***	1.398
Sale and self-consumption	−1.383***	0.503

***Significant at the 1% level (p<0.01). **Significant at the 5% level (p<0.05). *Significant at the 10% level (p<0.10).

Expressed as percentage effects, farmers with credit access market approximately 102.6% more rice than those without (β = 0.706); farmers with a sales contract market approximately 58.3% less than those without (β = −0.874). Self-consumption-oriented farmers market approximately 99.3% less than sale-oriented farmers (β = −4.968), and those combining both objectives market approximately 74.9% less (β = −1.383). Farmers on carriageway and non-carriageway roads market approximately 76.7% and 55.7% less, respectively, than those on paved roads; plateau producers market approximately 94.8% more than lowland producers; and producers using less-modern technology market approximately 67.8% less than those using modern technology (differences reported for coefficients significant at the 10% level or better).

Table 7. Determinants of local rice supply

EXPLANATORY VARIABLES	COEFFICIENT	TEST
Credit	0.706**	0.355
Sales contract	−0.874***	0.299
Accessibility		
Paved road	-	
Carriageway	−1.456***	0.533
Non carriageway	−0.814*	0.445
PRODUCTION TECHNOLOGY		
Modern	-	
Semi-modern	−0.380	0.333
Less-modern	−1.134**	0.530
Traditional	−0.771	0.593
Conservative	−0.482	0.518
Constant	0.442	0.69
R^2	74.41%	
F-statistic	18.88***	

***Significant at the 1% level (p<0.01). **Significant at the 5% level (p<0.05). *Significant at the 10% level (p<0.10).

5. Discussion

5.1 Price Elasticity and the Marketed Surplus Framework

This study shows that local rice supply in Glazoué responds strongly to output and input price signals, but that this response is mediated by institutional, ecological, and socio-economic conditions rather than by prices alone. The high elasticity of marketed supply with respect to the selling price (1.70) confirms that, in a context of active market integration, smallholders adjust the share of production sold much more than total output when prices rise. This result is consistent with the theoretical framework of agricultural household models, which distinguish between the production and consumption decisions of farm households and predict that marketed surplus responds more elastically to price incentives than total production (Singh et al., 1986). It departs from earlier supply-response studies in Benin and West Africa that reported inelastic total rice supply with respect to price (Nerlove, 1979; Thériault et al., 2018) but is consistent once one recognizes that these studies model total production rather than marketed surplus. In terms of institutional economics, this suggests that commercialization in Glazoué is governed by residual allocation decisions at the household level, where market-oriented farmers shift quantities from self-consumption to sales when the marginal value of cash increases relative to own consumption; a mechanism formalized in selectivity models of food marketing behavior in sub-Saharan Africa (Goetz, 1992; Key et al., 2000).

5.2 Fertilizer Price Elasticity and Input Market Vulnerabilities

The strong and negative elasticity of supply with respect to fertilizer prices (−3.86) further highlights the vulnerability of intensified rice systems to input price shocks. This magnitude exceeds estimates reported in cross-country studies on smallholder agricultural production in sub-Saharan Africa (Jayne et al., 2010) but aligns with recent evidence that fertilizer-intensive and irrigated cropping systems are disproportionately exposed to global commodity price volatility (Minot, 2014). Within an agrarian political economy perspective, this sensitivity reflects broader power asymmetries along the fertilizer value chain, where smallholders face high transaction costs and

limited bargaining power vis-à-vis importers and agrodealers (Jayne et al., 2019). The results therefore reinforce current calls for carefully designed input subsidy or voucher schemes that both lower effective fertilizer prices for smallholders and reduce their exposure to global market volatility, while avoiding the distortions associated with universal subsidies (Dorward & Chirwa, 2011; Minot & Benson, 2009).

5.3 Area, Market Distance, and Producer Experience

The positive influence of cultivated area, market distance, and producer experience on supply challenges linear narratives that equate proximity to markets with greater commercialization. This is in analogous settings with Stifel and Minten (2008) on isolation effects, and Chamberlin and Jayne (2013) on spatial heterogeneity in African agricultural markets. Contrary to many studies that find distance to be a barrier to market participation (Barrett, 2008; Fafchamps & Hill, 2005), Glazoué farmers located farther from rice markets supply more rice. One plausible explanation –which the present cross-sectional data cannot directly test– is that they cultivate larger plots on more available land and sell in bulk to itinerant traders; this interpretation is consistent with patterns reported in comparable West African settings (Chamberlin & Jayne, 2013; Stifel & Minten, 2008) but was not independently confirmed through farm-size or trader-channel data collected specifically for this study. This pattern resonates with rural sociology analyses that emphasize differentiated agrarian structures: more land-abundant, commercially oriented households in peripheral zones specialize in market production, while smaller farms closer to town balance market sales with subsistence needs (Bernstein, 2010). The positive role of farming experience also suggests learning effects and cumulative capabilities, consistent with innovation-systems perspectives and econometric evidence that experience and learning-by-doing shape agricultural technology uptake and marketing decisions over time (Foster & Rosenzweig, 1995).

5.4 Governance Variables: Roads, Contracts, and Credit

Governance-related variables such as village accessibility, presence of contracts, and credit access underscore the centrality of rural governance and institutional arrangements in shaping market participation. Better road access increases commercialization rates, in line with theoretical and empirical work demonstrating that rural infrastructure reduces transport costs, improves farm-gate prices, and expands market participation (Jacoby, 2000; Mu & van de Walle, 2011). However, the finding that formal sales contracts are associated with lower commercialization runs counter to evidence from other West African settings where contracts and vertical coordination often raise yields and marketed output (Ton et al., 2018). This divergence likely reflects context-specific contract design and enforcement problems in Glazoué –including delayed payments and disputes–, which turn contracts into a source of uncertainty rather than risk reduction, consistent with documented failures of contract governance in thin or weakly institutionalized markets (Warning & Key, 2002). By contrast, access to credit has the expected positive effect on marketed volumes, corroborating research linking financial inclusion and the adoption of improved technologies to higher market participation and welfare gains in rice systems (Fletschner & Kenney, 2014; Zeller et al., 1997).

5.5 Production Objectives and Gendered Commercialization Patterns

The analysis of production objectives and gendered patterns of commercialization adds an important socio-economic layer to conventional supply-response models. While much of the literature portrays smallholders as primarily subsistence-oriented, 86.67% of Glazoué farmers prioritize sales, which is a finding consistent with the broader literature documenting the progressive commercialization of smallholder agriculture in sub-Saharan Africa (Pingali & Rosegrant, 1995). Self-consumption-oriented households supply significantly less rice, supporting agrarian political economy arguments that smallholders are increasingly integrated into markets but face unequal terms of incorporation, with poorer and more food-insecure households maintaining higher self-consumption shares (Bernstein, 2010). Gendered differences in objectives and processing roles such as women's

stronger engagement in parboiling and higher self-consumption shares also reveal how intra-household division of labour and control over processing technologies shape commercialization outcomes (Doss, 2002; Fischer & Qaim, 2012), an aspect often neglected in macro-level supply analyses. These findings contribute to debates in rural sociology on how gender norms, household structures, and labor allocation mediate the impacts of market integration on livelihoods and food security (Carletto et al., 2017; Ruel et al., 2018).

5.6 Methodological Contributions and Limitations

Methodologically, the study advances supply-response analysis in West African rice systems by combining a static, cross-sectional adaptation of the Nerlove framework (Nerlove, 1958a) with mixed-methods household data and an explicit focus on marketed quantities. The use of heteroscedasticity-robust standard errors and variance inflation factor diagnostics strengthens confidence in the estimated coefficients (Askari & Cummings, 1977), while the instrumental-variable approach for credit access addresses a key source of potential endogeneity (Wooldridge, 2010). The mixed-methods design linking econometric models with qualitative insights from focus groups and key informants enhances the internal validity of the interpretations by situating statistical associations within concrete institutional and social dynamics (Teddlie & Tashakkori, 2009). At the same time, several limitations must be acknowledged. The cross-sectional nature of the household survey precludes estimation of the full dynamic Nerlove partial-adjustment model (Nerlove, 1979), including its adjustment coefficient and long-run elasticities; only the static, observed-quantity adaptation described in Section 3.3 is estimated here, and the operationalization of expected prices via a moving average relies on secondary series rather than farm-level perceptions (Mundlak, 2001). The commercialization rate is a proportion bounded between 0 and 100; ordinary least squares can in principle generate fitted values outside this range and tends to produce heteroskedastic errors for such variables. A fractional-response model (fractional logit or beta regression) would be the preferred specification and is noted as a direction for future re-estimation. The positive association between market distance and marketed quantity should also be interpreted cautiously: it may partly reflect omitted geographic or farm-structure heterogeneity across villages rather than a within-farmer behavioral response to distance. Locality fixed effects, or an interaction between distance and cultivated area, would help disentangle these channels but were not estimated in the present cross-sectional specification. Finally, the sample is confined to a single municipality with specific research infrastructure and processing capacity, which limits external validity to other rice-growing zones without similar institutional endowments.

6. Conclusion

This study highlights the various factors that determine the proportion of rice production marketed and the quantity of rice supplied across different markets. The findings reveal that selling price, cultivated rice area, distance from the farm to the nearest rice market, ecological conditions, production objectives at the start of the season, access to credit, sales contracts, and the accessibility of villages and urban districts are key factors influencing the proportion of production sold on the market. In addition to these factors, fertilizer purchase prices, the producer's experience in rice farming, and production technology also significantly impact the quantity of rice sold. To increase the volume of rice supplied to the market and contribute to food security in deficit areas, it is essential to implement targeted actions addressing these key determinants. The interventions comprise three complementary measures. First, fertilizer is subsidized for smallholders through a voucher scheme, justified by the estimated fertilizer price elasticity of −3.86: a 10% reduction in fertilizer prices is associated, under this elasticity, with an approximate 38.6% increase in marketed rice supply, which is a very large implied effect that should be treated as indicative rather than a precise forecast, given the uncertainty around this coefficient discussed in Section 5.6, and should not by itself be used to size a voucher program without further robustness testing. Second, rural road networks are expanded to reduce transport costs; this is supported by the significant positive

effect of village accessibility on the commercialization rate. Third, gender-sensitive credit programs prioritize women's access to processing equipment; this responds to the observed income gap between women and men and to the positive IV-estimated association between credit access and marketed supply. This study does not test whether the effect of credit differs by gender; a gender-by-credit interaction or gender-stratified models would be needed to directly support that link, and it is presented here as a hypothesis for future evaluation rather than a finding of this analysis.

Targeted fertilizer voucher schemes for smallholders, coupled with investments in rural roads linking remote production zones to primary markets, would stabilize input use and reduce transport bottlenecks, thereby leveraging the pronounced price and fertilizer elasticities identified in this study. Policymakers and development practitioners should co-design gender-sensitive credit products and contract arrangements with farmer organizations and processors to ensure timely payments, transparent clauses, and alignment with women's roles in processing and marketing. At the local level, municipal authorities, cooperatives, and women's groups can use these results to prioritize support for modern production and processing technologies, strengthen farmer organizations as governance intermediaries, and pilot scalable, context-adapted models of inclusive rice commercialization.

Transparency of Data

The authors are unable to share the underlying data because they are owned by AfricaRice and the survey respondents provided consent only for the publication of anonymized and aggregated results. Access to the raw data is therefore restricted to the public.

Author Contribution Statement

	AB Bessan	R Sossou	CL Hinnou	CH Sossou
Conceptualization	■		■	■
Data curation		■		
Formal analysis		■	■	
Funding acquisition	■			
Investigation		■	■	
Methodology	■		■	■
Project administration	■			
Resources	■			■
Supervision	■		■	■
Validation			■	■
Visualization		■		
Writing – original draft	■	■	■	
Writing – review and editing		■		■

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