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Vertical coordination mechanisms and farm performance amongst smallholder rice farmers in northern Ghana

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Abstract

Despite the fact that contracting facilitates farmer participation in agrifood value chains, evidence on farmers' participation in different forms of contracts and the impact on farm performance is still limited. This study examines the determinants and impacts of vertical coordination mechanism-spot market transactions, written, and verbal contract-on-farm performance of rice farmers in northern Ghana, using a multinomial BFG model to account for selectivity bias. The findings indicate that vertical coordination participation decision is significantly influenced by age, access to credit, labor, association membership, and sales to institutional buyers. The empirical results also reveal significant gains in farm performance outcomes from participating in written and verbal contracts, relative to spot market transactions.

ECONLIT CITATIONS

C34, C35, D23, Q12, Q13

1 | INTRODUCTION

Agrifood value chains in developing countries continue to undergo rapid transformation due to increasing incomes, urbanization, and consumer consciousness in food quality and safety (Minot & Sawyer, 2016). The expansion of agricultural commodity markets, supermarkets, agribusiness firms, and their requirements for food grades and standards drive the need for vertical coordination in agrifood value chains (Barrett et al., 2012; Henderson & Isaac, 2017). Some recent studies have shown that participation in agrifood value chains is associated with improved smallholder farmers' welfare (e.g., Rao & Qaim, 2011). However, challenges such as underdeveloped market systems and infrastructure, limited access to financial capital and technology, high transaction costs associated with input and output markets, among others, limit smallholder participation in agrifood value chains in developing

[Correction added on 18 November 2020, after first online publication: Projekt Deal funding statement has been added.]

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countries (Abdulai & Birachi, 2009; Otsuka, Nakano, & Takahashi, 2016). These challenges are still somehow unresolved and often make it difficult for farmers to take advantage of prevailing market opportunities (Swinnen & Maertens, 2007).

However, contracting is recognized as the dominant form of vertical coordination mechanism that facilitates smallholder farmers' participation in agrifood value chains (Bolwig, Gibbon, & Jones, 2009; Otsuka et al., 2016). It falls between spot market transaction (0% vertical coordination) and full vertical integration (100% vertical coordination), and addresses constraints related to inadequate access to credit and extension, market imperfections, and high transaction costs (Bellemare, 2012). Smallholder farmers enter into contractual agreements with downstream buyers to reduce transaction costs and obtain other benefits associated with using contracts (Barrett et al., 2012). Such agreements can involve specification about the transaction only, such as product quality, delivery times, as well as sales price (marketing contract), or specifications related to production process, product quality, seed variety, chemicals used among others (production contract; Maertens & Vande Velde, 2017; Roussy, Ridier, Chaib, & Boyet, 2018). Contracting is important in facilitating farmers' access to inputs, credit, and technology, as well as reduces risks associated with prices and markets (Kariuki & Loy, 2016; Mishra, Kumar, Joshi, & Dsouza, 2018). Buyers can prefinance smallholder farmers by providing them within puts, technology, and cash credit, and costs associated with these provisions are deducted from the final produce at the point of product delivery (Bellemare, 2012).

Contracting in smallholder output markets has received considerable attention in the development economics literature. In particular, some authors have modeled contracting in a dichotomous framework, involving farmers' decisions to enter into contracts with agribusiness firms and supermarkets, or supply produce in spot markets (e.g., Bellemare, 2012; Maertens & Vande Velde, 2017; Michelson, 2013). Recent empirical evidence in developing countries has highlighted positive welfare impacts associated with smallholder participation in the agrifood value chain through contracting (e.g., Michelson, 2013). In the vegetable sector in Kenya, Rao and Qaim (2011) show the positive impact of value chain participation on household income, while Michelson (2013) found that farmer participation in supermarket channels through contracts increases household productive asset holdings in Nicaragua. In output markets, evidence on smallholder farmers' participation in different forms of vertical coordination mechanisms, such as written contracts, verbal contracts, and spot market transactions, and their related impacts on farm performance is still limited in the empirical literature. To the best of our knowledge, only the studies by Ma and Abdulai (2016b) and Trifković (2016) investigated the impacts of different forms of vertical coordination mechanisms on smallholder farm performance. In particular, Ma and Abdulai (2016b) found significant increases in net farm returns associated with written and verbal contract participation by apple farmers in China. The study by Trifković (2016) found that in the catfish sector in Vietnam, vertically integrated and contract farms achieve higher yields and farm revenues than independent farms. Some previous studies investigated the determinants of farmers' market participation decisions, quantities of produce transacted, and the choice of the market place for output transactions (e.g., Abdulai & Birachi, 2009).

The present study contributes to the growing literature on vertical coordination mechanisms and their impacts on farm performance in three ways. First, we assess the factors influencing farmers' decisions to participate in a written contract, verbal contract, and spot market in output transactions, as well as highlight the impact of these factors on-farm performance. Second, we examine the causal effects of written and verbal contracts participation on-farm performance outcomes, such as net farm income, total farm income, and total household income, relative to spot market transactions. Finally, we decompose net farm income into margins (price margins) and yield effects (labor productivity), and examine the impact of the coordination mechanisms on these outcomes. This will provide policymakers with insights into the multidimensional effects of participating in the vertical coordination mechanisms, as well as which mechanism is of substantial benefits to smallholder farmers in agrifood value chains.

We use data from a recent survey of smallholder rice farmers in five districts of northern Ghana. In recent times, the Ghana government has intensified collaborative efforts with donor agencies and agribusiness firms to

upgrade the domestic cereal food staples including rice by implementing value chain interventions. The interventions aim at increasing efficiency of these value chains for the benefit of a large number of smallholders. The findings from this study can also enhance stakeholder policy–targeting efforts towards addressing multiple market failures facing smallholder farmers in Ghana. Given that participation in vertical coordination mechanisms is nonrandom, we employ the selectivity approach for the multinomial logit (MNL) model introduced by Bourguignon, Fournier, and Gurgand (2007) to account for selection bias associated with observed and unobserved attributes. We also compare the estimates from this approach to Lee's (1983) selection bias correction model, which computes only one selectivity correction term for all vertical coordination choices, to provide further insights into the differential impacts of coordination mechanisms on-farm performance in the rice value chain.

The rest of this paper proceeds as follows: Section 2 presents an overview of rice production and marketing in Ghana. Section 3 captures the data and summary statistics of the variables used in the analysis. A conceptual framework is captured in Section 4, followed by empirical specification in Section 5. The empirical results are presented in Section 6, while the final section concludes.

2 | OVERVIEW OF RICE PRODUCTION AND MARKETING IN GHANA

Rice has become the second most important cereal staple in Ghana after maize, and its production is done under three ecosystems: Rainfed lowland (78% of the arable area), rainfed upland (6%), and irrigation (16%) systems (MoFA, 2009). The major rice-producing areas in Ghana include Volta, Ashanti, Eastern, Northern, and Upper East regions (MoFA, 2009). Domestic rice production increased from 390,000 Metric Tons (MT) in 2016/2017 to 450,000 MT in 2017/2018 (GAIN, 2018). Rice forms an important part of Ghanaian diet and contributes to food security among rural and urban households. Rice consumption is increasing, driven by population growth, urbanization, and changing habits of consumers, which creates a gap between demand and local supply. The consumption of rice in 2017/2018 is estimated at 1.0 million MT, and the per capita rice consumption in 2016/2017 stood at 35 kg, and is estimated to reach about 40 kg by 2020 (GAIN, 2018). Domestic rice production still covers about 30–40% of consumer demand, allowing for imports of larger quantities to address both quantity and quality differences between local production and demand (Angelucci, Asante-Poku, & Anaadumba, 2013).

Other major cereal staples in Ghana include Maize, wheat, and sorghum. Maize is considered the most important cereal staple in Ghana mainly produced in the middle-southern part and northern regions. Statistics indicate that maize production increased from 1.75 million MT in 2016/2017 to 1.8 million MT in 2017/2018, with an estimated consumption of 1.9 million MT in 2017/2018 (GAIN, 2018). Ghana does not grow wheat domestically and relies on imports for all its wheat needs. Wheat is mostly processed into flour for making bread, cakes, and other pastries. Wheat consumption is estimated at 590,000 MT in 2017/2018, with per capita consumption of 20 kg per year (GAIN, 2018). Sorghum is also one of the fundamental cereal crops mostly produced in northern Ghana. Statistics indicate that sorghum production in Ghana declined (12%) from 262,000 MT in 2015 to about 229,000 MT in 2016 (MoFA, 2016). Consumption of sorghum was 199,756 MT in 2016, with an estimated per capita consumption of about 5 kg (Statistics, Research and Information Directorate SRID 2017).

The share of rice production in total cereal output in Ghana is about 16% (maize 62% and sorghum 14%). Recent increase in the production of rice and other cereal staples in Ghana is attributed to the renewed commitment of government and donor agencies to revamp the cereal staple chains by initiating a number of interventions.[1] For instance, under the government's 5-year Planting for Food and Jobs (PFJ) flagship program, 50% subsidy on seed and fertilizer was introduced to make it affordable for smallholder farmers for increased application rates and yields (GAIN, 2018). In northern Ghana, rice is grown by over 279,000 households with an

[1]Other interventions in northern Ghana include Feed the Future-USAID/ATT, Ghana Commercial Agriculture Project, ADVANCE II, GHASIP projects, and so forth.

average farm size of about two hectares, and cultivating about 70% of total land area (USAID, 2009). Majority of smallholder farmers grow improved rice varieties, although some still grow traditional varieties (Ragasa et al., 2013). Examples of improved rice varieties commonly grown by farmers in northern Ghana include Jasmine 85, AGRA rice, Togo marshal, Digang, Nerrica 1, Nerica 2, and Nabogo rice. The traditional varieties include GR 18, TOX 3108 (GR 22), and Mandii (Ragasa et al., 2013). Smallholder rice farmers produce and supply paddy rice to buyers, using vertical coordination mechanisms such as spot market transactions, written, and verbal contracts. These buyers are institutions or private companies,[2] aggregators, and processors mostly located in the regional capitals of northern Ghana and some parts of southern Ghana. They usually enter into seasonal marketing contracts with smallholder rice farmers at the beginning of the growing season and then travel to the contracted farmers after harvest to mobilize the paddy for onward processing and sales. These contractual arrangements, although not without challenges, have been found useful, because they provide assured markets for farmers and provide buyers with a regular supply of paddy for their agribusinesses. However, some smallholder rice farmers do not get the opportunity to enter into marketing contracts with these private companies and other buyers, compelling them to sell paddy in spot markets, by either selling at farmgate to buyers who randomly travel to the rice-growing areas during the harvest period, or transport to market centers for sale. In other cases, local rice processors in the communities also provide markets for this category of farmers.

3 | DATA AND SUMMARY STATISTICS

This study uses data from a recent farm household survey conducted from June to August, 2016 in five districts of northern Ghana—Tamale metropolis, Savelugu Nanton Municipal, Tolon, Kumbungu, and Sagnarigu districts. A multistage sampling approach was employed in selecting the sample for this study. First, we used purposive sampling technique to select these five districts based on the intensity of rice production, as well as their position as some of the major beneficiary areas of rice value chain interventions in northern Ghana. Second, in consultation with officials of development projects (FtF-USAID-Ghana[3]) and MoFA extension agents, we randomly selected two to three communities from each district in proportion to size of the district. Finally, we randomly sampled smallholder rice farmers in proportion to the farmer population in each area. In total, 458 rice farmers were sampled and interviewed, using a structured questionnaire with the help of trained research assistants, and under the supervision of one of the authors. The data collected covered information related to 2015 production season. The survey gathered information from farmers on personal, household and farm-level characteristics, asset ownership, and access to credit and marketing activities such as vertical coordination mechanisms.

Table 1 presents the definition and summary statistics of the variables used in the analysis. The dependent variables are the vertical coordination mechanisms (spot market, written, and verbal contracts) such that the chosen mechanism is assigned a value of one, and zero otherwise. The study sample constitutes 43% of farmers who supply paddy in spot markets, 33% use written contracts, and 24% use verbal contracts. The outcome variables include the net farm income, total farm income, and total household income. Table 1 shows that net farm income from rice production and sales constitute about 31% of total farm income and 28% of total household income. Table 2 reports systematic differences in farmer characteristics with respect to the vertical coordination mechanisms and associated *t* test results. Significant age differences exist between farmers who use verbal contracts in output transactions and those who carry out spot market transactions. In particular, farmers who

[2]Examples of the private companies that contract with smallholder rice farmers in northern Ghana include premium foods limited, AMSIG Resources, SAVBAN limited, BUSAKA enterprise, Investment Protocol Services Limited, and so forth

[3]The project components under the FtF-USAID-Ghana program include Agriculture Technology Transfer project (ATT), Resiliency in Northern Ghana (RING), Agricultural Development and Value Chain Enhancement (ADVANCE), Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) projects.

TABLE 1 Variable definition and summary statistics

Variable	Definition	Mean (standard deviation)
Spot market	1 if farmer chose spot market, 0 otherwise	0.43 (0.49)
Written contract	1 if farmer chose written contract, 0 otherwise	0.32 (0.47)
Verbal contract	1 if farmer chose verbal contract, 0 otherwise	0.24 (0.42)
Net farm income	Gross revenue from rice production less variable input cost (GH¢/ha)	1,152.29 (1,816.18)
Total farm income	Gross revenue from all crops including paddy rice less input cost (GH¢)	3,723.59 (4,056.53)
Total household income	Annual household income including off-farm earnings and remittances (GH¢)	4,102.50 (4,294.30)
Price margin	Selling price of paddy less the ratio of total input costs to total rice output (GH¢/kg)	0.67 (0.43)
Labor productivity	Total rice output divided by labor (kg/worker-day)	48.37 (148.06)
Age	Age of respondent (years)	37.46 (11.65)
Education	Education of respondent (years)	2.71 (4.40)
Gender	1 if farmer is male, 0 otherwise	0.88 (0.32)
Farm size	Size of farm (hectares)	1.14 (1.26)
Access to credit	1 if farmer is not credit constraint, 0 otherwise	0.40 (0.49)
Mobile phone	1 if farmer owns a mobile phone, 0 otherwise	0.45 (0.49)
Market perception	Farmer perception of paddy rice demand in previous year before the survey (1 = low, 0 = high)	0.35 (0.47)
Road status	1 if market road is motorable, 0 otherwise	0.73 (0.44)
Distance to market	Distance to market (km)	6.57 (4.08)
Labor	Total labor used in rice production (worker-days/ha)	55.86 (23.58)
Importance of legal contracts	1 if farmer considers legal contracts important, 0 otherwise	0.51 (0.50)
Institutional buyer	1 if farmer sells to institution, 0 otherwise	0.21 (0.41)
Association	1 if farmer belongs to farmer group, 0 otherwise	0.50 (0.50)
Farm vehicle	1 if farmer owns farm vehicle, 0 otherwise	0.07 (0.26)
Knowledge of credit source	1 if farmer is aware of existing credit sources, and 0 otherwise	0.05 (0.20)
Distance to association meeting venue	Distance to farmers' association meeting venue in the community (km)	3.38 (3.05)
Sagnarigu	1 if farmer is located in Sagnarigu district, 0 otherwise	0.12 (0.33)
Tolon	1 if farmer is located in Tolon district, 0 otherwise	0.22 (0.41)
Kumbungu	1 if farmer is located in Kumbungu district, 0 otherwise	0.24 (0.42)
Savelugu Nanton	1 if farmer is located in Savelugu Nanton Municipal, 0 otherwise	0.20 (0.40)
Tamale	1 if farmer is located in Tamale metropolitan area, 0 otherwise	0.20 (0.40)

Note: GH¢ is Ghanaian currency; US$1 = GH¢ 4.19 in 2016.

TABLE 2 Differences in characteristics among users of vertical coordination mechanisms

Variable	Spot market		Written contract			Verbal contract		
	Mean	Standard deviation	Mean	Standard deviation	[a]Diff. (*t*-stat.)	Mean	Standard deviation	[b]Diff. (*t*-stat.)
Age	36.451	11.534	37.370	10.789	0.75	39.427	12.828	2.08**
Credit access	0.289	0.454	0.516	0.501	4.41***	0.463	0.500	3.10***
Education	2.269	4.153	3.046	0.366	1.66*	3.054	4.648	1.52
Gender	0.888	0.315	0.887	0.317	0.02	0.872	0.334	−0.40
Farm size	1.071	0.941	1.190	1.592	0.86	1.207	1.252	1.07
Labor	50.304	21.794	62.540	24.474	4.92***	56.663	23.139	2.39**
Dist. to market	6.545	3.925	6.465	3.607	0.19	6.788	4.940	0.473
Mobile phone	0.299	0.459	0.582	0.494	5.51***	0.563	0.498	4.68***
Road status	0.705	0.456	0.761	0.427	1.16	0.736	0.442	0.572
Import. of legal contract	0.355	0.479	0.728	0.446	7.41***	0.527	0.501	2.96***
Market perception	0.208	0.406	0.556	0.498	7.17***	0.327	0.471	2.32**
Association	0.187	0.391	0.774	0.419	13.44***	0.718	0.451	10.75***
Farm vehicle	0.086	0.281	0.039	0.195	1.73*	0.100	0.301	0.39
Institutional buyer	0.101	0.302	0.364	0.482	6.20***	0.218	0.414	2.82***
Knowledge of credit source	0.040	0197	0.052	0.224	0.54	0.045	0.209	0.20
Distance to association meeting venue	4.014	4.413	3.999	3.002	1.50	3.779	3.391	−1.71*
Net farm income	929.992	1,365.047	1,223.066	1,690.430	1.78*	1,453.282	2,521.677	2.36**
Total farm income	3,237.234	3,331.721	4,210.974	4,737.583	2.24**	3,925.582	4,164.990	1.58
Total household income	3,392.254	3,468.399	4,898.470	4,942.842	3.34***	4,281.855	4,499.133	1.93**
Price margin	0.615	0.463	0.736	0.374	2.61***	0.704	0.451	1.62
Labor productivity	39.073	50.200	53.129	246.847	0.77	39.446	57.901	0.05
Sample size	197		151			110		

Note: *, **, and *** mean significant at 10%, 5%, and 1% levels, respectively.
[a]Differences in characteristics between written contract and spot market users.
[b]Differences in characteristics between verbal contract and spot market users.

supply paddy in the spot market and those who use written contracts are relatively younger than rice farmers who engage buyers with verbal contracts, suggesting that older farmers are more likely to choose verbal contracts for output transactions. Again, vertical coordination mechanism users significantly vary in terms of education. The results show that farmers who use written contracts for output transactions are more educated than farmers who

use verbal contracts and spot market supply. However, there are no significant differences in education between farmers who supply in the spot market and those who use verbal contracts.

We also observe that farmers who use written contracts and those who engage in transactions via verbal contracts constitute higher proportion of farmers who are not credit constrained, receive higher prices for the paddy, as well as generate higher net farm incomes, total farm income, and total household income relative to farmers who supply in spot market. We also observe that farmers who use written contracts and those who use verbal contracts mostly own mobile phones, attach greater importance to legal contracts, mostly belong to farmers' associations, employ higher amount of labor, and mostly sell paddy to institutional buyers, as compared to farmers who supply paddy in spot markets. It is important to mention that the differences in outcomes by coordination mechanisms cannot be interpreted as impacts since other confounding factors are not accounted for in the means.

4 | CONCEPTUAL FRAMEWORK

4.1 | Vertical coordination mechanism participation decision

In this section, we present a conceptual framework in relation to farmers' decisions to participate in vertical coordination mechanisms for output transactions. Following the concepts presented in Ma and Abdulai (2016b), we assume that farmers are risk neutral to simplify our model. Given that a rice farmer engages a buyer in an output transaction involving quantity of paddy at a given price, and associated input cost, using a coordination mechanism j among M coordination mechanisms, farmer's objective would be to maximize expected net farm income (V^*), specified as

$$V^*_{\max} = pQ(\omega, Z) - W\omega, \tag{1}$$

where p is the output price per kg, Q is the output (paddy) quantity in kg, W is the input prices, ω is a vector of input quantities (e.g., fertilizer, herbicide, and labor), and Z is a vector of farm and household level characteristics. Participation in vertical coordination mechanisms by farmers can increase their net farm incomes through the prices received and other benefits (input and market support) associated with the participation. Therefore, net farm income (V) can be expressed as a function of input and output prices, farm and household-level characteristics, and the choice of vertical coordination mechanism (D_j) as follows:

$$V = V(P, W, Z, D). \tag{2}$$

For any well-behaved profit (net farm income) function, applying Hoteling's lemma directly to Equation (1) yields a reduced form of the following rice output supply function:

$$Q = Q(P, W, Z, D) \tag{3}$$

Equations (2) and (3) suggest that net farm income from rice production (V) and rice output (Q) are influenced by the input and output prices, farm and household-level characteristics, and choice of vertical coordination mechanism (D_j). Following Ito, Bao, and Su (2012), we also decompose net farm income into labor (L), productivity (Q/L), and price margin ($p - W\omega/Q$) to evaluate the contribution of vertical coordination mechanisms to these farm performance outcomes, which is one of the objectives of this study.

To establish a link between participation in coordination mechanism and farm outcome such as net farm income, we assume that farmer i participates in the coordination mechanism j that yields maximum expected net farm income represented by V^*_{ij} compared to any other value chain coordination mechanism $V^*_{i\tau}$. Given the three coordination mechanisms in the study, $j = 1, 2, 3$, the expected net farm income associated with each coordination mechanism cannot be directly observed. What is observed is the participation decision in vertical coordination

mechanism (D_j). However, the expected net farm income can be expressed as a function of observable factors in a latent variable model as

$$V_{ij}^* = Z_{ij}\beta_j + \eta_{ij}D_{ij} = \begin{cases} 1 & \text{if } V_{i1}^* > \max\left(V_{i\tau}^*\right) \\ & \quad \tau \neq 1 \\ & \quad \vdots \\ M & \text{if } V_{iM}^* > \max\left(V_{i\tau}^*\right) \\ & \quad \tau \neq M \end{cases}, \tag{4}$$

where β_j is the parameter to be estimated and η_{ij} is the error term; and Z_{ij} is a vector of farm and household level factors influencing vertical coordination mechanism participation. These variables include age, gender, education, access to credit, farm size, association membership, labor, road status ownership of the mobile phone, farm vehicle, distance to markets, and location variables. These variables are included in the analysis based on the existing literature (e.g., Abdulai & Birachi, 2009; Winter-Nelson & Temu, 2005; Ito et al., 2012).

It is also assumed that the observed covariates in Z_{ij} are uncorrelated with the unobserved stochastic component η_{ij}, that is, $E(\eta_{ij} \mid Z_{ij}) = 0$. In addition, assuming that η_{ij} are independently and identically Gumbel distributed, the selection Equation (4) leads to a MNL model (McFadden, 1973). The probability that vertical coordination mechanism j is chosen by farmer i is specified as

$$P_{ij} = P(\varepsilon_{ij} < 0 \mid Z_{ij}) = \frac{\exp(Z_{ij}\beta_j)}{\sum_{\tau\neq 1}^{m}\exp\left(Z_{ij}\beta_\tau\right)},\ j = 1,\ 2,\ 3. \tag{5}$$

As stated earlier, the three vertical coordination mechanisms examined in this study include spot market transactions ($j = 1$), written contract ($j = 2$), and verbal contract ($j = 3$). Note that farmers who supply paddy in the spot market are the base group for comparison in the present analysis. The MNL model constitutes the first stage and is estimated with the maximum likelihood method to obtain coefficients associated with each coordination mechanism. However, we compute the marginal effects of the coefficients to allow for better interpretation of the results (Wooldridge, 2010). We also test the MNL model for the independence of irrelevant alternatives (IIA) assumption by conducting suest-based Hausman test, which is a modification of Hausman and McFadden test (Long & Freese, 2005).

4.2 | Impact evaluation and selection bias

This study also investigates the impact of each coordination mechanism j on a set of farm performance outcomes. Given that the vector of outcome variables is a linear function of household and farm level factors X_{ij} and a coordination mechanism choice dummy (D_{ij}), the outcome equation is specified as

$$Y_{ij} = X_{ij}\gamma + D_{ij}\delta + \mu_{ij}, \tag{6}$$

where Y_{ij} is a vector of outcome variables, γ and δ are vectors of parameters to be estimated; μ_i is the error term and satisfies $\mu_i \sim N(0, \sigma)$. It is worth noting that the parameter δ captures the impact of vertical coordination mechanism on the outcomes. However, given that farmers self-select into choice of coordination mechanisms for output transactions, using the OLS method could result in selectivity bias. In this case, the error terms in the coordination choice model η_{ij} and the outcome equations μ_{ij} are correlated, and the expected values of μ_{ij} conditional on sample selection are nonzero, which leads to inconsistent estimates. To account for the potential selectivity bias, we consider the methods proposed by Lee (1983), Dubin and McFadden (hereinafter DMF (1984), and the approach developed by Bourguignon et al. (hereinafter BFG, 2007).

Lee makes restrictive assumptions and fails to take into account the risk of multicollinearity, which is considered in the DMF's approach. Moreover, Lee's (1983) approach estimates only one selectivity term, even when there are multiple alternatives (Bourguignon et al., 2007). The DMF approach is also restrictive because it only extends the number of correction parameters to $M - 1$ for M alternatives. Given the limitations of the two approaches, Bourguignon et al. (2007) proposed an approach to account for selectivity bias with multiple outcomes, while accounting for the limitations of the Lee and DMF's approaches. It relaxes the restrictive assumption by estimating different selectivity correction terms for each coordination mechanism alternative. That is, the number of selectivity correction terms is equal to the number of vertical coordination alternatives. It also identifies the direction and sources of bias (Park, Mishra, & Wozniak, 2014). In this study, we use the selectivity bias correction method by Bourguignon et al. (2007), which we refer to as "Multinomial BFG Model", as it provides deeper insights into the impact of coordination mechanisms on-farm performance.

5 | EMPIRICAL SPECIFICATION

5.1 | Multinomial BFG model

The multinomial BFG model is a two-stage impact assessment procedure. In the first stage, we estimate MNL model (Equation (5)) to examine the determinants of coordination mechanism participation, and then compute selectivity correction terms, which are included in the second stage, to estimate the outcomes consistently. To estimate the impact of coordination mechanisms on the outcomes in the second stage, we specify the following three regimes of outcome equations:

$$\text{Regime 1 (Spot Market): } Y_{i1} = X_{i1}\gamma_1 + \mu_{i1} \text{ if } V = 1 \tag{7}$$

$$\text{Regime 2 (written contract): } Y_{i2} = X_{i2}\gamma_2 + \mu_{i2} \text{ if } V = 2 \tag{8}$$

$$\text{Regime 3 (Verbal Contract): } Y_{i3} = X_{i3}\gamma_3 + \mu_{i3} \text{ if } V = 3, \tag{9}$$

where Y_{i1}, Y_{i2}, and Y_{i3} are outcomes, such as net farm incomes, total farm income, and total household income from participating in spot markets, written, and verbal contracts, respectively; X is a vector of household and farm level factors; γ is a vector of parameters to be estimated, and μ is the error term. We identify the model since variables in Z in Equation (4) and X in Equations (7–9) are allowed to overlap during estimation. In such cases, at least one variable in Z should not feature in X (see Section 6.1). Therefore, to obtain unbiased and consistent estimates of γ in the outcome equations, we estimate the following regimes of selection bias-corrected outcome equations (Bourguignon et al., 2007):

$$\text{Regime 1: } Y_{iSM} = X_{i1}\gamma_1 + \sigma_1\left[\rho_1 m(P_{i1}) + \sum_j \rho_j m(P_{ij})\frac{P_{ij}}{(P_{ij} - 1)}\right] + \nu_{i1} \text{ if } V = 1 \tag{10}$$

$$\text{Regime 2: } Y_{iWC} = X_{i2}\gamma_2 + \sigma_2\left[\rho_2 m(P_{i2}) + \sum_j \rho_j m(P_{ij})\frac{P_{ij}}{(P_{ij} - 1)}\right] + \nu_{i2} \text{ if } V = 2 \tag{11}$$

$$\text{Regime 3: } Y_{iVC} = X_{i3}\gamma_3 + \sigma_3\left[\rho_3 m(P_{i3}) + \sum_j \rho_j m(P_{ij})\frac{P_{ij}}{(P_{ij} - 1)}\right] + \nu_{i3} \text{ if } V = 3, \tag{12}$$

where P_{ij} is the probability that farmer i chooses coordination mechanism j, ρ_j represents the correlation between μ_{ij} and η_{ij}, and $m(P_{ij})$ is the conditional expectation of η_{ij} used to correct for selection bias, σ_j is the standard deviation of μ_{ij}, and ν_{ij} is the error term. Note that a significant selectivity correction term $m(P_{ij})$ associated with

any coordination specification indicates the presence of selection bias, and insignificant term suggests that selection bias is absent and OLS method could produce consistent estimates.

5.2 | Treatment effects of vertical coordination mechanisms

The average treatment effects on the treated (ATT), which is the causal effect of vertical coordination mechanisms, can also be estimated using the multinomial BFG model. Farmers who participate in written contracts and those who use verbal contracts constitute the treatment groups and separate predictions of the treatment effects which are carried out, relative to farmers who supply paddy in spot markets. In particular, the conditional expectations of the outcomes from written contract ($j = 2$) and verbal contract ($j = 3$) participation, with spot market as base, is specified as (Bourguignon et al., 2007):

$$E(Y_{i2}\,|V = 2) = X_{i2}\gamma_2 + \sigma_2\left[\rho_2 m(P_{i2}) + \rho_1 m(P_{i1})\frac{P_{i1}}{(P_{i1} - 1)} + \rho_3 m(P_{i3})\frac{P_{i3}}{(P_{i3} - 1)}\right] \tag{13}$$

$$E(Y_{i3}|\ V = 3) = X_{i3}\gamma_3 + \sigma_3\left[\rho_3 m(P_{i3}) + \rho_1 m(P_{i1})\frac{P_{i1}}{(P_{i1} - 1)} + \rho_2 m(P_{i2})\frac{P_{i2}}{(P_{i2} - 1)}\right]. \tag{14}$$

The conditional expectations of the outcomes of farmers who participate in written contracts and those who use verbal contracts in output transactions in the counterfactual case that they sell in spot market is specified as

$$E(Y_{i1}\,|V = 2) = X_{i1}\gamma_1 + \sigma_1\left[\rho_1 m(P_{i2}) + \rho_2 m(P_{i1})\frac{P_{i1}}{(P_{i1} - 1)} + \rho_3 m(P_{i3})\frac{P_{i3}}{(P_{i3} - 1)}\right] \tag{15}$$

$$E(Y_{i1}|\ V = 3) = X_{i1}\gamma_1 + \sigma_1\left[\rho_1 m(P_{i3}) + \rho_2 m(P_{i1})\frac{P_{i1}}{(P_{i1} - 1)} + \rho_3 m(P_{i2})\frac{P_{i2}}{(P_{i2} - 1)}\right]. \tag{16}$$

The ATT is computed as the difference between Equations (13) and (15), and (14) and (16), respectively. If we represent the inverse mills ratios in the brackets of Equations (13) and (15), and (14) and (16) by λ, the ATTs for the written contract (17) and verbal contract (18) can be respectively specified as

$$ATT_{WC} = E(Y_{i2}|\ V = 2) - E(Y_{i1}\,|V = 2) = X_{i2}(\gamma_2 - \gamma_1) + \lambda_{i2}(\sigma_2 - \sigma_1) \tag{17}$$

$$ATT_{VC} = E(Y_{i3}\,|V = 3) - E(Y_{i1}\,|V = 3) = X_{i3}(\gamma_3 - \gamma_1) + \lambda_{i3}(\sigma_3 - \sigma_1). \tag{18}$$

6 | EMPIRICAL RESULTS AND DISCUSSION

6.1 | Drivers of vertical coordination mechanism choices among rice farmers

The marginal effects of factors affecting farmers' coordination mechanism choices are presented in Table 3. Note that farmers who supply paddy in spot market constitute the base group for comparison in the analysis. The results from diagnostic tests, such as the suest-based Hausman tests of IIA and Wald test for combining alternatives indicate that the null hypotheses fail to be rejected, implying that the farmers have been appropriately categorized based on the coordination mechanism participation (see Table A3 in appendix). We also identified the multinomial BFG model to ensure unbiased and consistent outcome estimates, by including in the coordination choice model, two valid instruments that significantly influence coordination choice decisions but are uncorrelated with the outcomes. In particular, we use variables representing farmers' perceptions about paddy market demand and

TABLE 3 Determinants of farmer's vertical coordination mechanism choices: MNL model

Variable	Spot market		Written contract		Verbal contract	
	Marginal effects	Std. err.	Marginal effects	Std. err.	Marginal effects	Std. err.
Age	−0.002	0.003	−0.003	0.002	0.005**	0.002
Credit access	−0.206***	0.067	0.147**	0.062	0.058	0.058
Education	−0.012	0.008	0.004	0.006	0.008	0.006
Gender	0.026	0.105	0.039	0.085	−0.065	0.092
Farm size	−0.036	0.027	−0.016	0.023	0.019	0.022
Labor	−0.003**	0.001	0.002**	0.001	0.001	0.001
Dist. to market	0.002	0.008	−0.007	0.007	0.005	0.006
Mobile phone	−0.214**	0.089	0.112	0.081	0.101	0.075
Road status	−0.067	0.098	0.066	0.084	0.001	0.081
Import. of legal contract	−0.330***	0.088	0.349***	0.076	−0.019	0.075
Market perception	−0.223***	0.074	0.287***	0.075	−0.063	0.065
Association	−0.560***	0.047	0.305***	0.049	0.254***	0.048
Farm vehicle	0.120	0.128	−0.178**	0.078	0.058	0.109
Institutional buyer	−0.340***	0.065	0.354***	0.090	−0.013	0.078
Sagnarigu	0.055	0.169	0.189	0.165	−0.245***	0.065
Savelugu Nanton	−0.200**	0.085	0.342***	0.102	−0.141***	0.068
Tolon	−0.104	0.103	0.173	0.114	−0.068	0.081
Kumbungu	0.079	0.112	0.100	0.107	−0.179**	0.068
Credit residual	−0.041	0.247	0.175	0.220	−0.133	0.213
Association residual	0.508	0.505	−0.588	0.469	0.079	0.413

Note: Based group is spot market; ** and *** mean significant at 5% and 1% levels, respectively.

importance attached to legal contracts as instruments. In a two-stage procedure, these instruments are included in both stages of the multinomial BFG model and their significance levels tested in each stage (Dimova & Gang, 2007). The χ^2 tests indicate the significance of these instruments at 1% level in the coordination choice model and insignificant in the outcome models for all the three coordination specifications, suggesting that the instruments are valid (see Table A3 in the appendix). As shown in Table 3, farmers with a perception of low paddy market demand are more likely to engage buyers via written contracts and less likely to supply paddy in spot markets. This finding is consistent with the notion that contracting is used to deal with sluggish markets by providing smallholder farmers with guaranteed markets. In addition, farmers who consider legal contracts important in output transactions are more likely to engage buyers with written contracts and less likely to supply in the spot market. This suggests that farmer sensitization on contracting and output market management in value chain interventions is yielding positive results in the study area.

It is important to point out that some of the variables in the coordination choice model such as access to credit and association membership are potentially endogenous. Access to credit is an important determinant of vertical coordination choice for output transactions in the study area. Farmers who are resource-constraint require sufficient financial capital to purchase inputs and pay for labor expenses. In this study, access to credit variable was constructed by seeking responses from a farmer on whether he/she needed credit, and if so whether he/she obtained the amount of credit required (Abdulai & Huffman, 2005; Baydas, Meyer, & Aguilera-Alfred, 1994; Jappelli, 1990; Jappelli, Pischke, & Souleles, 1998). Therefore, a farmer who did not require credit, or demanded credit for paddy production and marketing, applied for it, and received the required credit amount is

assigned a value of one, and zero otherwise. Agribusiness companies and other produce buyers in supply contract agreement with farmers may advance credit to these farmers, which is deducted from produce at the point of delivery. On the other hand, farmers who received credit from financial institutions may choose to enter into contracts with buyers to ensure a guaranteed market for their produce, as well as facilitate timely credit repayment. Therefore, farmers' decisions to participate in contract and access credit may be jointly determined, making access to credit variable potentially endogenous in coordination choice model. In the same vein, smallholder farmers often join associations to enter into contractual arrangements with a buyer, reduce transaction costs, and improve their bargaining power in output markets (Bolwig et al., 2009; Kleemann, Abdulai, & Buss, 2014; Ragasa & Golan, 2014). In that case, belonging to a farmer association could be regarded as a precondition for participating in vertical coordination. This makes association membership potentially endogenous in the vertical coordination model.

We account for the endogeneity of access to credit and association membership variables using a two-stage control function approach outlined in Wooldridge (2015). The first stage involves estimating separately access to credit and association membership variables as functions of all other explanatory variables in the vertical coordination choice model, including a set of valid instruments. These instruments should significantly influence access to credit and association membership, but not a participation in vertical coordination. For access to credit, we use farmers' knowledge of credit sources as an instrument, which significantly influences access to credit, but not vertical coordination choice. The available credit sources in the study area include commercial banks, rural banks, financial NGOs, and microfinance companies, although farmers may also obtain credit from informal sources including friends and relatives, as well as other informal money lenders. In this study, the farmers' knowledge of credit sources variable is captured as a dummy variable, where one is assigned to a farmer who is aware of these existing credit sources, and zero otherwise. The results indicate that farmers with knowledge of credit sources are more likely to apply for credit, a finding that is consistent with the result reported by Dutta and Magableh (2006) for Jordan. However, having knowledge of credit sources does not appear to influence farmers' decisions to participate in vertical coordination in output transactions.

With regard to membership in farmers' associations, we used distance from a farmer's home to meeting venue of the association as an instrument. We argue that further distance to association's meeting point discourages potential members from joining the association, as they may not effectively take part in meetings and other group activities. The results reveal that farmers who reside further away from the association's meeting venue are less likely to be members of farmers' associations. However, distance to the association's meeting venue did not have a significant influence on vertical coordination participation. The results of the first stage regression estimates are presented in Table A2 in the appendix. In the second stage, both the observed access to credit and association membership variables and their respective predicted residuals from the first stage are included in the vertical coordination choice model (MNL). Table 3 shows that the access to credit and association membership residuals for all the coordination specifications are not statistically significant, implying that these variables have been estimated consistently (Wooldridge, 2010).

The marginal effect of observed access to credit variable is positive and significant for written contracts and significantly negative for spot market specification, suggesting that rice farmers who had access to enough credit, and not credit-constrained are more likely to engage buyers using written contracts and less likely to supply paddy in spot markets. Association membership exhibits a positive and significant impact on written contracts and verbal contracts choices but negative and significant impact on spot market transactions, suggesting that farmers who belong to farmer associations are more likely to engage paddy buyers in output transactions, using written contracts and verbal contracts but less likely to supply paddy in spot markets. This finding is consistent with Bellemare and Novak (2017) and Maertens and Vande Velde (2017). Farmers belonging to farmers' associations normally benefit from collective action through collective marketing, bulk input purchase, and other group activities, which enable members to enjoy economies of scale, increased bargaining power, and reduced transaction costs.

Age exhibits a positive effect on verbal contract choice, suggesting that relatively older farmers are more likely to choose verbal contracts in output transactions, and are less likely to choose written contracts and spot market transactions. The results also show that farmers who engage more labor in farm activities are more likely to choose written contracts in output transactions and less likely to supply in the spot market. Mobile phone ownership shows a significant negative effect on spot market transactions and positive but insignificant effect on written and verbal contracts, suggesting that farmers who own mobile phones are less likely to sell in spot markets and more likely to engage buyers using written and verbal contracts. The use of mobile phones promotes effective communication and facilitates the acquisition of information on inputs and output prices, which could guide farmers to negotiate for better prices as well as reduce transaction costs associated with buyer search and setting up transactions (Aker, Ghosh, & Burrell, 2016). In addition, farmers who use written and verbal contracts already have their produce buyers and have carried out successful business exchanges with the farmers over the past 5 years. This category of farmers easily contacts and notify their buyers to arrange for produce pick-up, especially when paddy delivery is at farmgate.

We also find that farmers who sell their produce to institutions and produce buying companies are more likely to engage these buyers via written contracts and less likely with verbal contracts and spot market. The findings on location variables reveal that relative to Tamale metropolis (reference area), rice farmers in Savelugu Nanton and Kumbungu districts are more likely to use written contracts but less likely to engage buyers through spot market and verbal contracts, implying that location fixed effects also play important role in vertical coordination choices in output markets.

6.2 | Impact of vertical coordination mechanisms on-farm performance outcomes

The multinomial BFG model is estimated for each farm performance outcome: Net farm income, total farm income, and total household income. However, we display only the net farm income estimates (Table 4) due to space limitation, but estimates of the other outcomes are available upon request. Note that the estimator variances were bootstrapped with 100 replications to account for heteroscedasticity (Huesca & Camberos, 2010). Three selectivity correction terms related to the three coordination mechanisms have been revealed by the study, which is used to control for selection bias. According to Dimova and Gang (2007), for each net farm income specification, a negative (positive) selectivity correction term related to any coordination choice indicates lower (higher) net farm income than those of randomly chosen farmers, suggesting that farmers with better (worse) unobserved attributes switch from using the given coordination mechanism into using the alternative coordination mechanism.

The results show significant selectivity correction terms for spot market and written contract specifications, indicating the presence of selection bias and lending support to the estimation of the multinomial BFG model. In particular, the selectivity correction term related to the verbal contract in the spot market specification is found to be negative and statistically significant at 5% level, suggesting that the net farm income from spot market transactions are downward biased relative to randomly chosen farmers. This means that for farmers using verbal contracts, switching to spot market transactions would lead to a significantly negative impact on their net farm incomes. Also, in spot markets, farmers with unobserved attributes linked to higher net farm income have switched towards using verbal contracts in output transactions. The results also reveal a positive and significant selectivity correction term related to verbal contract in the written contract specification. In other words, net farm incomes from participating in written contracts are upward biased, because farmers with worse unobserved attributes switch from using written contracts to engaging buyers with verbal contracts.

We also present net farm income estimates when Lee's model is used in accounting for selection bias (see Table A1 in appendix). As previously stated, Lee's model estimates a single selectivity correction term for all coordination choices and fails to provide insight as to which coordination mechanism constitutes the source of the bias. It reveals insignificant selectivity correction term in the net farm income estimation, suggesting

that the model fails to account for the fact that the net farm incomes have been influenced by farmers who move to different coordination mechanisms, because they do not perform well under other coordination mechanisms.

Examining the determinants of net farm incomes conditional on the choice of coordination mechanisms, Table 4 shows a positive and statistically significant effect of farm size on net farm income associated with the coordination mechanism specifications. This finding suggests that farmers with relatively larger farm sizes earn significantly higher net farm incomes. While our finding is consistent with studies by Park et al. (2014), other studies found a negative and statistically significant impact of farm size on net farm incomes (e.g., Ma & Abdulai, 2016). Education exhibits a positive and statistically significant impact on net farm incomes for the written contract specification, suggesting that better education contributes to higher net farm incomes for farmers participating in written contracts.

The results also show that farmers who own farm vehicles and participate in verbal contracts, or supply paddy in spot market tend to obtain higher net farm incomes, as revealed by the positive and significant coefficients of farm vehicle ownership for spot market and verbal contract specifications. The variable representing sales to institutional buyers has a negative and statistically significant impact on net farm incomes from spot market transactions, implying that this category of farmers earns significantly lower net farm incomes. A number of factors could be driving this finding. First, farmers who supply in spot markets may not be able to produce paddy to meet the quality requirement of institutional buyers due to resource constraints,

TABLE 4 Impact of vertical coordination mechanisms on net farm income: BFG estimation

	Spot market		Written contract		Verbal contract	
Variable	Coefficients	Std. err.	Coefficients	Std. err.	Coefficients	Std. err.
Constant	4.092***	0.558	7.022***	1.325	2.574	2.681
Age	0.011	0.010	−0.014	0.012	0.005	0.013
Credit access	−0.450	0.276	0.191	0.264	0.231	0.302
Education	−0.011	0.032	0.043**	0.022	0.055	0.038
Gender	1.045***	0.356	0.084	0.503	1.912**	0.905
Farm size	0.224**	0.115	0.212**	0.096	0.329**	0.149
Labor	0.001	0.005	−0.007*	0.004	−0.006	0.005
Dist. to market	−0.025	0.028	−0.020	0.029	−0.010	0.030
Mobile phone	−0.173	0.346	0.511**	0.263	0.872**	0.435
Road status	0.245	0.274	−0.112	0.237	0.143	0.308
Association	−0.706	0.739	0.333	0.522	0.290	0.915
Farm vehicle	0.560*	0.339	−0.547	0.559	1.207***	0.405
Institutional buyer	−1.077**	0.442	0.257	0.333	0.747	0.515
Sagnarigu	−0.251	0.571	−0.167	0.684	−0.458	0.748
Savelugu Nanton	0.415	0.349	0.305	0.458	0.148	0.639
Tolon	0.115	0.275	0.157	0.421	0.654	0.398
Kumbungu	1.090***	0.382	0.808**	0.401	0.389	0.653
m (P1)	−0.087	0.901	−0.047	1.813	−2.461	2.595
m (P2)	−1.206	1.798	−0.061	0.627	−2.478	1.895
m (P3)	−2.013**	0.904	2.906**	1.538	−0.078	0.768

Note: The dependent variable is log of net farm income; *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

thus resulting in lower produce prices and ultimately lower net farm incomes. In addition, this category of farmers may lack the capacity to negotiate effectively for better prices for their produce, also contributing to reduced net farm incomes.

6.3 | Average treatment effects of vertical coordination mechanisms on-farm performance outcomes

Table 5 reports the ATT of written and verbal contracts participation on-farm performance outcomes, such as net farm income, total farm income, and total household income, using the multinomial BFG method. As shown in Table 5, participating in written contracts is associated with a significant increase in net farm income, total farm income, and total household income by 8.10%, 4.38%, and 5.47%, respectively, relative to spot market supply. For rice farmers who engage buyers through verbal contracts, participation significantly increases net farm income, total farm income and total household income by 5.61%, 2.70%, and 2.85%, respectively, compared to that of farmers who supply paddy in the spot market. Our findings are consistent with other recent studies, which report that the use of contracts in output markets contributes significantly to promoting market access and increasing incomes of smallholder farmers (e.g., Bellemare, 2012; Ma & Abdulai, 2016b).

As stated earlier, one of the objectives of this study is to examine the impact of vertical coordination mechanisms on labor productivity (Q/L) and price margin ($p - W\omega/Q$). The results are shown in the lower part of Table 5. We find that participation in written contracts increases labor productivity by 5.27% at the 1% significance level. However, verbal contract participation is associated with about 2.42% increase in labor productivity, although not statistically significant. Table 5 also shows that farmers who transact with paddy buyers through written contracts experience 29.14% significant increase in price margin, while verbal contract participation is

TABLE 5 Average treatment effects of vertical coordination mechanisms on outcomes

Outcome variable	Mean outcome		ATT	*t* value	Change (%)
Net farm income	Written contract	Spot market			
	6.559 (0.634)	6.068 (0.987)	0.491	5.144***	8.10
	Verbal contract	Spot market			
	6.495 (0.828)	6.150 (0.847)	0.345	3.057***	5.61
Total farm income	Written contract	Spot market			
	7.904 (0.560)	7.572 (0.922)	0.332	3.775***	4.38
	Verbal contract	Spot market			
	7.827 (0.642)	7.621 (0.713)	0.206	2.253**	2.70
Total household income	Written contract	Spot market			
	8.132 (0.496)	7.710(0.818)	0.422	5.424***	5.47
	Verbal contract	Spot market			
	7.882 (0.626)	7.663 (0.723)	0.219	2.405**	2.85
Labor productivity	Written contract	Spot market			
	3.135 (0.520)	2.977 (0.822)	0.157	1.991***	5.27
	Verbal contract	Spot market			
	3.167 (0.485)	3.092 (0.709)	0.075	0.915	2.42
Price margin	Written contract	Spot market			
	0.523 (0.098)	0.405 (0.153)	0.118	8.139***	29.14
	Verbal contract	Spot market			
	0.519 (0.099)	0.457 (0.142)	0.061	3.725***	13.34

Note: ATT is average treatment effect on the treated, the dependent variable is the log of the outcome variables. Computation of ATT is based on the log of the predictions. ** and *** mean significant at 5% and 1% levels, respectively.

associated with a significant increase in price margin by 13.34%. These findings are consistent with the results obtained by Ito et al. (2012) and suggest that output market transactions using written and verbal contracts contribute to improvement in labor productivity and price margins, relative to spot market transactions, with the highest gains associated with the use of written contracts.

To gain further insights on the impact of vertical coordination mechanisms on-farm performance, we examine the differential impacts of written and verbal contracts participation on net farm income, labor productivity, and price margin for different farm sizes. Based on the nature of our data, and the fact that smallholder rice farmers in the study area cultivate an average of less than two hectares (MoFA, 2016), we have classified farm size into two categories (small, ≤1.5 ha; and large, >1.5 ha), which is in line with the MoFA classification. The estimates are presented in Table 6. As can be observed from the table, the results show that farmers with small farm sizes participating in written and verbal contracts experience a significant increase in net farm incomes by 9.64% and 5.97%, respectively, relative to spot market transactions. On the other hand, gains in net farm incomes associated with written and verbal contracts participation for farmers with large farm sizes are although positive, but not significantly different from zero. This finding is consistent with the results obtained by Ito et al. (2012) and Ma and Abdulai (2016a). With respect to labor productivity, Table 6 shows that relative to spot market transactions, participation in written and verbal contracts are associated with a significant increase in labor productivity by 9.88% and 6.06%, respectively for farmers with small farm sizes. However, for farmers with large farm sizes, participating in written and verbal contracts decreases labor productivity, although not statistically significant. This finding can be attributed to the fact that farmers with

TABLE 6 Average treatment effects of vertical coordination mechanisms on outcomes disaggregated by farm size

Outcome variable	Mean outcome		ATT	*t* value	Change (%)
Net farm income	Written contract	Spot market			
Small (≤1.5 ha)	6.449 (0.544)	5.882 (0.869)	0.567	6.127***	9.64
Large (>1.5 ha)	7.044 (0.772)	6.885 (1.071)	0.159	0.637	2.30
	Verbal contract	Spot market			
Small (≤1.5 ha)	6.319 (0.766)	5.962 (0.780)	0.356	3.026***	5.97
Large (>1.5 ha)	7.128 (0.739)	6.823 (0.742)	0.304	1.424	4.45
Labor productivity	Written contract	Spot market			
Small (≤1.5 ha)	3.046(0.447)	2.771 (0.502)	0.274	4.526***	9.88
Large (>1.5 ha)	3.527 (0.634)	3.883 (1.254)	−0.356	−1.340	−9.16
	Verbal contract	Spot market			
Small (≤1.5 ha)	3.071 (0.425)	2.896 (0.500)	0.174	2.466**	6.06
Large (>1.5 ha)	3.514 (0.538)	3.795 (0.896)	−0.281	−1.319	−7.40
Price margin	Written contract	Spot market			
Small (≤1.5 ha)	0.526 (0.092)	0.423 (0.135)	0.103	7.005***	24.34
Large (>1.5 ha)	0.508 (0.085)	0.325 (0.200)	0.182	4.452***	56.00
	Verbal contract	Spot market			
Small (≤1.5 ha)	0.496 (0.084)	0.381 (0.142)	0.115	5.322***	30.18
Large (>1.5 ha)	0.600 (0.105)	0.370 (0.182)	0.230	5.367***	62.16

Note: ATT is average treatment effect on the treated, the dependent variable is the log of the outcome variables. Computation of ATT is based on the log of the predictions. **, *** mean significant at 5% and 1% levels, respectively.

large farm sizes employ a relatively higher amount of labor in paddy production, which contributes to declining labor productivity.

We also find that participation in written and verbal contacts tends to increase price margins, albeit more favorable for farmers with large farm sizes. In particular, farmers with small farm sizes who participate in written and verbal contracts experience significant gains in price margins by 24.34% and 30.18%, respectively, while farmers with large farm sizes tend to obtain 56.00% and 62.16% increases in price margins, respectively. These results suggest that farmers with large farm sizes tend to benefit more in terms of price margins, compared to farmers with small farm sizes, which is in line with the notion of scale economies, since average fixed costs associated with written and verbal contract participants decline with larger farm sizes. The results of the ATT generally indicate that participation in written and verbal contracts tends to improve farm performance significantly, relative spot market transactions.

7 | CONCLUSIONS

This study examined the determinants of smallholder participation in vertical coordination mechanisms and their related impacts on-farm performance, using a multinomial BFG model to account for selection bias associated with observed and unobserved attributes. The empirical results revealed that participation in written and verbal contracts in smallholder output transactions tend to improve farm performance outcomes such as net farm income, total farm income, total household income, labor productivity, and price margins, relative to farmers who supply paddy in spot markets. The estimates disaggregated by farm sizes indicate that farmers with small farm sizes and participating in written and verbal contracts earn higher net farm income, total farm income, total household income, and labor productivity than farmers with large farm sizes. However, farmers with large farm sizes tend to benefit more from price margins.

Participation in vertical coordination is significantly influenced by access to credit, mobile phone ownership, labor, membership in farmers' associations, sales to institutional buyers, market perception, and importance attached to legal contracts. Education, farm size, mobile phone, and farm vehicle ownership are found to be the important determinants of net farm incomes. Our estimates also show that accounting for selection bias using the multinomial BFG model is more appropriate, because not only does it consistently estimate the impact on farm performance outcomes but also provides information on the source and direction of the bias. The significant selectivity correction terms associated with the spot market and written contract specifications indicate the presence of selection bias.

The findings from this study do have some policy implications, and clearly suggest that targeting output transactions with innovative marketing and risk management techniques such as contracting would improve smallholder farm performance and livelihoods significantly. This calls for promotion of contracts in smallholder output transactions, especially with the renewed interests of government and donor agencies in transforming the domestic rice value chain in Ghana. However, Government and NGOs in collaboration with private agribusinesses, aggregators, and other produce buyers should intensify their engagement with smallholder farmers on the importance and use of legal contracts in output transactions, which could be an important contributor to improved and effective participation in agrifood value chains. The positive impact of education on contractual choices and farm performance calls for government investment in rural education, which could build up and protect human capital for improved labor productivity, and other rural livelihood opportunities. Incorporating credit schemes into agricultural value chain interventions could also ease smallholder credit constraints, promote pro-poor agricultural growth and smallholder welfare in Ghana. Finally, institutional innovations such as the formation of farmer associations could also be re-examined and promoted, because of its role in reducing transaction costs and enhancing market access.

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APPENDIX

Table A1, Table A2, Table A3

TABLE A1 Impact of vertical coordination mechanisms on net farm income: Lee estimation

	Spot market		Written contract		Verbal contract	
Variable	Coefficients	Std. err.	Coefficients	Std. err.	Coefficients	Std. err.
Constant	4.040***	0.551	6.832***	1.203	5.000**	2.826
Age	0.015*	0.008	−0.021**	0.010	−0.005	0.021
Credit access	−0.384**	0.187	0.141	0.201	0.155	0.337
Education	−0.011	0.027	0.036*	0.021	0.040	0.054
Gender	1.086**	0.482	0.158	0.478	0.862	0.564
Farm Size	0.148	0.118	0.199**	0.091	0.326**	0.146
Labor	0.001	0.005	−0.006	0.004	−0.006	0.008
Dist. to market	−0.017	0.031	−0.031	0.028	−0.023	0.067
Mobile phone	−0.115	0.229	0.239	0.207	0.188	0.353
Road status	0.214	0.200	−0.132	0.215	0.134	0.311
Association	−0.884*	0.512	0.011	0.338	0.072	0.775
Farm vehicle	0.156	0.368	−0.676	0.732	1.064**	0.469
Institutional buyer	−0.961**	0.423	0.299	0.219	0.807	0.790
Sagnarigu	−0.173	0.414	0.350	0.437	−0.001	0.960
Savelugu Nanton	0.577**	0.296	0.617	0.387	0.463	0.720
Tolon	0.193	0.376	0.417	0.389	0.800	0.514
Kumbungu	1.196***	0.289	1.039***	0.386	0.755	0.767
m (P_i)	−0.710	0.602	0.198	0.368	0.025	1.538

Note: The dependent variable is the log of net farm income; *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

TABLE A2 First stage estimates for addressing potential endogeneity

	Credit access		Association	
Variables	**Coefficient**	**Std. err.**	**Coefficient**	**Std. err**
Constant	−1.752***	0.642	−2.056	0.672
Age	0.007	0.008	0.008	0.009
Education	0.000	0.023	0.020	0.024
Gender	0.050	0.350	−0.172	0.351
Farm Size	0.041	0.080	−0.153	0.095
Labor	0.006	0.004	0.008*	0.004
Dist. to market	−0.014	0.027	0.044	0.032
Mobile phone	0.104	0.220	0.555**	0.220
Road status	0.064	0.241	0.575**	0.247
Import. of legal contract	0.087	0.209	0.682***	0.212
Market perception	0.391*	0.231	0.392*	0.237
Farm vehicle	0.021	0.397	0.110	0.403
Institutional buyer	−0.036	0.267	0.303	0.290
Sagnarigu	0.235	0.403	0.383	0.429
Savelugu Nanton	0.243	0.336	0.344	0.340
Tolon	0.208	0.337	0.384	0.342
Kumbungu	0.049	0.331	0.384	0.334
Association	0.344	0.215	–	–
Knowledge of credit sources	0.661***	0.220	–	–
Credit access	–	–	0.265	0.210
Distance to association meeting venue	–	–	−0.057**	0.022
Log likelihood	−285.29		−277.92	
Number of observations	458		458	

Note: *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

TABLE A3 Instrument validity and other diagnostic tests

Instrument variables (market perception and importance of legal contract)			
Multinomial logit model			
		χ^2	p
Vertical coordination mechanisms (VCMs) choices		22.98	.0001
BFG Impact specifications			
VCM Specification (net farm income)		χ^2	p
1. Open market		1.37	.5044
2. Written contract		0.68	.7101
3. Verbal contract		0.71	.7008
VCM Specification (Total farm income)			
1. Open market		0.56	.7703
2. Written contract		1.14	.5645
3. Verbal contract		0.16	.9250
VCM Specification (Total household income)			
1. Open market		0.25	.8843
2. Written contract		0.92	.6306
3. Verbal contract		0.22	.8955
VCM Specification (labor productivity)			
1. Open market		0.31	.8579
2. Written contract		0.99	.6106
3. Verbal contract		0.30	.8601
VCM Specification (price margin)			
1. Open market		0.49	.7825
2. Written contract		1.75	.4168
3. Verbal contract		0.06	.9683
Diagnostic tests results Suest-based Hausman tests of IIA assumption ($N = 458$) Ho: Odds (Outcome-J vs Outcome-K) are independent of other alternatives			
Choice alternative	χ^2	df	$p > \chi^2$
1	14.348	21	.854
2	17.031	21	.709
3	16.416	21	.746
Wald tests for combining alternatives ($N = 458$) Ho: All coefficients except intercepts associated with a given pair of alternatives are 0 (i.e., alternatives can be combined)			
Choice alternative	χ^2	df	$p > \chi^2$
1 and 2	124.320	20	.000
1 and 3	89.772	20	.000
2 and 3	44.210	20	.001

Note: A significant test is evidence against Ho; *df* means degrees of freedom.