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Article

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Suggested Citation: Kien, Nguyen Duc et al. (2024) : Farmer-trader vertical coordination: drivers and impact on the lotus-grain value chains in central Vietnam, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 12, Iss. 1, pp. 1-23, <https://doi.org/10.1080/23322039.2024.2357154>

This Version is available at:

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To cite this article: Nguyen Duc Kien, Thi Kim Oanh Dinh, Truong Tan Quan, Nguyen Thai Phan, Nguyen Cong Dinh, Pham Xuan Hung & Dung Truong Quang (2024) Farmer-trader vertical coordination: drivers and impact on the lotus-grain value chains in central Vietnam, Cogent Economics & Finance, 12:1, 2357154, DOI: [10.1080/23322039.2024.2357154](https://doi.org/10.1080/23322039.2024.2357154)

To link to this article: <https://doi.org/10.1080/23322039.2024.2357154>



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Farmer-trader vertical coordination: drivers and impact on the lotus-grain value chains in central Vietnam

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ABSTRACT

Lotus plants have emerged as a relatively new commodity in the food industry in Vietnam, with significant economic potential from its diverse applications in medicine, cosmetics, food, and decoration. Vertical coordination, involving strategic alignment and collaboration among different actors in the value chain, plays a critical role in supporting the small-grain grower-trader relationship. This study aimed to investigate the factors driving the adoption of vertical coordination mechanisms within lotus-grain value chains and to assess the impact of different coordination strategies applied by farmers on their well-being in central Vietnam. Employing a multinomial endogenous switching regression methodology, the study offers nuanced insights into the adoption patterns and impacts of various coordination strategies, controlling for both sample selection bias and unobservable factors. The results highlight the importance of trust, input management, and strategic decision-making in enhancing yield and revenue outcomes among smallholder farming households. Trust between farmers and traders significantly influences the adoption of such strategies in agricultural transactions. Higher trust levels correlate with an increased likelihood of adopting verbal, input, or written contracts. The positive impacts of input contracts on lotus grain yield and revenue, highlighting the importance of effective input management. These findings deepen our understanding of vertical coordination within lotus-grain value chains and assist stakeholders in making evidence-based decisions when selecting vertical coordination strategies for sustainable value chain management.

IMPACT STATEMENT

Vertical coordination between farmers and traders has emerged as a promising strategy for enhancing efficiency, promoting mutual benefits, and improving livelihoods within Central Vietnam's lotus grain value chain. By addressing existing challenges and charting future directions, vertical coordination holds the potential to significantly contribute to the sustainable development of the lotus grain industry in the region. This study highlights the importance of trust, input management, and strategic decision-making in enhancing yield and revenue. Trust between farmers and traders significantly influences the adoption of verbal, input, or written contracts. The positive impacts of input contracts on lotus grain yield and revenue underscore the importance of effective input management. These findings assist stakeholders in making evidence-based decisions for sustainable value chain management.

ARTICLE HISTORY

Received 20 February 2024
Revised 29 April 2024
Accepted 9 May 2024

KEYWORDS

Vertical coordination; Lotus-grain value chains; Smallholder farming; Welfare impact, Vietnam

REVIEWING EDITOR

Goodness Aye, University of Agriculture, Makurdi Benue State, Nigeria


SUBJECTS

Economic Development; Agricultural Economics; Agribusiness and Management

1. Introduction

In developing nations such as Vietnam, the agricultural sector plays a crucial role in ensuring food security, reducing poverty, and improving rural income and living standards. Over the past three decades, this sector

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/23322039.2024.2357154>.

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has shown consistent growth, with an annual rate ranging from 2.5 to 3.5%. It makes a significant contribution to the annual GDP, accounting for 13%, and employs a substantial portion of the labor force, approximately 29% (World Bank, 2023). Furthermore, in addition to its economic impact, the expansion of the agricultural sector has facilitated Vietnam's integration into the global market, establishing a sustainable food system. Notably, high-commercialization products such as lotus grains play a significant role in this context. The need for coordination within agricultural value chains has become increasingly vital amid growing market integration. This coordination involves complex interlinkages among various stakeholders within the value chain, spanning from primary agricultural producers to end consumers of food products. The agricultural coordination in Central Vietnam has witnessed a transformation towards more sustainable, inclusive, and efficient practices, driven by policies promoting vertical integration, sustainability, digital adoption, and gender equity (Chaudhary, 2021; Dung et al., 2020; Pham & Jinjark, 2022; Truong et al., 2022).

Vertical coordination and market institutions play critical roles in supporting small grain growers, particularly in regions vulnerable to external shocks, by enhancing their resilience (Bezabeh et al., 2022; Dube-Takaza et al., 2022; Falkowski, 2015; Hanf & Török, 2009; Moreno-Miranda & Dries, 2022; Tadele & Hibistu, 2022). In the realm of agricultural value chains, vertical coordination involves strategic alignment and collaboration among the different stages or levels of actors involved in the production, processing, and distribution of agricultural products (Chu & Pham, 2022; Dung et al., 2021; Handayati et al., 2015; Kliem, 2022; Smith, 2008). These mechanisms encompass a variety of tools, such as contracts, alliances, partnerships, and collaborative arrangements, aimed at improving communication, reducing information asymmetry, and aligning incentives across actors within the agricultural value chain. Their overarching goal is to enhance the efficiency and competitiveness of the value chain, enabling better adaptation to market demands and fostering sustainable, mutually beneficial relationships among participants. For example, in Zimbabwe, contract farming has been adopted, with farmers allocating more than 3 hectares to small-grain agricultural enterprises (Dube-Takaza et al., 2022). Through such coordinated efforts, small grain growers gain access to resources, expertise, and markets, thereby strengthening their resilience in the face of external challenges.

The literature on vertical coordination within agricultural value chains has made significant progress in identifying the factors that influence coordination mechanisms. These factors include geographical distance to markets, access to credit, availability of extension services, and affiliation with farming groups (Clay & Feeney, 2019; Dube-Takaza et al., 2022; Hellin et al., 2009). Some studies have focused on specific aspects of vertical coordination, such as trust levels, information asymmetry, and regulatory environments (Fan & Salas Garcia, 2018; Mishra & Dey, 2018; Phan et al., 2022; Tadesse & Kassie, 2017). While these studies offer valuable insights into the factors influencing coordination mechanisms, they often ignore the direct consequences of these choices on value chain efficiency, profitability, and broader socio-economic development (Burkitbayeva et al., 2020). Consequently, a significant research gap remains in fully understanding this complex relationship. Bridging this gap would greatly enhance our understanding of agricultural value chains and aid stakeholders in making informed decisions. The relevance of studying vertical coordination in lotus-grain value chains lies in its profound implications for agricultural sustainability, economic development, and livelihoods in regions like Central Vietnam. Therefore, this study aims to address the following research questions:

- What are the primary drivers behind the adoption of vertical coordination mechanisms within lotus-grain value chains, focusing on the relationship between small-scale growers and traders in developing countries like Vietnam?
- How do the diverse vertical coordination strategies employed by lotus grain producers influence their socioeconomic well-being in Central Vietnam?

This research makes substantial contributions to the existing body of literature in multiple aspects. This study not only complements previous empirical research but also expands upon it by thoroughly examining the adoption of various vertical coordination strategies and their resulting effects within a specific lotus-grain value chain located in central Vietnam. To achieve this goal, we employed a multinomial endogenous switching regression (MESR) methodology, which offers a flexible representation of the different choices made by lotus farmers. Importantly, this approach allows us to carefully control for both selection bias and unobservable factors that might influence outcomes, drawing on the studies of

Kassie et al. (2015), Midingoyi et al. (2019), and Martey et al. (2020). One distinctive aspect of our contribution is our departure from the common practice of exclusively focusing on a single specific strategy, which is often observed in many existing empirical studies. Instead, we examine a broader range of vertical coordination strategies to gain a more comprehensive understanding of their adoption patterns and impacts within the context of the lotus-grain value chain. Furthermore, our thorough examination reveals heterogeneity in the effects of technology adoption, providing nuanced insights into the varied outcomes associated with different vertical coordination strategies.

2. Background and literature review

2.1. Development of lotus value chains

Lotus cultivation is a widespread practice worldwide, with significant production occurring in countries such as India, China, Japan, South Korea, Southeast Asia, Russia, and select African nations. While lotus plants are cultivated primarily for food, pharmaceutical, or ornamental purposes in these regions, they are cultivated mainly for ornamental reasons in European and American countries (Guo, 2009). However, comprehensive global statistical data on the cultivated areas of lotus plants have not been obtained. In Vietnam, lotus plants have emerged as a relatively new commodity in the food industry, alongside traditional crops such as peanuts, soy, coffee, rubber, tea, cashews, and pepper. Notably, Vietnam's lotus value chain has experienced significant growth owing to the active participation of small-scale farmers and enterprises. The country's value chain places significant emphasis on processing and marketing. The estimated total cultivated area for lotus plants in Vietnam exceeds 3,000 hectares and is concentrated mainly in provinces such as Hung Yen, Hai Duong, Thai Binh, Nghe An, Nam Dinh, Thua Thien Hue, and the Mekong Delta region (including Dong Thap, Vinh Long, Tra Vinh, Long An, and Ben Tre). In Thua Thien Hue Province, there was a consistent increase in the lotus cultivation area from 372.9 hectares in 2017 to 638.9 hectares in 2020. This expansion is primarily concentrated in districts such as Phong Dien, Phu Vang, Huong Tra, and Quang Dien (see Appendix Figure A1). This growth aligns with a strategic shift in crop structures, moving away from an exclusive reliance on rice cultivation and maximizing the utilization of available land resources, including fallow water surfaces, ponds, lakes, and low-lying paddy fields.

The economic potential of lotus stems from its diverse applications in medicine, cosmetics, food, and decoration. Different parts of the lotus plant, including seeds, leaves, buds, and roots, offer value in medicinal herbs, cosmetics, and daily dietary consumption. Seeds, for instance, are used to produce roasted seeds, milk, tea, and wine. The cultivation process is straightforward and has low maintenance requirements, leading to a significant expansion in lotus cultivation. Retail prices range from 30,000 to 60,000 VND/kg, surpassing rice prices four to six times. The development of high-quality lotus varieties for seed production could enhance the economic value of these plants. Lotus products, especially seeds, are extensively used in culinary and health-related contexts, both domestically and internationally. Despite contributing to rural income, lotus cultivation has not yet fully realized its potential (Majumder & Barman, 2013).

2.2. Conceptual framework for vertical coordination among actors in agri-food chains

Within the ambit of Value Chain Management (VCM), the paradigm is lauded as an optimal methodology for concurrently engendering consumer value and remunerating actors across the chain. However, empirical examples of fully integrated and successful value chains within developing economies are scant. Cox (2004) articulated the position that it is neither feasible nor advisable for an enterprise to forge comprehensive linkages with all members of the value chain. As a result, value chains have traditionally been conceptualized as a series of dyadic relationships between enterprises (Dung et al., 2021). It is incumbent upon members of the value chain to endeavor to cultivate intimate inter-organizational relationships with those actors with whom they interact directly. As this management of dyadic relationships proliferates throughout the chain, it engenders greater integration and oversight.

The strategic rapport between buyers and sellers is predicated on the maximization of value creation within the value chain (Ambrose et al., 2010). A collaborative relationship between buyer and seller possesses the capacity to reallocate costs and inventory among chain actors both upstream and

downstream, thereby augmenting the overall efficacy and efficiency of the chain (Ireland & Bruce, 2000). Furthermore, a prosperous relationship affords the parties involved opportunities to realize benefits that would be arduous to secure through solitary efforts (Duffy & Fearn, 2004; Narayandas & Rangan, 2004). For buyers, an intimate relationship with a supplier facilitates the production of higher-quality products at reduced costs by incorporating materials provided at the nascent stages of product development (Ahearne et al., 2022). Conversely, for sellers, a fruitful business relationship yields myriad advantages, such as diminishing uncertainty by stabilizing rewards and orders, improving access to core materials culminating in heightened productivity, and bolstering customer loyalty (Fischer & Reynolds, 2010).

The continuum of buyer–seller relationships spans from open market negotiations (transactional relationships) to collaboration (supply chain partnerships) (Duffy & Fearn, 2004). Spekman et al. (1998) delineated the evolution of the buyer–seller relationship from mere open market negotiations to full-blown collaboration in Figure 1.

In transactional relationships, the focus is on the prompt exchange of goods for competitive prices, with such exchanges frequently occurring in auction settings. Cooperation signifies a stage wherein firms exchange information and enter into longer-term contracts. At this juncture, buyers commence the selection of suppliers from a pool of potential firms. In addition to the coordination stage, enhanced information linkages fortify communication between buyers and sellers. Notably, a majority of firms have attained either the cooperation or coordination stage (Spekman et al., 1998). The zenith of the buyer–seller relationship, collaboration, necessitates elevated levels of trust, commitment, sharing of information and technology, and joint future planning. The variances between the two polar extremes of the buyer–seller relationship continuum are provided by Duffy and Fearn (2004) in Appendix Table A1.

In this study, we proposed a conceptual framework for investigating vertical coordination among actors in agri-food chains (Figure 2). The framework encapsulates three key elements: vertical farmers, representing smallholder agricultural producers engaged in Lotus grain cultivation; traders, acting as intermediaries facilitating the processing and distribution of Lotus grains; and the Lotus grain value chain encompassing

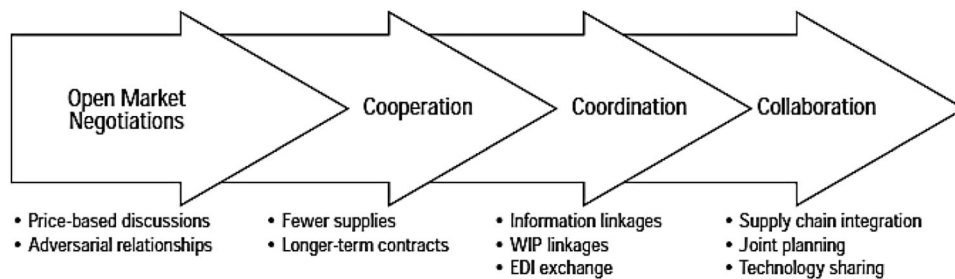


Figure 1. Transition from open market negotiations to collaboration. Source: Spekman et al. (1998).

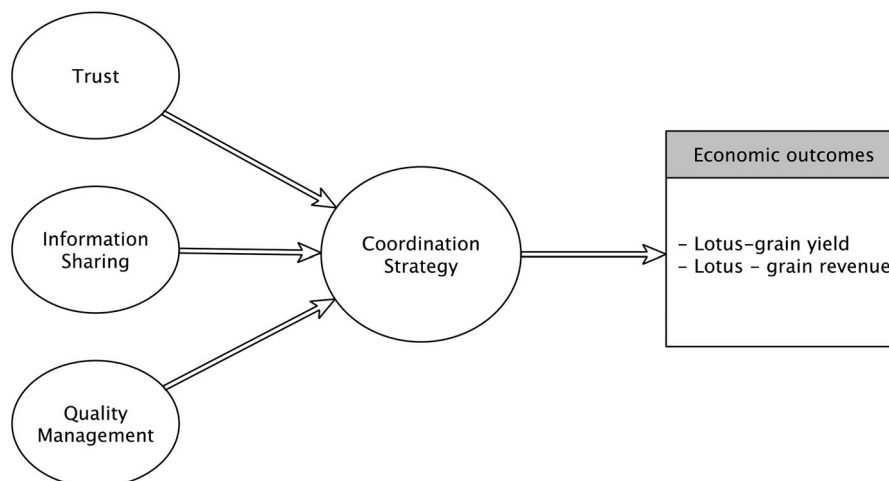


Figure 2. Conceptual framework.

sequential activities from cultivation to market access (Kaplinsky & Morris, 2000). The vertical coordination mechanisms within this framework are multifaceted and integrate information sharing, collaboration mechanisms, and quality assurance practices (Gibbon, 2001; Fan & Salas Garcia, 2018). Information sharing entails the exchange of market intelligence, encompassing pricing trends, consumer demands, and quality benchmarks (Chuku & Okoye, 2009). This aligns with Kaplinsky and Morris (2000) assertion that market information is crucial for improving decision-making and enhancing value chain efficiency. Collaboration mechanisms, such as formal contracts or joint technology adoption, are fundamental drivers for fostering trust and mutual benefit between farmers and traders (Tallontire et al., 2004). Quality management mechanisms involve adherence to stringent quality standards and joint monitoring to ensure consistency and reliability in Lotus grain production (Gibbon, 2001). This dimension emphasizes on the significance of quality control measures in enhancing market competitiveness. The drivers propelling this coordination encompass the mutual interest of both parties in optimizing operations and profitability (Kaplinsky & Morris, 2000).

The impacts resulting from successful coordination between vertical farmers and traders within the lotus grain value chain are diverse and far-reaching. Economically, this collaboration leads to increased income generation for both farmers and traders through cost reduction, improved market access (Bezabeh et al., 2022; Chuku & Okoye, 2009) and better prices (Nyamamba et al., 2022). Socially, climate change enhances the livelihoods of farming communities by providing stability and opportunities for skill development (Tallontire et al., 2004). Ultimately, this comprehensive conceptual framework provides a structured approach to comprehending the synergistic farmer-trader relationship in the lotus grain value chain in Central Vietnam, highlighting the interconnectedness of components and the multifaceted impacts that stem from effective coordination. In this study, we expanded the literature by adding critical facets of lotus grain cultivation, including yield, revenue, farmer-trader relationships, price determination dynamics, participation in trading-support groups, demographic characteristics of farmers, farm dimensions, postharvest loss rates, processing practices, planting density, food traceability adoption, gate-price metrics, access to extension services, training engagement, credit accessibility, and proximity to the primary lotus grain market.

2.3. Factors affecting the choices of vertical coordination strategies in agri-food chains

In the context of short value chains, vertical coordination involves aligning activities and processes across different levels of the supply chain, from producers to processors and retailers. This coordination is crucial for ensuring food quality and safety and for meeting the specific demands of modern retail markets. Mechanisms for vertical coordination in food chains include quality arrangements, monitoring, and resource allocation (Widadie et al., 2022). It encompasses various actors and methods, significantly impacting supply chain performance and the quality and safety of food products.

Within a value chain, actors can utilize different coordination strategies, which are pivotal for shaping relationships and ensuring effective collaboration. Based on the results of the focus group discussion, we summarize the main characteristics of popular vertical coordination strategies applied by lotus grain growers in [Appendix Table A2](#). The choice of strategy depends on factors such as the transactional nature, required formality, and specific objectives of the parties involved. Ranging from immediate spot market transactions to formal written contracts, each strategy contributes to the overall efficiency and functionality of the agricultural value chain. These markets may involve the immediate sale of agricultural commodities with little to no collaboration between farmers and traders (Abdul-Rahaman & Abdulai, 2020; Hernandez et al., 2017). Verbal contracts, also known as oral contracts, are spoken agreements without written documentation and are commonly seen as informal verbal agreements for localized exchange within agricultural value chains (Cotula et al., 2021). Despite their informality, verbal contracts can be complex and may lead to misunderstandings due to the lack of written records (Akyüz et al., 2023).

Input contracts in agricultural value chains typically involve providing specific inputs (such as seeds or fertilizers) to farmers by a contractor, often in exchange for a commitment to sell the resulting produce to the contractor. These contracts address challenges related to credit access, insurance, high-quality inputs, and other relevant services (Hoang, 2021). On the other hand, written contracts are formal legal documents outlining the terms and conditions of an agreement between parties.

The choice of coordination strategy is influenced by various factors, including farmer and farming characteristics, farmer-trader relationships, price determination practices, participation in support groups, and

access to input and output information. Trust and cooperation between farmers and traders often lead to the adoption of long-term contracts, fostering more flexible and cooperative arrangements. Farmers' education and experience influence the adoption of formal coordination mechanisms such as written contracts (Bidzakin et al., 2019; Hoang, 2021), while farm size and asset ownership may affect bargaining power and coordination choices (Abdul-Rahaman & Abdulai, 2020). Additionally, power dynamics and access to market information can shape coordination outcomes, influencing the preference for informal or formal mechanisms (Hernandez et al., 2017; Clay & Feeney, 2019). Participation in trading-support groups and access to input and output information also play significant roles in coordination decisions, affecting the choice of mechanisms such as input contracts (Shiferaw et al., 2008; Moreno-Miranda & Dries, 2022). Understanding these factors can aid policymakers and development practitioners in designing interventions to promote efficient and equitable coordination among actors in the lotus supply chain.

3. Data and analytical methods

3.1. Data

This study employed a stratified sampling approach, meticulously dividing regions into districts, communes, and communities to ensure representative selection across intricate lotus value chains. Primary data collection involved direct engagement through structured interviews using semi-structured questionnaires. These interviews were strategically conducted at pivotal locations integral to the lotus value chains, including the Dong Ba ward in Hue city and the Phong Hien and Phong An commune within the Phong Dien district of Thua Thien Hue Province in central Vietnam. The selection of these study areas and participants in research on agricultural coordination within lotus-grain value chains in Central Vietnam is driven by the need to ensure relevance, representativeness, feasibility, diversity, and ethical considerations.

Stratification facilitated diverse representation within the sample sizes, allocated as follows: 363 farmers, 30 traders, 92 consumers, 15 representatives from local government and regulatory agencies, 5 agriculture extension experts, and 5 entities actively involved in supporting and facilitating the lotus value chain. The intentional selection of these specific locations and varied stakeholders aimed to capture a holistic perspective and multifaceted insights into the dynamics of lotus production, trade, consumption, and the regulatory framework. In preprocessing and cleaning data for research on agricultural coordination within lotus-grain value chains in Central Vietnam, several key steps are typically undertaken. These include handling missing data through imputation techniques, detecting and removing outliers to enhance the dataset's integrity, normalizing data to ensure consistent scaling, encoding categorical variables, and performing data cleaning. The questionnaire designs encompassed an array of themes, delving into the nuanced realms of lotus cultivation, trade practices, producer-trader relationships, consumer-oriented behaviors, regulatory aspects, technological interventions, and the supportive ecosystem fostering lotus value chains.

Actors in the lotus-grain value chains in the study areas employ various vertical coordination strategies to foster effective collaboration and shape relationships (see Figure 3). The most common way for lotus growers in Vietnam to sell their products directly to sellers is through simplicity and lack of formal agreements or contracts. However, this mechanism can also be risky for farmers, as they may not receive a fair price for their crops. Input contracts, on the other hand, are agreements between farmers and traders providing upfront inputs, such as fertilizers and pesticides, at the beginning of the cropping season. These contracts specify the type and amount of inputs required and can also set the input prices. Written contracts represent the most formal type of vertical coordination strategy and are legally binding and detail the agreement terms. While beneficial for preventing disputes, written contracts can be time-consuming and expensive to prepare.

Figure 3 describes the adoption of vertical coordination strategies by farming households (eg Non-adoption of vertical coordination, verbal contracts, input contracts, or written contracts). The graph indicates that non-adoption of any vertical coordination is the most common strategy, with more than 33% of households selling lotus grains in this manner. A smaller proportion of households use verbal contracts (28%) and input contracts (32%), and a very limited number opt for written contracts (6.6%). The overall trend suggests a preference for informal coordination strategies over formal ones among lotus growers in Vietnam. Factors contributing to this preference may include a lack of trust between farmers and traders, high transaction costs associated with formal contracts, and farmers' preference for

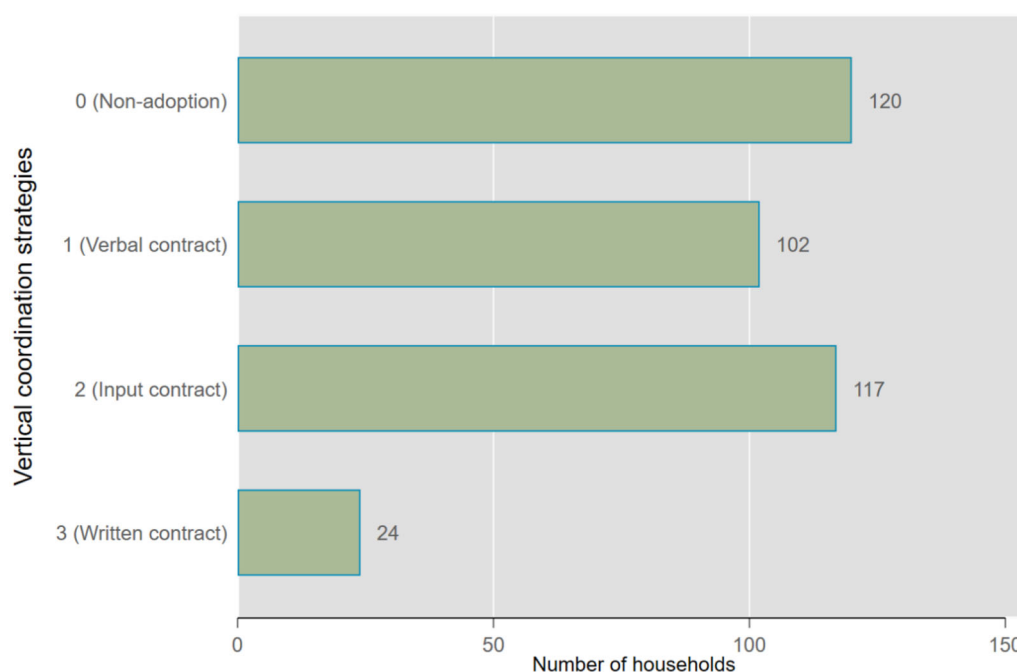


Figure 3. The adoption of different vertical coordination strategies by farming households. Source: Authors' calculations.

flexibility and autonomy. However, an emerging trend toward the use of written contracts is apparent, possibly influenced by increasing demand for high-quality lotus grains and the rise of healthy food brands in the area, necessitating enhanced coordination between farmers and traders to secure lotus grain supplies. The input contract represents a compelling aspect within the study area, where farmers receive input subsidies from traders and, in return, commit to delivering a specified amount of outputs. This dynamic relationship has evolved over time, playing a pivotal role in enhancing the overall efficiency and seamless functionality of the lotus value chain. The symbiotic interaction between farmers and traders, facilitated by input contracts, underscores the interconnectedness of stakeholders and significantly contributes to the sustainability and success of the lotus production system in the region.

Table 1 provides a comprehensive description of the variables utilized in the study. For the outcome variables, lotus grain production has an average yield of 1.68 tons per hectare, corresponding to a revenue of 64.5 million VND per hectare. Key variables illustrating the interaction dynamics between farmers and traders demonstrate a relatively weak association, with an average score of 1.23 on a 1–5 scale. Farmers exert a certain degree of influence on price determination, as indicated by an average score of 1.83 on a scale of 1–3, where 1 signifies exclusive farmer determination and 3 signifies exclusive trader determination. Notably, 53% of the farmers actively participate in trading support groups.

For the control variables, the typical lotus-grain grower profile was aligned with that of a 58-year-old male with 4.83 years of farming experience. Their management spans a 0.56-hectare farm comprising 1.93 ponds or land plots. Postharvest loss remained relatively high at 16.93%, while 31% of the farmers engaged in premarket processing of lotus grains. The average planting density was 22.83 trees/square meter, with 3.3% of the farmers adopting food traceability practices. The gate price for lotus grains averages 37.08 VND/kg, and approximately 51% of farmers have access to extension services. On average, farmers attend 0.633 training courses related to lotus cultivation. Credit accessibility is limited, with only 9% of farmers having access to credit, and the average credit amount extends to 5.3 million VND. Furthermore, the average distance between a farmer's lotus grain farm and the primary market is 3.41 km.

3.2. Analytical methods

This study explored how various strategies for vertical coordination impact lotus farm performance, with a specific focus on lotus grain yield and revenue. It employs a comprehensive two-stage decision-making process. In the first stage, involving decision-making, and the subsequent stage, where these decisions

Table 1. Summary statistics of the variables in the study.

Variables	Non-adoption		Verbal contract		Input contract		Written contract		Full sample	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Outcome variables										
Lotus-grain yield (ton/ha)	1.46	1.03	1.50	1.22	2.05	1.98	1.68	1.69	1.68	1.54
Lotus-grain revenue (Mill.VND/ha)	57.00	44.06	56.15	45.99	82.77	101.8	61.05	56.63	64.5	67.6
Explanatory variables										
Farmers-traders trust (weak to strong, 1–5)	1.15	0.529	1.35	0.875	1.25	0.811	1.17	0.681	1.23	0.732
Price determination (1 = farmers, 2 = both, 3 = traders)	1.92	1.25	1.73	1.12	1.76	1.19	1.89	1.20	1.83	1.19
Join trading-support group (yes = 1)	0.625	0.486	0.529	0.502	0.462	0.501	0.486	0.502	0.527	0.5
Control variables										
<i>Farmers and farming characteristics</i>										
Gender of household head (Male = 1)	0.875	0.332	0.765	0.426	0.769	0.423	0.838	0.37	0.813	0.39
Age (years)	58.1	8.94	58.55	9.06	58.53	8.80	57.21	9.94	58.1	9.17
Household size										
Experience of household head (years)	4.67	3.02	4.94	4.1	4.71	3.87	5.02	3.80	4.83	3.69
Farm size (ha)	0.696	1.15	0.699	0.849	0.325	0.24	0.541	0.594	0.562	0.801
Number of ponds (plots)	1.92	1.10	2.05	1.44	1.97	0.923	1.78	0.846	1.93	1.09
Planting density (tree per m ²)	21.17	3.66	24.70	6.99	22.89	5.30	22.83	3.79	22.83	5.18
Postharvest loss (%)	29.12	41.91	11.32	27.39	11.02	28.11	15.13	33.99	16.93	34.33
Apply processing (yes = 1)	0.275	0.448	0.324	0.47	0.333	0.473	0.324	0.47	0.313	0.464
Apply food traceability (yes = 1)	0.075	0.264	0.029	0.17	0.026	0.159	0	0	0.033	0.18
<i>Input and output information</i>										
Gate-price of lotus-grain (VND/kg)	36.82	10.03	37.5	8.28	36.12	9.34	38.0	7.77	37.08	8.94
Access to extension services (yes = 1)	0.65	0.479	0.471	0.502	0.487	0.502	0.432	0.498	0.513	0.5
Number of training courses attended (Course)	0.675	0.688	0.441	0.606	0.846	1.317	0.541	0.723	0.633	0.899
Access to credit (yes = 1)	0.15	0.359	0.088	0.285	0.051	0.222	0.081	0.274	0.093	0.291
Credit amount (Mill.VND)	8.5	23.71	5.29	19.22	3.33	16.45	3.91	16.96	5.3	19.41
Instrumental variables										
Distance to main market (km)	3.60	2.019	3.19	2.051	3.42	1.86	3.39	1.96	3.41	1.97

VND: Vietnamese Dong (approximately 23,015 VND/\$U.S. as of 2023); SD: standard deviation. Source: Authors' calculations.

affect farm performance indicators, simultaneous modeling is conducted using the MESR method. This method has been extensively utilized in previous empirical studies (Haghani et al., 2021; Kassie et al., 2015). To address any potential selection bias, this evaluation employs ordinary least squares (OLS) supplemented by inverse Mills ratios (IMRs) as additional covariates. Stata's 'mlogit' command is used for Stage 1, while the user-written command 'selmlog' is employed for Stage 2, following the methodology outlined by Bourguignon et al. (2007).

Stage 1 focuses on the drivers of vertical coordination strategy adoption utilizing the multinomial logit model. This model operates under the assumption that a farmer, denoted as i , faces various decisions regarding their interaction with traders: ' $j = 1$ ' represents Non-adoption; ' $j = 2$ ' indicates the adoption of a verbal contract; ' $j = 3$ ' reflects the adoption of an input contract; and ' $j = 4$ ' signifies the adoption of a written contract. While the utility associated with these choices remains unobservable, the decisions made provide insights into perceived utility. Drawing from the works of Kassie et al. (2015), the model considers a latent approach: $l_{ji}^* = Z' \beta + \varepsilon$, suggesting that if farmer i chooses j over other alternatives m , this signifies that the farmer perceives this choice as offering greater utility than the alternatives.

$$Y = \begin{cases} 1 & \text{if } Y_{ji}^* > \max_{m \neq 1} (Y_{mi}^*) \text{ or } \tau_{1i} < 0 \\ \vdots & \text{for all } m \neq j \\ J & \text{if } Y_{ji}^* > \max_{m \neq J} (Y_{mi}^*) \text{ or } \tau_{Ji} < 0 \end{cases} \quad (1)$$

Y_{ji}^* represents an underlying response model reflecting the observed decisions of farming households regarding whether they adopted or did not adopt specific strategies. The vector X encompasses both explanatory variables (Z) and instrumental variables (IV), while ε signifies the distinction between two random errors, essentially unobservable factors.

The IMRs for each vertical coordinate are defined as $IMR = \phi(F(X' \beta)) / \Phi(F(X' \beta))$, where ϕ signifies the probability density function, Φ represents the cumulative distribution function, and β represents a parameter vector. By employing this methodology, two-stage estimation is intertwined by integrating the

IMRs derived from Stage 1 into Stage 2. This integration allows us to address potential correlations between the residuals of both stages, ensuring more accurate estimations and avoiding biases.

Phase 2: Impact of vertical coordination strategies employed on measures of farm performance within the MESR structure

During the second phase of the MESR analysis, the correlation between farm performance indicators (such as lotus-grain yield and revenue) and a specified group of explanatory factors (referred to as Z) was computed for each technological choice category ($j = 1, 2, 3, 4$). The model equation for each regime (j) is outlined as follows:

$$\left\{ \begin{array}{l} \text{Regime 1: } I_{1i} = Z'_{1i}\varphi_1 + \widehat{IMR}_{1i} \lambda_1 + \varepsilon_{1i} \text{ if } J = 1 \\ \cdot \\ \cdot \quad j = 2, 3, 4 \\ \cdot \\ \text{Regime } J: I_{ji} = Z'_{ji}\varphi_j + \widehat{IMR}_{ji} \lambda_j + \varepsilon_{ji} \text{ if } J = j \end{array} \right. \quad (2)$$

where I_{ji} represents the farm performance metrics for the i^{th} farmer within a given regime (j).

The same analytical process was applied to assess the impacts of adopting three farm performance indicators: lotus grain yield and revenue. The coefficients derived from the MESR model provide insights into the average treatment effect on the treated (ATT) by comparing expected outcomes for both participants and nonparticipants in both actual and hypothetical scenarios. However, using nonrandomized experimental data for impact assessment may introduce biased estimates due to sample selection bias. To address this issue, instrumental variables were employed, a methodology widely used in various empirical studies to address similar concerns (Kassie et al., 2015; Midingoyi et al., 2019; Martey et al., 2020). We used distance to the nearest market as an IV, and the validity of this instrument was confirmed by the Montiel-Pflueger robust weak instrument test (Appendix Table B1). This provides evidence that distance to market is sufficiently correlated with the endogenous variable (eg choice of coordination mechanism) and excludable from the outcome equation. This strengthens the credibility of your IV strategy and enhances the validity of the MESR model estimates.

3.3. Treatment effects

The study utilized the MESR framework to gauge the average treatment effect on the treated (ATT). This approach aims to mitigate biased treatment effects often present in observational studies. It compares the expected performance indicators of farms that have adopted a particular practice with those that have not, considering a hypothetical scenario where adopters do not adopt, and vice versa.

In essence, the ATT is computed post-estimation by assessing the difference between two equations: Equation (3), which represents the observed outcomes for adopters with adoption; and Equation (4), which portrays the expected outcomes for adopters who had chosen not to adopt. The calculation involves predicting the anticipated values for farm performance outcomes under both scenarios based on the MESR estimation.

Adopters with adoption (actually observed in the sample)

$$(E_{I_{ji}} \mid j = j, Z, \widehat{IMR}) = Z_{ji}\varphi_j + \widehat{IMR}_{ji}\lambda_j \quad (3)$$

Adopters had they decided not to adopt (counterfactual expected outcomes of adopters)

$$(E_{I_{1i}} \mid J = 1, Z, \widehat{IMR}) = Z_{1i}\varphi_1 + \widehat{IMR}_{1i}\lambda_1 \quad (4)$$

This process enables the comparison of the expected performance between adopters and nonadopters in both actual and counterfactual situations, a methodology previously outlined by Kassie et al. (2015).

$$\begin{aligned} ATT &= (E_{I_{ji}} \mid j = j, Z, \widehat{IMR}) - E_{I_{1i}} \mid J = 1, Z, \widehat{IMR}) \\ &= Z_{ji}(\varphi_j - \varphi_1) + \widehat{IMR}_{ji}(\lambda_j - \lambda_1) \end{aligned} \quad (5)$$

Initially, we employed a nonparametric method involving a kernel density plot to examine the correlation between the adoption of distinct vertical coordination strategies and enhanced farm performance. Through the comparison of cumulative probability curves, we ascertained the graphical dominance of the adopted practices when their curves consistently exhibited smaller areas across all outcome levels than did those of an alternative approach. This approach offers an impartial preliminary assessment of the influence of these practices on farms, laying the groundwork for more sophisticated statistical analyses such as the MESR framework.

4. Empirical results and discussion

4.1. Description of the lotus-grain value chain at the study sites

The lotus-grain value chain at the study sites is depicted in Appendix [Figure A2](#). Farmers primarily obtain lotus seeds from other farmers, covering the entire process from seed procurement to transportation to planting. The cost of one cutting, including transportation and planting expenses, ranges between 20,000 and 25,000 VND. The frequency of seed replacement varies based on factors such as farmer expertise, pond characteristics, productivity, and pest prevalence, typically occurring every 3-5 years for optimal productivity. Essential agricultural inputs, including fertilizers (primarily NPK), pesticides, and lime powder, are sourced from local dealers. Lotus cultivation usually begins between late January and early February on the solar calendar, with seed harvest occurring from May to August, with a focus primarily on seed acquisition. While some households collect additional lotus products such as flowers, leaves, roots, and stems, this aspect is marginally addressed in this study.

During the harvest season (May to August), farmers eat lotus stems approximately 10-15 times per month, harvesting every other day. Workers are employed to separate seeds from lotus stems, either at the pond or at home, utilizing available family labor, including the elderly and children. The labor cost for harvesting and separating seeds ranges between 6000 and 8000 VND/kg. Fresh lotus seeds are typically sold on the day of separation to prevent quality deterioration. The findings indicate that approximately 94.6% of fresh lotus seeds are distributed through large- and small-scale collectors in Thua Thien Hue Province, with approximately 5.4% consumed by households through alternative channels such as local retail markets or through further processed forms (eg dried seeds). Subsequently, the collected lotus plant reached wholesalers at major markets such as Phu Hau and Dong Ba or at preliminary processing facilities in Hue city. Some large collectors also engage in preliminary lotus processing by separating the shell and heart, yielding silk lotus seeds and lotus heart. Survey results indicate that approximately 62.4% of silk lotus seeds and 35.2% of lotus hearts are sold to market wholesalers, while 37.6% of silk lotus seeds and 64.8% of lotus hearts are directed to processing establishments that refine final lotus products, primarily dried seeds, lotus jam, etc. Certain enterprises undertake both preliminary processing and product refinement, particularly those involved in lotus-heart tea production (100%). The consumption of lotus products occurs predominantly within the domestic market. However, to enhance the value of lotus products, strategic plans are essential for governmental and commercial entities to upgrade products and expand export avenues.

In the context of the lotus value chain in the study area, the relationship between farmers and traders significantly influences the chain's dynamics. Farmers, as primary producers of lotus seeds, form foundational links by cultivating and harvesting lotus plants, primarily through a focus on seed production. Their interdependence is evident through seed exchange or purchase, which contributes to seed diversity and is crucial for sustainable cultivation. Traders serve as intermediaries, linking farmers to wholesalers, processing facilities, or markets. They purchase lotus seeds from farmers, facilitating distribution and providing logistical support. The relationship is characterized by mutual dependency and trust, with farmers relying on traders for market access and timely transactions and traders depending on farmers for quality seed supply.

4.2. Results of nonparametric analysis

Using a kernel density plot, [Figures 4 and 5](#) visually illustrate the outcomes of a nonparametric estimation investigating the correlation between different vertical coordination strategies (Non-adoption, verbal

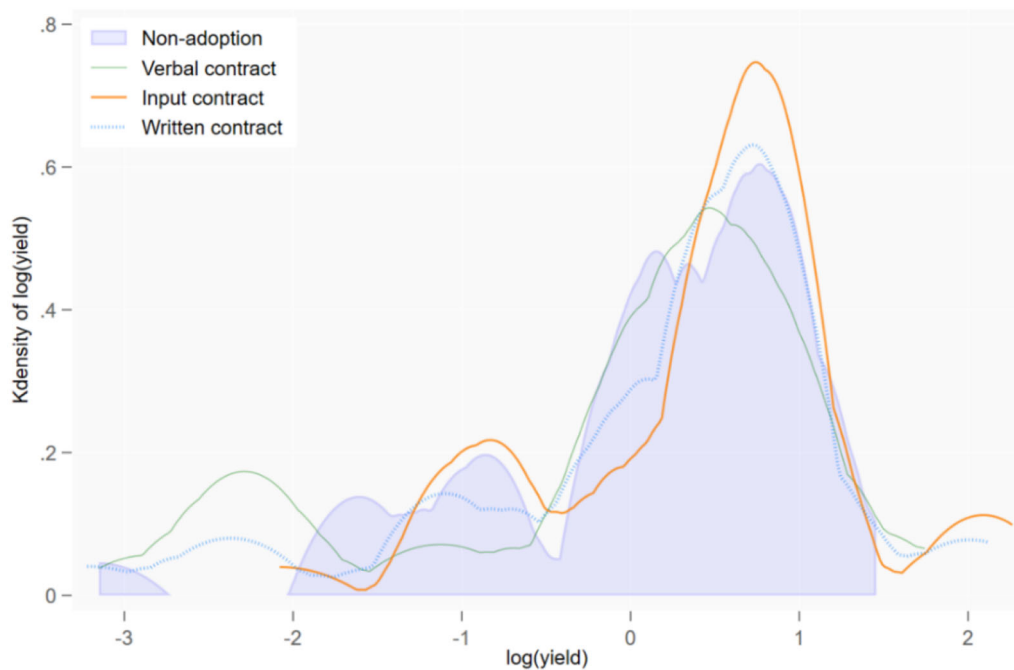


Figure 4. Unconditional lotus-grain yield density distribution.

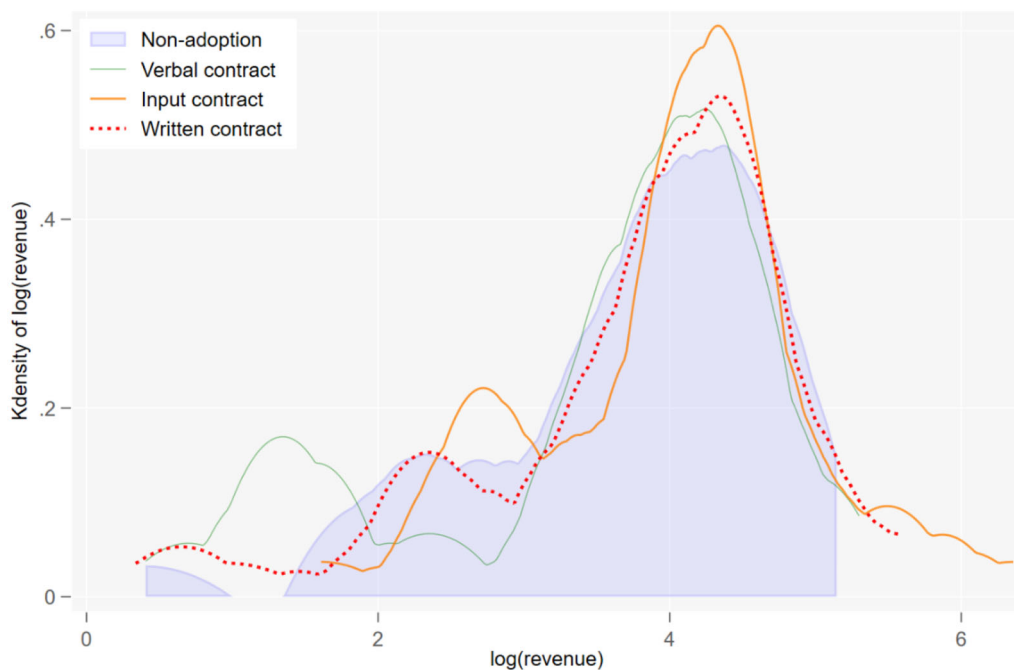


Figure 5. Unconditional lotus-grain revenue density distribution. Source: Authors' calculations.

contract, input contract, and written contract) and lotus grain yield and revenue. The results indicate a positive correlation between vertical coordination and both lotus grain yield and revenue, with input and written contracts showing the strongest associations. This finding suggests that the use of formal contracts effectively aligns the interests of farmers and traders, implying that farmers employing more structured coordination mechanisms tend to achieve significantly greater lotus-grain yields. These initial findings emphasize the importance of further investigations using more rigorous methodologies to confirm the impact of vertical strategy adoption by farming households.

4.3. Impact assessment of adopting vertical coordination strategies via the MESR approach

4.3.1. Factors affecting the choices of vertical coordination strategies

In Stage 1, we investigate the factors influencing farmers' choices of vertical coordination strategies. We use a multinomial logit selection model with Non-adoption as the base category, and Table 2 displays the estimated results. Several key factors emerge as influential in farmers' decisions regarding these strategies. Notably, the level of trust between farmers and traders has a significant impact. The positive coefficients for trust across all three vertical coordination strategies—verbal, input, and written contracts—highlight the crucial role of trust in fostering collaborative agreements. Higher levels of trust correlate with a greater likelihood of adopting these coordination mechanisms, underscoring the importance of interpersonal relationships in agricultural transactions. This finding suggests that robust trust between farmers and traders is essential for contract adoption. This aligns with Lu et al. (2010), who show a significant effect on trusting relationship building with buyers and on their investment behavior for transaction-specific assets.

The variable 'Join Trading-Support Group' has a significantly negative relationship with input and written contracts. This suggests that farmers involved in such groups are less inclined to adopt these contract types. This could be due to the benefits or support provided by these groups, which might mitigate the need for formal contracts. This is supported by Fischer and Qaim (2012), who emphasize that the choice to join such groups depends on the comparison of benefits and costs, indicating that individual comparative advantage plays a significant role (Fischer & Qaim, 2012). Additionally, Vu et al. (2020) highlight that membership in associations can provide socio-economic benefits to farmers through group activities, which could reduce their inclination to seek formal contracts (Vu et al., 2020).

The coefficients for price determination—whether prices are determined solely by farmers, by both farmers and traders, or by traders alone—provide intriguing insights into the influence of pricing mechanisms on farmers' choices of vertical coordination strategies. However, this variable does not exhibit statistical significance for any of the contract types (verbal, input, written). This implies that, based on our findings, the party determining the price does not significantly impact the choice of vertical coordination strategy. Nonetheless, this does not necessarily diminish the importance of price determination in real-world scenarios. Other factors in the model may capture some effects of price determination, or the effect may vary widely among individual farmers, making it difficult to discern as statistically significant on average. In reality, the process of price determination in agricultural markets is often multifaceted and involves negotiation, market conditions, relationships, and other variables. Additionally, control variables such as the gender of the household head, household size, and various farm-specific characteristics (eg farm size, planting density, number of ponds) play pivotal roles in shaping the choices of vertical coordination strategies.

Table 2. Factors associated with the adoption of vertical coordination strategies: First-stage MESR estimation.

Vertical coordination strategies	Verbal contract		Input contract		Written contract	
	Coef	St.Err	Coef	St.Err	Coef	St.Err
Farmers-traders trust (weak to strong, 1–5)	0.43***	0.156	0.429	0.044	0.369	0.099
Price determination (1 = farmers, 2 = both, 3 = traders)	−0.556	0.757	−0.403	0.298	−0.163	0.204
Join trading-support group (yes = 1)	−0.935	0.618	1.185***	0.179	1.176***	0.247
Gender of household head (Male = 1)	−1.091**	0.486	−1.05**	0.481	−0.283	0.942
Age (years)	0.006	0.017	−0.021***	0.008	−0.016	0.014
Household size	0.171*	0.102	0.128**	0.059	0.077	0.104
Experience of household head (years)	0.09*	0.054	0.107	.087	0.087	0.064
Farm size (ha)	0.051	0.141	−2.748***	0.89	−0.215	0.335
Number of ponds (plots)	0.361**	0.151	0.619***	0.188	0.186	0.134
Planting density (tree per m ²)	0.168***	0.022	0.079***	0.03	0.098***	0.03
Postharvest loss (%)	−0.007***	0.003	−0.011***	0.002	−0.007	0.009
Apply processing (yes = 1)	0.239	0.771	0.379	0.415	0.775*	0.462
Apply food traceability (yes = 1)	−2.528	1.937	−1.831	1.252	−15.812***	0.83
Gate-price of lotus-grain (VND/kg)	0.011	0.043	0.012	0.051	0.039	0.034
Access to credit (yes = 1)	−1.257***	0.131	−1.342**	0.525	−0.819	0.93
Access to extension services (yes = 1)	−0.453	0.647	0.348	0.665	−0.732	0.705
Distance to main market (km)	−0.126**	0.057	−0.077*	0.043	−0.084**	0.033
Constant	−5.545***	1.721	−0.582	1.23	−2.485*	1.359

* **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Source: Authors' calculations.

4.3.2. Factors affecting lotus grain yield and revenue conditional on the vertical coordination strategies adopted: second-stage MESR estimation

4.3.2.1. Yield. We investigated how the adoption of vertical coordination strategies affects lotus grain yield using second-stage (MESR) estimation (Appendix Table A3). This analysis sheds light on the factors influencing yield outcomes depending on the vertical coordination strategies employed.

The coefficients linked to farmer-trader trust reveal nuanced impacts on lotus grain yield. With input contracts, stronger trust is significantly linked to an increase in yield, indicating potential benefits with this coordination approach. Conversely, the negative coefficient for verbal contracts suggests a detrimental relationship with trust, implying that higher trust levels correlate with lower yields for this strategy.

The variable 'price determination' remains a significant factor influencing yield outcomes within vertical coordination strategies. Interestingly, all coordination strategies exhibit a negative coefficient for price determination, indicating that when traders solely set prices, there may be an adverse impact on yield. This observation suggested that shifting toward more farmer-centric price determination mechanisms could lead to positive outcomes in terms of crop yield within the agricultural landscape under examination.

4.3.2.2. Income. The impact of vertical coordination strategies on revenue is multifaceted and influenced by various factors (Appendix Table A4). Our research indicates that the level of trust between farmers and traders, as determined by the type of contract (verbal, written, or input), can significantly affect lotus-grain revenue. The coefficients related to trust between farmers and traders have diverse effects on revenue outcomes. Notably, in the case of verbal and written contracts, increased levels of trust are associated with a decrease in revenue, suggesting potential challenges or risks inherent in these coordination mechanisms (Chebiwot et al., 2021; Spicer, 2022). However, the positive and statistically significant coefficient for input contracts presents a different scenario, indicating a positive relationship between higher levels of trust and increased revenue within this particular strategy.

Similarly, the variable 'price determination' has a significant influence on revenue outcomes. For input contracts, a positive coefficient for both farmers' and traders' determination of prices suggests a potential positive impact on revenue. Conversely, the negative coefficient for written contracts implies that when traders solely dictate prices, a significant decrease in revenue occurs. Moreover, participation in a trading-support group emerges as a positive factor influencing revenue outcomes, although statistical significance is observed only for verbal contracts. This suggests that farmers involved in such groups experience increased revenue, highlighting the complex dynamics involved in adopting different vertical coordination strategies (Parwada, 2023).

4.3.3. Welfare impact of the vertical coordination strategies adopted

Table 3 presents the estimated results of the mean effects of the sample response (MESR) on lotus-grain household welfare, focusing on the average treatment effects of vertical coordination strategies. The analysis evaluates how various coordination approaches affect two key welfare indicators: lotus-grain yield and revenue. The study aimed to compare the outcomes between adopters and nonadopters while accounting for observed and unobserved factors that could lead to selection bias. The values reported are the unconditional average treatment effect on the treated (ATET), indicating the change in outcome variables between adopters and nonadopters. Additionally, the percentage change serves as a standardized measure, facilitating a comparative evaluation of the impact sizes across different coordination strategies.

4.3.3.1. Yield effects of adopting vertical coordination strategies. Table 3 underscores a significant discovery: the adoption of input contracts emerges as the sole vertical coordination strategy that positively impacts lotus grain yield. Farmers who embraced this technology achieved notably greater yields than did their non-adopting counterparts. This positive outcome aligns with the recognized importance of input availability, quantity, and timing in lotus grain cultivation, as emphasized by Tivet and Boulakia (2017).

Specifically, the adoption of input contracts, identified as a key vertical coordination strategy, led to a substantial 50.3% increase in lotus grain yield for farmers compared to those who did not adopt such

Table 3. Estimated results of the average treatment effects of vertical coordination strategies on lotus-grain household welfare in the MESR.

Outcome variables	Combinations	Adoption ($j = 2/3/4$) (a)	Non-adoption ($j = 1$) (b)	ATT (c) = (a) – (b)	Change in outcome (%)
Lotus-grain yield (ton/ha)	Verbal contract vs Non-adoption	1.30	1.91	–0.61 *	–31.9
	Input contract vs Non-adoption	3.05	2.02	1.03 ***	50.3
	Written contract vs Non-adoption	1.49	2.06	–0.57	–27.6
Lotus-grain revenue (Million VND/ha)	Verbal contract vs Non-adoption	58.3	79.0	–30.7*	–26.2
	Input contract vs Non-adoption	108.6	80.7	27.8***	34.5
	Written contract vs Non-adoption	64.7	91.5	–26.7	–29.2

1) VND = Vietnamese Dong (approximately 23,015 VND/\$U.S. as of 2023); Outcome variables in log form.

2) Calculated using the STATA user-written command `selmlog` (Bourguignon et al., 2007); t-test employed for mean group comparisons; *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Authors' calculations.

contracts. This highlights the crucial role of effective input management, encompassing the availability, quantity, and timing of inputs, in shaping agricultural productivity within the lotus cultivation context in Vietnam. For written contracts, these findings contradict those of BIRTHAL et al. (2005), who suggest that innovative institutional arrangements such as contract farming significantly reduce transaction costs and enhance market efficiency, thereby benefiting smallholders. This contradiction may arise from the lack of commitment observed among farmers at the study sites, which leads them to break the contract when market prices are more favorable.

The estimated treatment effects on lotus grain yield using the MESR validated and strengthened earlier findings observed via kernel density estimation (Figure 3). Consequently, for smallholder farming households in Vietnam, this empirical evidence underscores the strategic advantages of adopting input contracts as a vertical coordination strategy. This adoption optimizes input management practices, ultimately resulting in improvements in lotus grain yield. Such insights are crucial for crafting policies that specifically target effective input management strategies in the dynamic landscape of smallholder farming systems, with a focus on lotus cultivation.

4.3.3.2. Revenue effects of adopting vertical coordination strategies. Lotus cultivation serves as a vital source of income for many rural households in Vietnam. When investigating the financial impacts of adopting vertical coordination strategies in lotus cultivation, the estimated treatment effects indicate a positive correlation between adoption and increased revenue, with notable differences depending on the strategies employed. Similarly, as observed with yield effects, the adoption of specific strategies had discernible effects on lotus revenue. Notably, employing the input contract strategy had the most significant impact, resulting in a 50.3% increase in lotus revenue. This was followed by the written contract strategy, which resulted in a 27.6% increase in revenue, whereas the verbal contract strategy led to a 26.2% decrease in lotus revenue.

The findings from the multiple endogenous switching regression (MESR) on lotus revenue align with the results of the nonparametric analysis depicted in Figure 4. The kernel density of the lotus revenue distributions for adoption combinations consistently shifts to the right compared to that for Non-adoption combinations, which is particularly evident for the input contract strategy. This consistency reinforces the positive influence of adopting vertical coordination strategies on lotus revenue and offers empirical evidence to guide decision-making in relation to lotus cultivation among smallholder farming households in Vietnam.

These findings resonate with the broader literature on agricultural contracts and trust dynamics. For example, studies such as JARNHOLT (2020) illuminate the complex relationships between contract farming and economic outcomes in agriculture, highlighting that farmers benefit from exchanges such as inputs, credits, and market access through engaging in contract farming. The nuanced interactions revealed in our analysis contribute to a growing body of literature emphasizing the significance of trust and contract design in shaping agricultural revenue outcomes, particularly in the context of lotus grain cultivation. These findings are also in line with the results of the focus group discussion in the study areas

(Appendix Table A2), indicating that input contracts offer several advantages over other types of contracts, particularly in short lotus-grain value chains in developing countries. Input contracts provide clear agreement on the quantity, quality, and timing of inputs required for lotus grain cultivation. This assurance is crucial in developing countries where access to reliable inputs may be limited or uncertain, ensuring that farmers have the necessary resources for successful production. Moreover, input contracts often involve medium- to long-term agreements, allowing farmers to plan their production cycles more effectively. In brief, in lotus-grain value chains, where timing is critical due to perishability, having a clear schedule for input delivery and cultivation activities enhances efficiency and productivity. By providing upfront commitments for input purchases, input contracts offer farmers a degree of income stability, reducing their exposure to market volatility. This is especially important for smallholder farmers in developing countries who rely heavily on agriculture for their livelihoods.

5. Concluding remarks and policy implications

Vertical coordination between farmers and traders has emerged as a promising strategy for enhancing efficiency, promoting mutual benefits, and improving livelihoods within Central Vietnam's lotus grain value chain. By addressing existing challenges and charting future directions, vertical coordination holds the potential to significantly contribute to the sustainable development of the lotus grain industry in the region.

An analysis of the factors influencing farmers' choices regarding vertical coordination strategies reveals several key insights. First, trust between farmers and traders plays a pivotal role in determining the adoption of coordination mechanisms. Higher levels of trust are positively associated with the likelihood of adopting verbal, input, and written contracts, underscoring the importance of interpersonal relationships in agricultural transactions. Additionally, the presence of trading support groups negatively impacts the adoption of input and written contracts, possibly due to the supportive environment reducing the necessity for formal contracts.

Regarding the effects of adopting vertical coordination strategies on lotus-grain household welfare, the analysis demonstrated that the adoption of input contracts positively impacts lotus-grain yield, resulting in a significant increase compared to that of non-adopters. This underscores the importance of effective input management in boosting agricultural productivity. Similarly, the adoption of vertical coordination strategies, particularly input contracts, positively affects lotus revenue, with notable variations across different strategies. These findings align with the broader literature on agricultural contracts and trust dynamics, emphasizing the significance of trust and contract design in shaping agricultural revenue outcomes. These findings deepen our understanding of vertical coordination within lotus-grain value chains and assist stakeholders in making evidence-based decisions and policies to promote coordination strategies for sustainable value chain management.

This study provides valuable insights into the significance of trust, input management, and strategic decision-making for improving both yield and revenue outcomes in lotus cultivation among smallholder farming households in Vietnam. Nonetheless, it's crucial to acknowledge its limitations, including potential challenges in generalizability, limitations in capturing the dynamic nature of vertical coordination strategies over time, and issues with small sample size and representativeness. To address these gaps, further research could focus on longitudinal analyses to track the sustainability and long-term impacts of vertical coordination strategies within Central Vietnam's lotus-grain value chains. This could involve comparing the effectiveness of different coordination mechanisms, exploring the influence of external factors, understanding stakeholder perspectives, assessing sustainability implications, and examining strategies for scaling up successful initiatives. By doing so, future studies can offer comprehensive insights for promoting sustainable development in the lotus grain industry, benefiting policymakers, practitioners, and researchers seeking to foster efficient and mutually beneficial value chain management in the region.

Acknowledgements

This work is supported by The Vietnam Ministry of Education and Training under research project B2023-DHH-26. We thank the participants of the workshop organized by the Department of Science and Technology of Thua Thien Hue province for their valuable comments and suggestions, provided under project TTH.2021-KX.06.

Authors contributions

Conceptualization, N.D.K., T.Q.D., T.T.Q and D.T.K.O.; methodology, N.D.K., D.T.K.O.; validation, T.Q.D.; formal analysis, N.D.K., T.Q.D. and D.T.K.O.; writing—original draft preparation, N.D.K., T.Q.D., T.T.Q and D.T.K.O.; writing—review and editing, N.D.K., T.Q.D. and D.T.K.O.; supervision, T.T.Q All authors have read and agreed to the published version of the manuscript.

Ethical approval

The Committee of Science and Education of University of Economics, Hue University approved the ethical proposal 2023-001 of the study.

Participant consent

Informed consent was obtained from all subjects involved in the study prior to the survey. The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, supporting data is not available.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

Code to obtain results for the study is available upon reasonable request.

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Appendix A

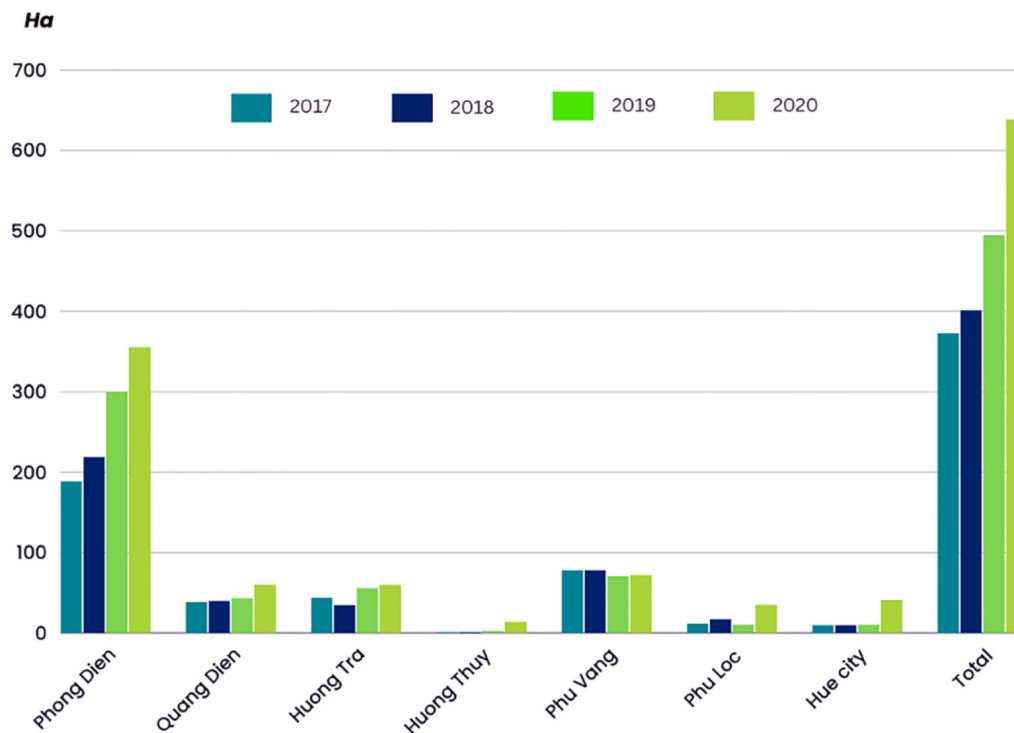


Figure A1. Lotus cultivation in Thua Thien Hue Province (2017–2020).

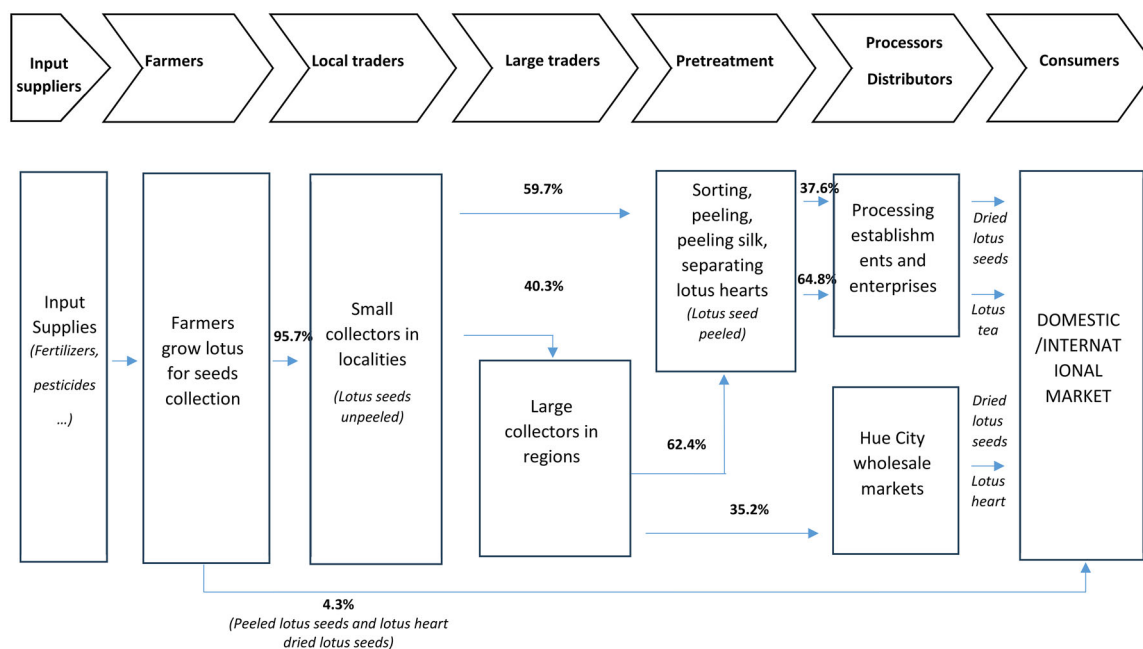


Figure A2. Lotus value chain in Central Vietnam (source: Authors' calculations).

Table A1. The variances between the two polar extremes of the buyer–seller relationship continuum.

Traditional arm's-lengths relationships	Supply chain partnerships
Short-term focus on individual transactions	Commitment to long-term relationships
Buying decision made on price	Buying decision made on value
Many suppliers	Fewer selected suppliers
Low interdependence	High interdependence
Haphazard production and supply scheduling	Order driven production and supply
Limited communication restricted between sales and purchasing	Open communication facilitated by multilevel relationship
Little co-ordination of work processes	Integration of work processes
Relationship specific investments avoided	Increases in relationship specific investments
Information is proprietary	Information is shared
Clear delineation of business boundaries	Creation of intercompany teams
Use of threats to resolve disputes	Joint problem solving approach to conflicts
Unilateral improvement initiatives	Continuous joint improvement sought
Separate activities	Engage in joint activities
Dictation of terms by more powerful firm	Joint decision making
Adversarial attitudes	Co-operative attitudes
Conflicting goals	Compatible goals
Behave opportunistically	Mutual trust exists
Act only in own interest	Act for mutual benefit
Win–lose orientation	Win–win orientation

Source: Duffy and Fearne (2004).

Table A2. Key characteristics distinguishing verbal, input, and written contracts in vertical coordination strategies in the lotus-grain value chain in the study areas from focus group discussions.

Characteristics	Verbal Contract	Input Contract	Written Contract
Nature of Agreement	Oral agreement, often informal	Formal agreement specifying input provisions	Formal written agreement outlining terms
Documentation	Typically, not documented	Documented, specifying input quantities/timing	Formally documented with detailed terms
Trust Requirement	Moderate to high trust between parties	Moderate trust, more formalized relationship	Trust needed, but terms explicitly stated
Flexibility	High flexibility in terms of arrangements	Some flexibility, but terms usually specified	Less flexibility, terms are predetermined
Risk Allocation	Often shared between parties	Shared, but clearer delineation of responsibilities	Defined risk allocation, usually favoring one party
Transparency	Limited transparency due to informal nature	Moderate transparency, terms specified in contract	Transparent, terms explicitly outlined
Complexity	Low complexity, simpler agreements	Moderate complexity, detailing inputs and terms	Higher complexity, detailed legal provisions
Duration	Often short-term, subject to change	Medium to long-term agreements	Medium to long-term, with fixed terms
Cost	Lower transaction costs due to informality	Moderate transaction costs for documentation	Higher transaction costs for legal drafting
Common Challenges	Ambiguity in terms, lack of formal recourse	Ensuring input quality/timeliness, contract enforcement	Legal disputes, adherence to contract terms

Table A3. Determinants of the adoption of vertical coordination strategies for lotus grain yield: Second-stage MESR estimation.

Lotus-grain yield	Non-adoption		Verbal contract		Input contract		Written contract	
	Coef	S.E	Coef	S.E	Coef	S.E	Coef	S.E
Farmers-traders trust (weak to strong, 1–5)	–0.433	1.173	–0.677***	0.162	0.308*	0.261	–0.562	0.336
Price determination (1 = farmers, 2 = both, 3 = traders)	–0.668	–0.617	0.527*	0.399	–0.678*	0.520	–1.204***	0.204
Join trading-support group (yes = 1)	–0.598	0.797	0.804***	0.269	0.141	0.885	0.227	0.267
Gender of household head (Male = 1)	–2.325***	0.778	–0.692	1.162	0.224	0.878	–0.608***	0.242
Age (years)	0.013	0.043	0.021	0.026	–0.025	0.038	0.019	0.021
Household size	–0.066	0.153	0.182	0.154	–0.073	0.210	0.336***	0.141
Experience of household head (years)	–0.046	0.064	0.007	0.098	–0.076***	0.028	0.035**	0.017
Farm size (ha)	0.584	0.400	0.511	0.497	–1.485	1.694	0.666***	0.154
Number of ponds (plots)	0.752*	0.381	0.100	0.147	0.124	0.191	–0.175	0.213
Planting density (tree per m ²)	–0.021	0.095	0.110	0.101	0.129	0.137	0.170***	0.023
Postharvest loss (%)	–0.001	0.006	0.021**	0.009	0.004	0.007	–0.006	0.003
Apply processing (yes = 1)	1.127	0.933	0.312	0.345	0.217	1.496	–1.139***	0.404
Gate-price of lotus-grain (VND/kg)	0.028	0.036	–0.032*	0.021	0.034***	0.006	–0.058***	0.019
Credit amount (Mill.VND)	–0.038***	0.005	–0.019*	0.012	0.017	0.051	–0.040***	0.007
_m1	3.903**	2.145	2.468	0.300	–1.128	0.924	–1.218	1.178
_m2	–0.916	0.753	–1.858	1.171	1.663	4.904	2.095	1.818
_m3	–2.971	2.298	–1.565	1.810	–0.471	3.510	–0.428	0.418
_cons	0.487	2.246	–5.527	6.694	–1.645	3.553	–1.745***	0.683
Sigma2	18.615	19.252	9.590*	5.152	3.588***	61.759	5.129	3.071
rho1	1.160***	0.209	1.022***	0.212	–0.764	0.368	–0.690***	0.665
rho2	–0.272	0.320	–0.769*	0.487	1.126	0.777	1.186	1.075
rho3	–0.883***	0.295	–0.648	0.635	–0.319	0.711	–0.242	0.286

Table A4. Determinants of the adoption of vertical coordination strategies for lotus-grain revenue: Second-stage MESR estimation.

Lotus-grain revenue	Non-adoption		Verbal contract		Input contract		Written contract	
	Coef	S.E	Coef	S.E	Coef	S.E	Coef	S.E
Farmers-traders trust (weak to strong, 1–5)	–0.430	1.429	–0.692*	0.333	0.403**	0.273	–0.588	0.424
Price determination (1 = farmers, 2 = both, 3 = traders)	–0.660*	0.314	0.587	0.813	–0.651**	0.342	–1.188**	0.532
Join trading-support group (yes = 1)	–0.593	0.798	0.777**	0.333	0.203	0.196	0.247	0.291
Gender of household head (Male = 1)	–2.326***	0.825	–0.668	0.607	0.230	0.430	–0.605	0.994
Age (years)	0.013***	0.004	0.020	0.065	–0.024	0.019	0.021	0.035
Household size	–0.068*	0.040	0.175	0.245	–0.074*	0.059	0.339***	0.112
Experience of household head (years)	–0.045	0.085	0.009	0.050	–0.079*	0.056	0.036	0.073
Farm size (ha)	0.583***	0.112	0.520	1.096	–1.383	0.972	0.691**	0.331
Number of ponds (plots)	0.743*	0.445	0.079	0.234	0.100	0.237	–0.194	0.187
Planting density (tree per m ²)	–0.020	0.067	0.105***	0.038	0.133*	0.091	0.167*	0.125
Postharvest loss (%)	–0.001	0.010	0.021***	0.004	0.004**	0.002	–0.007	0.009
Apply processing (yes = 1)	1.109	0.867	0.332	0.591	0.156	0.239	–1.150	1.082
Gate-price of lotus-grain (VND/kg)	0.051***	0.034	–0.009	0.030	0.055***	0.022	–0.035	0.053
Credit amount (Mill.VND)	–0.038*	0.006	–0.020	0.028	0.017	0.020	–0.040***	0.017
_m1	3.853*	2.235	2.439	0.761	–1.096	0.891	–1.178	2.364
_m2	–0.928	0.945	–1.956*	1.323	1.694	1.991	2.083	3.641
_m3	–2.909*	1.532	–1.377	1.654	–0.486	1.388	–0.436	0.750
_cons	3.264	3.322	–2.431	8.211	1.131	2.156	1.059	1.901
Sigma2	8.065	16.703	9.307	9.111	3.636	10.926	5.014	5.170
rho1	1.163*	0.574	1.025	0.149	–0.737	0.394	–0.675	0.602
rho2	–0.280	0.594	–0.822*	0.445	1.139	0.913	1.193	1.198
rho3	–0.878***	0.051	–0.579*	0.422	–0.327	0.721	–0.250	0.389

Appendix B. Weak instrument test

Table B1. Montiel-Pflueger robust weak instrument test.

Effective F statistic:	51.292	
Confidence level alpha:	5%	
Critical Values	TOLS	LIML
% of Worst Case Bias		
tau = 5%	37.418	37.418
tau = 10%	23.109	23.109
tau = 20%	15.062	15.062
tau = 30%	12.039	12.039