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Production and Market Participation of Buckwheat Farmers: Micro-Evidence from Shaanxi Province, China

Rie Muraoka [1,2,*], Hsiaoping Chien [1] and Minjuan Zhao [3]

[1] Social Science Division, Japan International Research Center for Agricultural Sciences, 1-1 Ohwashi, Tsukuba 305-8686, Japan
[2] Policy Research Center, National Graduate Institute for Policy Studies, 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan
[3] College of Economy & Management, Northwest Agricultural and Forestry University, 3 Taicheng Road, Yangling 712100, China
* Correspondence: muraokarie@affrc.go.jp

Abstract: Buckwheat is an important coarse grain often grown in China's marginal and dry mountainous areas; however, few empirical studies have quantified the factors that increase land productivity and encourage buckwheat farmers' market participation. To address this gap in the literature, this study aims to empirically identify the factors associated with the land productivity of buckwheat, those associated with buckwheat farmers' decisions regarding market participation, and those associated with buckwheat selling prices; unique survey data collected from rural buckwheat farmers in China in 2016 are used for the analysis. Our estimation results showed that fertilizer costs and rental machine costs were negatively associated with buckwheat income, indicating the sub-optimality of buckwheat farming. Farmers are likely to sell their buckwheat at high prices if they conduct the initial processing and sell it to processing firms. Providing technical training on the initial processing and information on market channels for buckwheat farmers could serve as efficacious policy interventions. The household head's educational attainment was positively associated with buckwheat productivity and market participation, indicating the importance of the effort to narrow the educational gap between urban and rural areas in China.

Keywords: buckwheat; productivity; market participation; China

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1. Introduction

Buckwheat (*Fagopyrum esculentum*) is believed to have originated in Southern China 4000–5000 years ago [1] and has been cultivated in China since then [2]. It is highly adaptive to agroecological conditions and can be planted in extreme environments [3]. Known as a "hill crop" in China, which requires low soil fertility, it grows during a short season, competes with weeds, and is tolerant to high stress [4]. Vertical distribution of buckwheat can reach the mountainous area of Kanbazoong, Tibet, at an altitude of over 4000 m [5]. It has grown in the marginal and dry mountainous areas of North China, Northwest China, and Southwest China, which are inhabited by ethnic minorities [5].

People in these mountainous areas often suffer from poverty [6]. Coarse grain planting and impoverished areas in China often overlap [7]. Although buckwheat does not require intensive care, its yield is much lower than that of other cereal crops [8]. Owing to its low yield, buckwheat has been overlooked for a long time in China. Its high resistance and nutritional value are not well recognized by the government and the public. Consequently, support in buckwheat production for farmers has been insufficient, and investment in research and development regarding buckwheat production has been stagnant for a long time.

However, as people's interests in healthy diets have been growing recently, buckwheat has been re-evaluated owing to its functional and nutritional values [9]. Buckwheat is rich in lysine; arginine; balanced amino acids; and flavonoids, such as rutin, orientin, vitexin,

quercetin, isovitexin, and isoorientin, which are expected to reduce hyperlipidemia and lower blood pressure [2,10,11]. The demand for buckwheat food products, such as noodles, flour, steamed buns, bread, tea, wine, sprouts, and oatmeal, has been growing in recent years in China [9].

Though buckwheat is an important staple crop for poor farmers in dry and marginal mountainous areas in China, and its growing demand as a health food could expand its market channels, limited empirical analysis has examined buckwheat production and the market participation of buckwheat farmers. Therefore, this study attempts to fill this literature gap by quantifying the factors associated with buckwheat yield, revenue, and income, and examines the factors related to buckwheat farmers' decisions regarding market participation, the quantity of buckwheat sold, and the selling prices of buckwheat, using farm household data collected in buckwheat production areas in Dingbian County, Yulin City, and Shaanxi Province, China, in 2016. To the best of our knowledge, this is the first empirical study to quantify the factors associated with buckwheat farmers' behavior and decisions regarding market participation in China. The empirical evidence generated in this study could contribute to the formulation of effective policies in the context of raising land productivity and promoting the market participation of buckwheat farmers. This could alleviate poverty in China's dry and marginal mountainous areas.

The remainder of this paper is organized as follows. The next section provides a literature review of the existing studies on buckwheat production and market participation of buckwheat farmers in China. The third section describes the data and presents the descriptive statistics. In the fourth section, we present the identification strategies used in this study. In the fifth section, we discuss the estimation results. The sixth section presents the main findings and their implications. The final section concludes the study and presents the limitation of this study and future research directions.

2. Literature Review

2.1. Buckwheat Production Analysis in China

Several studies have analyzed buckwheat production in China using farm survey data. All those studies have examined buckwheat production's technical efficiency (TE). Utilizing data from buckwheat farmers collected in Liangshan Yi Autonomous Prefecture, Sichuan Province, in 2017, Xu et al. [7] showed that buckwheat farming in survey areas mainly depended on land areas, labor, and fertilizer and was characterized by low utilization of new varieties of buckwheat and modern machinery. The estimated TE of the buckwheat production was 0.814. Household size, planting duration and ratio, plot size, and sowing technology were significant positive determinants of TE. They also showed that approximately 30% of farmers had TE values below the mean, and their input-utilizing efficiency was low.

Using the same dataset, Xue et al. [12] classified buckwheat farms into three categories (small-scale, medium-scale, and large-scale farms) and measured the overall TE, pure technical efficiency (PE), and scale efficiency (SC). They showed that while TE and SE were higher for larger farms, PE was higher for smaller farms. This suggested that larger farms were more efficient because of their scale efficiency. They also found that the educational attainments of farmers, planting techniques, and technical training could enhance the TE in buckwheat production.

Cai et al. [13] conducted a study similar to that of Xue et al. [12] using farm household survey data from Dingbian County in Shaanxi Province. They categorized buckwheat farms into three groups (small traditional, large traditional, and large professional farms) and estimated their TE. Contrary to Xue et al. [12], their results showed that the average TE of small traditional farms was 0.86; that of large traditional farms was 0.82; and that of large professional farms was 0.79, indicating that smaller farms might be more efficient in buckwheat production. They also showed that land and labor were the most important means of buckwheat production, as these output elasticities were positive.

Although past studies have provided fundamental analyses of the TE of buckwheat production, more empirical analysis in China is necessary to identify ways to improve the land productivity of buckwheat. Therefore, we conducted an empirical analysis to identify the factors associated with buckwheat land productivity in rural mountainous areas in China.

2.2. Market Participation of Buckwheat Farmers in China

While enhancing crop productivity is one way for poor farmers to escape poverty, increasing crop sales is another. Boosting rural income in developing countries requires shifting the farming system from an extensive and semi-subsistence production level to intensive and complex farming and commercialization in response to market demand [14,15]. Agricultural production oriented to the markets could accelerate specialization, economic growth, the exchange of ideas among stakeholders, and the profit of farmers [16].

Despite the importance of agricultural commercialization, rural buckwheat farmers in China often face challenges in terms of market participation. Based on 15 years of data on coarse grain farming in Gansu Province, China, Liu et al. [17] found no good coarse grain breeding or supply system for improved varieties. Only a limited number of cultivars were available for industrial processing; however, supply systems for such varieties were underdeveloped. Additionally, the development of the coarse grain industry had occurred sporadically, constraining farmers' participation in well-developed buckwheat value chains. Furthermore, the government had not paid significant attention to these issues.

Few simple empirical studies have focused on the market participation of coarse grain farmers in China. Li [18] found that the quantity of millet sold was positively correlated with the scale of production in Shaanxi Province. Zhang and Li [19] showed that small-scale farmers face price volatility from weather and accidental conditions, leading to unstable and poor performance in coarse grain production.

To formulate adequate support for the market participation of rural buckwheat farmers, we need to understand the challenges and constraints farmers face. However, to our knowledge, no empirical studies have analyzed these. Therefore, by utilizing unique data collected from rural buckwheat farmers in China, we aimed to quantify the factors associated with a buckwheat farmer's decision to participate in the market and the factors associated with buckwheat selling prices.

3. Materials

3.1. Data

This study utilizes data collected in Dìngbian County, Yulin City, Shaanxi Province, China, in 2016. Shaanxi Province has the second-largest planting area of common buckwheat in China. Dìngbian County is a famous production area of common buckwheat. Its average altitude is 1605 m, and it has a moderate summer suitable for buckwheat cultivation. We adopted the stratified random sampling method. First, townships and villages in Dìngbian County were listed, and data were collected regarding buckwheat production, areas in which buckwheat is planted, population size, accessibility, and the per capita income of townships and villages. Based on these data, the survey team selected five townships that could represent the buckwheat production areas of Dìngbian County. Then, the survey team randomly selected 25 villages from five townships and approximately 12 households in each village. The locations of the surveyed villages are shown in Figure 1.

A face-to-face interview survey was conducted jointly by the Japan International Research Center for Agricultural Sciences and Northwest Agricultural and Forestry University. In total, the survey team interviewed 303 buckwheat-producing households. The survey data included agricultural production details, such as inputs, outputs, sales, agricultural practices, and household demography. We focused on buckwheat production and collected data on farmers' willingness to produce buckwheat; their experience; and the constraints, extension, and marketing, as well as on the support that a farmer needed. We excluded the outcome variables to address the outliers if the values were more than four standard deviations from the mean.

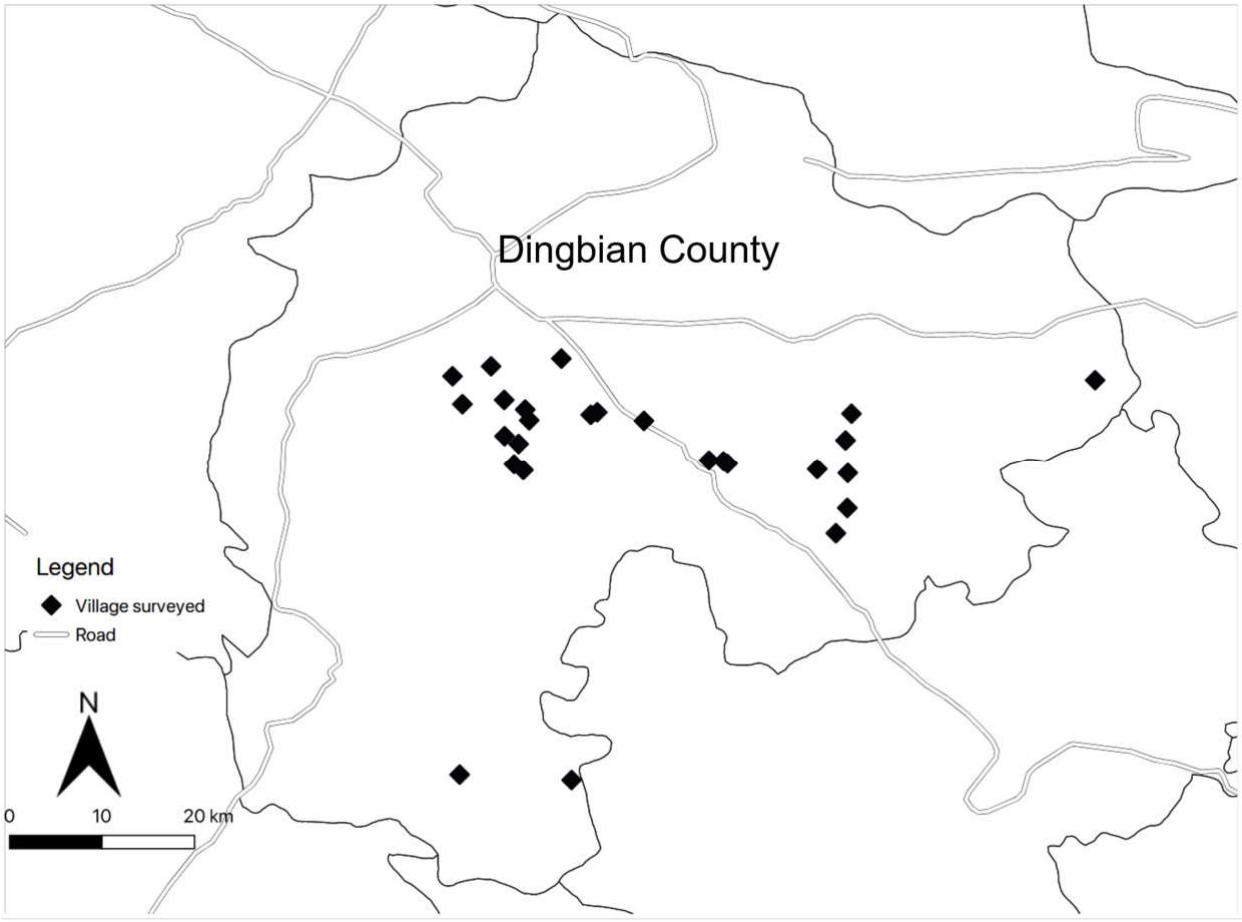

Figure 1. Locations of surveyed villages in Dìngbian county, Yulin city, Shaanxi province, China.

3.2. Crop Production

Table 1 describes the crops produced by households surveyed in 2016. Table 1 shows that the surveyed households planted buckwheat, potatoes, maize, oilseeds, and other crops. This indicates that buckwheat was the most frequently planted crop and brought the greatest revenue and income to households, among other crops, showing that buckwheat is the main crop in the surveyed areas.

Table 1. Crop production.

	Planted Area		Crop Revenue		Production Costs		Crop Income	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Buckwheat	2.35	2.00	9286	8870	5703	5704	4035	7897
Potato	1.23	1.27	8565	11,584	5005	6598	3651	8805
Maize	0.27	0.43	1013	2041	1145	2099	−313	3447
Oilseeds	0.22	0.41	1099	2256	432	900	680	1583
Others	0.12	0.29	678	2004	288	829	367	1463
Total	4.35	2.98	21,812	19,035	13,298	11,120	8835	14,102

3.3. Household Characteristics

Table 2 reports the characteristics of the surveyed households in 2016. The average household size in the surveyed area was 4.75, greater than the national average of 3.0 [20]. The household size was decomposed into 2.96 laborers, 1.48 dependents (babies, infants, and elders), and others. The average age of the household head was approximately 53 years. Regarding education, 46% of the household heads had completed primary school, 27% had

completed secondary school, and 8% had completed high school, college, or university. The corresponding percentages of national averages were 18%, 43%, and 20% in 2016 [20]. This indicates that the educational attainments of household heads in the survey areas were much lower, showing the social disadvantage of the rural buckwheat farmers. The average total farm size was approximately five hectares, much larger than the national average of 0.52 hectares [21]. This may be because the farmlands of the survey area are infertile, marginal, high-altitude, and unsuitable for intensive farming.

Table 2. Household characteristics.

	Mean	SD
Household demography		
Household size	4.75	1.79
Number of laborers	2.96	1.16
Number of dependents	1.48	1.41
Household head's age	52.67	8.52
Head graduated from primary school (=1)	0.46	0.50
Head graduated from secondary school (=1)	0.27	0.44
Head graduated from high school, college, or university (=1)	0.08	0.28
Total farm size (ha)	5.07	3.39
Household income decomposition [1]		
Crop income (CNY)	8835	14,102
Livestock income (CNY)	243	7161
Non-agricultural income (CNY)	4789	14,569
Subsidy received (CNY)	2188	2754
Total household income (CNY)	17,295	24,649

[1] Income is defined as the revenue minus associated paid-out costs.

The mean total household income of the survey area was CNY 17,295, decomposed into CNY 8835 for crop income, CNY 243 for livestock income, CNY 4789 for nonfarm income, and CNY 2188 for subsidies. In 2016, the national average household income in China was CNY 71,463, and that of rural farm households was 40,799 [20]. This indicates that the average income of buckwheat farmers in the survey area was much lower than the national average.

3.4. Buckwheat Production in 2016

Table 3 presents the details of buckwheat production in the survey area in 2016. Their average number of years of experience in buckwheat production was 32. While all households produced common buckwheat, only 7% produced Tartary buckwheat. Most farmers, 93%, were willing to plant common buckwheat in the future. Only 14% of them conducted the initial processing of harvested buckwheat. This indicates that offering technical assistance for the initial processing of harvested buckwheat could increase the number of buckwheat farmers conducting the initial processing and add high value to harvested buckwheat. Only 5% of buckwheat farmers had received technical assistance from the government, cooperatives, or other organizations. Most of the households, 88%, sold harvested buckwheat, and the mean quantity of buckwheat was 1103 kg/ha among farmers who sold their buckwheat.

Table 3 shows an interesting pattern of inputs of buckwheat production in the survey area. Almost all farmers used chemical fertilizers and rental machines for buckwheat farming. Only 9% of farm households applied manure, and no one used agrochemicals, had access to irrigation water, or practiced mulching. This indicates that the inputs of buckwheat production were almost only chemical fertilizers. The costs of buckwheat production were primarily derived from chemical fertilizers. The average cost of chemical fertilizers was CNY 983 ha, that of rental machines was CNY 6.79 ha, and that of hired labor was only CNY 0.13 ha.

Table 3. Buckwheat production in 2016.

	Mean	SD
Years of experience in buckwheat production	32	11
Producing common buckwheat (=1)	1.00	0.06
Producing Tartary buckwheat (=1)	0.07	0.25
Willing to continue buckwheat production (=1)	0.93	0.25
Conducting initial processing of buckwheat (=1)	0.14	0.35
The ratio of households who received technical assistance	0.05	0.22
Buckwheat-planted area (ha)	42.71	74.23
Sold buckwheat (=1)	0.88	0.33
Quantity of buckwheat sold (for only those who sold buckwheat) (kg/ha)	1103	406
Input use		
Applying chemical fertilizers (=1)	0.98	0.14
Applying manure (=1)	0.09	0.29
Applying agrochemicals (=1) [1]	0.00	0.00
Mulching (=1)	0.00	0.00
Utilizing irrigation water (=1)	0.00	0.00
Utilizing rental machinery (=1)	0.95	0.21
Amount of buckwheat seeds planted (kg/ha)	60	38
Cost of chemical fertilizers applied (CNY/ha)	983	588
Cost of rental machinery (CNY/ha)	6.79	1.54
Cost of hired labor (CNY/ha)	0.13	0.86
Harvest, revenue, and income		
Buckwheat yield (kg/ha)	1406	405
Buckwheat revenue (CNY/ha)	3882	1213
Buckwheat production cost (CNY/ha)	2329	853
Buckwheat income (CNY/ha) [2]	1684	1273

[1] This includes herbicides, pesticides, fungicides, and other chemical inputs. [2] Buckwheat income is defined as the value of harvested buckwheat minus all paid-out costs associated with buckwheat production.

The average buckwheat yield was approximately 1400 kg/ha, close to the global average [22]. The average revenue and cost were approximately CNY 3900 and 2300 ha, respectively; the average income was CNY 1700 ha in 2016.

3.5. Buyers and Prices of Buckwheat

Table 4 displays to whom farmers sold their buckwheat and the selling prices. The overall average selling price was CNY 2.77 kg. Middlemen were the most common buyers of buckwheat for farmers in the survey area, as 88% of farmers sold their buckwheat to middlemen. Further, 6% of farmers sold their buckwheat to wholesalers and 5% of them to processing firms. The sale of buckwheat to cooperatives was rare; only two households did so.

Table 4. Buyers and selling prices of buckwheat for farmers who sold their buckwheat.

		Mean	SD
Selling price (CNY/kg)		2.77	0.29
Buyers			
Middlemen	Ratio	0.88	0.32
	Selling price (CNY/kg)	2.74	0.20
Wholesalers	Ratio	0.06	0.24
	Selling price (CNY/kg)	2.76	0.14
Processing firms	Ratio	0.05	0.22
	Selling price (CNY/kg)	3.27	0.83
Cooperatives	Ratio	0.01	0.08
	Selling price (CNY/kg)	2.60	0.00

Interestingly, the average selling prices of buckwheat differed among those to whom farmers sold their buckwheat. The farmers who sold their buckwheat to processing firms received the highest average selling price, CNY 3.27 kg, much higher than the selling price to middlemen, CNY 2.74 kg, and wholesalers, CNY 2.76 kg. This indicates that selling prices vary depending on to whom farmers sold their buckwheat.

3.6. Constraints of Buckwheat Production

Table 5 lists the buckwheat production constraints faced by farmers in 2016. This is anecdotal evidence of buckwheat farmers' production constraints and could provide ideas on how the government could support buckwheat production. Table 5 indicates that there were several constraints faced by farmers. The first was insufficient irrigation water. Kreft [23] explained that insufficient water for buckwheat cultivation led to low yield because buckwheat requires water when the branches and flower buds are actively growing. The second was the lack of an output market. This is a common problem in buckwheat production in China. The third was lack of credit. Insufficient funds constrain investments in buckwheat production and prevent the adoption of new technologies or farming practices. The fourth and the fifth were labor shortages and a lack of technology, respectively. Managing five hectares of farmland is problematic for three laborers, the average number of laborers in the survey area. Additionally, it could be challenging to hire laborers due to a lack of credit. The government is expected to provide effective support to solve these problems.

Table 5. Constraints of buckwheat production.

	Mean	SD
Insufficient irrigation water	0.48	0.50
Lack of output market	0.41	0.49
Lack of credit	0.40	0.49
Labor shortage	0.11	0.32
Lack of technology	0.11	0.31

4. Methods

This section presents the estimation methods used to quantify the factors associated with buckwheat yield, revenue, and income; factors associated with market participation; and factors associated with buckwheat selling prices.

4.1. Factors Associated with Buckwheat Yield, Revenue, and Income

First, we were interested in the factors associated with the land productivity of buckwheat. For this purpose, we specified the following reduced form of the equation.

$$lnY_{iv} = \alpha_0 + \alpha_1 lnA_{iv} + \alpha_2 lnL_{iv} + \alpha_3 lnX_{iv} + \alpha_4 lnZ_{iv} + \alpha_5 D_v + \varepsilon_{iv} \quad (1)$$

where Y_{iv} is the amount of buckwheat harvested per hectare, the buckwheat revenue per hectare, or the buckwheat income, which is defined as revenue minus paid-out cultivation costs per hectare of household i in township v. A_{iv} is the buckwheat-planted area in hectares. L_{iv} is the number of workers available in the household. X_{iv} is the vector of inputs, such as the amount of buckwheat seeds planted per hectare, costs of chemical fertilizers per hectare, costs of the rental machine per hectare, costs of hired labor per hectare, and a dummy variable indicating whether manure was applied. Z_{iv} is the vector of household characteristic variables, including a dummy variable indicating whether the household received technical advice on buckwheat production. It also includesyears of experience in buckwheat production, age of the household head, educational attainment of the head, amount of agricultural subsidy received, a dummy variable indicating whether the household had access to credit, and the livestock holding index (Livestock holding is indexed using principal component analysis. Please see Appendix A for details). D_v

is a vector of the four township dummy variables used to control regional heterogeneity. We estimated this model using a multivariate ordinary least squares (OLS) approach, a technique that is often used in micro-empirical analyses.

Note that we were not able to eliminate the possibility of endogeneity issues. The error terms likely include variables that affect both the explanatory and outcome variables. For example, a farmer's innate ability, enthusiasm for agriculture, entrepreneurship, and unmeasured wealth level could affect a farmer's adoption decision and land productivity at the same time. In this case, the estimates are biased and inconsistent. Thus, we need to interpret the estimated coefficients as associations rather than causality.

4.2. Factors Associated with Market Participation

Second, we modeled the market participation behavior of buckwheat farmers following Barrett's [24] non-separable household model; Barrett [24] modeled that a household maximizes its utility over a vector of agricultural commodities subject to cash budget constraints and non-tradable availability constraints. In this model, each household-specific crop price is determined by the net position of the household. The market price given by a household is endogenously determined by the specific markets that are geographically accessible to each household.

Following Barrett [24] and Olwande et al. [16], let k be a dummy variable indicating whether a household decides to participate in the buckwheat market as a seller, and let the sales quantity of buckwheat, M^B, be nonzero if k equals one. M^B is expressed as follows:

$$M_{iv}^B = M_{iv}^B(k,\ A,\ L,\ Z,\ P,\ D) \tag{2}$$

where P is the buckwheat selling price of each household.

As described above, farmers' market participation decisions involve two steps: first, whether they sell their products, and second, how much buckwheat they sell. Market participation studies usually adopt this two-step model, and they generally employ a "two-stage", "type 2 Tobit", or "double-hurdle" approach [25]. The Heckman two-stage model treats zero values as unobserved data [26]. Our model does not fit well with a two-stage model because both k and M^B are choice variables, and the zero value of sales quantity is not the outcome of a latent unobserved decision.

Another approach is the adoption of corner solution models. The Tobit model and Cragg's double-hurdle model are two representative models of corner solutions [27]. The Tobit model is suitable for cases where two decisions (k and M^B) are made simultaneously using the same process [28]. The double-hurdle model is a more flexible alternative to the Tobit model because it allows two decisions (k and M^B) to be made through different processes. Following previous studies [16,29], we estimated Model (2) using the double-hurdle model.

The following is the reduced form of (2):

$$P(k_{iv} = 1) = P\left(M_{iv}^B > 0\right) = \beta_0 + \beta_1 A_{iv} + \beta_2 L_{iv} + \beta_3 Z_{iv} + \beta_4 P_{iv} + \beta_5 D_v + \epsilon_{iv} \tag{3}$$

$$M_{iv}^B = \gamma_0 + \gamma_1 A_{iv} + \gamma_2 L_{iv} + \gamma_3 Z_{iv} + \gamma_4 P_{iv} + \gamma_5 D_v + \mu_{iv.} \tag{4}$$

The first-stage Equation (3) is the model of market entry k, and the second-stage Equation (4) is the model of the sales quantity of buckwheat. The explanatory variables in (3) and (4) may or may not be identical; they are the same in our study. Following Cragg [27], we estimated the first stage using a probit model and the second stage using a linear model.

4.3. Factors Associated with Buckwheat Price

Lastly, we introduced a model explaining factors associated with the buckwheat selling price of each household, following Minten et al. [30]. The buckwheat selling price could be decomposed as follows:

$$P_{iv} = \delta_0 + \delta_1 A_{iv} + \delta_2 L_{iv} + \delta_3 Z_{iv} + \delta_4 S_{iv} + \delta_5 D_v + \mu_{iv.} \quad (5)$$

where S_{iv} is the vector to which a household sold buckwheat, including the broker, wholesaler, and processing firm. This model was estimated using a multivariate OLS approach. Again, since we were not able to control for endogeneity issues, such as omitted variables, as in Section 3.1, we interpreted the estimates as associations rather than causality.

5. Results

5.1. Estimation Results of Factors Associated with Buckwheat Yield, Revenue, and Income

Table 6 presents the factors associated with the yield, defined as the amount of harvested buckwheat per hectare, and the revenue and income from the harvested buckwheat per hectare. The results showed that the number of laborers in households was positively and significantly associated with buckwheat yield and revenue, as a 10% increase in household labor was likely to raise the yield and revenue of buckwheat by approximately 2% on average. A 10% increase in chemical fertilizer and rental machine costs was expected to significantly reduce the buckwheat income by approximately 1% and 0.6% on average, indicating the high costs of chemical fertilizers and rental machines.

Table 6. Factors associated with buckwheat yield, revenue, and income.

	Log of Buckwheat Income per Hectare (kg/ha)	Log of Buckwheat Revenue per Hectare (CNY/ha)	Log of Buckwheat Income per Hectare (CNY/ha) [1,2]
Explanatory variables	(1)	(2)	(3)
Log of buckwheat-planted area (ha)	−0.074	−0.061	0.046
	(0.074)	(0.083)	(0.060)
Log of number of laborers in household	0.185 **	0.202 **	0.045
	(0.083)	(0.092)	(0.104)
Log of buckwheat seeds planted (kg/ha)	−0.113	−0.135	0.052
	(0.154)	(0.175)	(0.071)
Log of chemical fertilizer cost (CNY/ha)	0.000	−0.004	−0.109 **
	(0.031)	(0.034)	(0.049)
Log of rental machine cost (CNY/ha)	0.003	0.005	−0.060 *
	(0.017)	(0.018)	(0.035)
Log of hired labor cost (CNY/ha)	0.019	0.029	0.045
	(0.056)	(0.063)	(0.038)
Applied manure (=1)	−0.068	0.018	0.061
	(0.075)	(0.076)	(0.147)
Years of experience in buckwheat production	0.008	0.009	−0.001
	(0.008)	(0.009)	(0.004)
Received technical assistance (=1)	0.016	0.053	0.189
	(0.152)	(0.163)	(0.140)
Household head's age	−0.004	−0.005	0.005
	(0.008)	(0.008)	(0.006)
Household head graduated from primary school (=1)	0.116	0.112	0.365 **
	(0.091)	(0.099)	(0.160)
Household head graduated from secondary school (=1)	0.198 ***	0.201 ***	0.385 **
	(0.073)	(0.077)	(0.164)
Household head graduated from high school, college, or university (=1)	0.085	0.081	0.262
	(0.084)	(0.090)	(0.198)
Log of total farm area (ha)	0.000	0.001	0.017
	(0.047)	(0.049)	(0.089)
Log of agricultural subsidies received (ha)	−0.005	−0.002	0.004
	(0.008)	(0.009)	(0.012)
Had access to credit (=1)	0.060	0.073	−0.080
	(0.066)	(0.072)	(0.083)
Index of livestock holdings	−0.009	−0.012	−0.042
	(0.019)	(0.021)	(0.036)
Baiwanzi township (=1)	−0.124 **	−0.210 ***	−0.423 ***
	(0.059)	(0.062)	(0.121)
Yangjing township (=1)	−0.223	−0.305 *	−0.245 *
	(0.164)	(0.184)	(0.127)
Jiban township (=1)	−0.048	−0.067	−0.108
	(0.090)	(0.100)	(0.125)
Hejuan township (=1)	0.016	−0.006	−0.065
	(0.066)	(0.066)	(0.150)
Constant	7.621 ***	8.689 ***	7.704 ***
	(0.961)	(1.092)	(0.573)
Observations	281	281	281
R-squared	0.093	0.109	0.939

Robust standard errors in parentheses. ***, **, and * indicate significance at 1, 5% and 10%, respectively. [1] Buckwheat income is defined as the value of harvested buckwheat minus all paid-out costs associated with buckwheat production. [2] Negative income dummy variable is included in the regression (3).

The estimated results indicated that education, especially secondary education, was a strong positive factor related to the land productivity of buckwheat in the survey area. If the household head had completed secondary school, the amount of harvested buckwheat per hectare and the revenue and income of buckwheat per hectare were likely to increase by 20%, 20%, and 39% on average, respectively. The income from buckwheat per hectare was likely to rise by 37% with the head's primary school completion. Higher education levels, however, were not significantly related to land productivity. This indicates that although buckwheat production might not require a higher level of education, secondary education could be a powerful tool for efficient farm management in buckwheat production.

The Baiwanzi township dummy variable had a consistently negative and significant association with the yield, revenue, and income of buckwheat per hectare. This indicates that the Baiwanzi township likely had some regional disadvantages in buckwheat production, including soil fertility and market access.

5.2. Estimation Results of Factors Associated with Market Participation and Sales Quantity Decisions

Table 7 presents estimation results from the double-hurdle model regarding the factors associated with market participation and sales quantity decisions. The coefficients of hurdle 1, in (1) of Table 7, are the average marginal effects of each explanatory variable on the participation decision. A 1% increase in the buckwheat-planted areas was associated with an approximately 11% increase in the selling probability of buckwheat on average. Unexpectedly, a farm receiving agricultural technical assistance had a probability of selling buckwheat that was reduced by 9.2%. An additional year of buckwheat production experience was related to a 0.3% increase in the probability of selling buckwheat. As expected, a farmer who faced an increase in buckwheat selling price by CNY 1 kg was approximately 40% more likely to sell buckwheat on average. This indicates that the selling price of buckwheat could be the greatest motivation to participate in marketing for farmers.

Column (2) of Table 7 displays the estimated coefficients of Hurdle 2, which indicate the average marginal effects of the explanatory variables on the quantities of buckwheat sold, given that farmers decided to sell buckwheat. As in Hurdle 1, buckwheat-planted area, years of experience in buckwheat production, and selling price were positively associated with the quantity of buckwheat sold. A 1% increase in the buckwheat-planted area was associated with an approximately 185 kg/ha increase in the quantity of buckwheat sold on average. A farmer with one more year of experience in buckwheat production was likely to sell 5.1 kg/ha more buckwheat. If farmers could sell their buckwheat at CNY 1 kg more, they were expected to sell it by about 465 kg/ha more on average. The livestock holding index was negatively associated with the quantity of buckwheat sold. Secondary education and higher educational attainment of the household head was positively associated with the quantity of buckwheat sold by approximately 184 and 221 kg/ha, respectively. These results indicate that the buckwheat-planted area, educational attainment of the household head, and the buckwheat selling price could be important factors on how much on how much quantity of buckwheat farmers would sell.

5.3. Estimation Results of Factors Associated with Buckwheat Prices

As the estimated results in Table 7 indicate, the selling price of buckwheat could be an essential factor associated with a farmer's decision to participate in the market. Thus, we wondered how farmers could sell their buckwheat at high prices. To explore this, Table 8 presents the factors related to the price of buckwheat sold by each household.

The estimates show that if a farmer conducted the initial buckwheat processing, they could sell buckwheat at a price 3% higher. Although the magnitude of the price increase was small, the effort paid off. To whom a farmer sold buckwheat also affected the buckwheat price. Farmers who sold their buckwheat to processing firms tended to charge a higher price than other buckwheat buyers. This indicates that if a household could obtain information about buyers who buy buckwheat at a higher price, they could earn a higher income.

Additionally, farmers in Banwanzi, Yangjing, and Jiban were likely to sell buckwheat at lower prices than those in other townships. This suggests a systematic difference in selling prices according to where the farmers live. This could be due to the lack of market information or difficulty in accessing alternative buyers. A more in-depth survey is required to determine why this systematic difference was observed.

Table 7. Average marginal effects of the double-hurdle model of buckwheat sales market participation.

	Hurdle 1	**Hurdle 2**
	Selling Buckwheat (=1)	**Quantity of Buckwheat Sold (kg/ha)**
	Probit	**Linear**
Explanatory variables	(1)	(2)
Log of total farm area (ha)	−0.024	51.696
	(0.028)	(60.706)
Log of buckwheat-planted area (ha)	0.109 ***	184.638 ***
	(0.024)	(45.848)
Number of laborers in household	0.012	9.936
	(0.015)	(25.003)
Received technical assistance (=1)	−0.092 *	68.446
	(0.049)	(115.676)
Log of agricultural subsidies received (ha)	0.007	−2.211
	(0.004)	(8.158)
Years of experience in buckwheat production	0.003 *	5.100 *
	(0.001)	(2.719)
Household head's age	−0.002	−2.660
	(0.002)	(3.896)
Household head graduated from primary school (=1)	−0.005	100.730
	(0.039)	(75.309)
Household head graduated from secondary school (=1)	0.065	183.820 **
	(0.054)	(89.545)
Household head graduated from high school, college, or university (=1)	0.123	221.224 *
	(0.090)	(129.323)
Had access to credit (=1)	−0.057	−84.717
	(0.035)	(58.089)
Index of livestock holdings	−0.004	−58.778 ***
	(0.012)	(22.259)
The selling price of buckwheat (CNY/kg)	0.398 **	464.732 *
	(0.191)	(250.227)
Baiwanzi township (=1)	−0.069	−161.868 **
	(0.043)	(76.559)
Yangjing township (=1)	−0.022	50.556
	(0.045)	(81.919)
Jiban township (=1)	0.026	−76.998
	(0.067)	(99.046)
Hejuan township (=1)	−0.083	−66.740
	(0.070)	(112.845)
Observations	288	288
Pseudo R-squared	0.3102	0.0221

Standard errors in parentheses. ***, **, and * indicate significance at 1, 5% and 10%.

Table 8. Factors associated with buckwheat prices.

	Log of the Buckwheat Selling Price (CNY/kg)
Log of total farm area (ha)	0.001
	(0.016)
Log of buckwheat-planted area (ha)	0.012
	(0.011)
Number of laborers in household	0.007
	(0.005)
Received technical assistance (=1)	0.032
	(0.037)

Table 8. *Cont.*

	Log of the Buckwheat Selling Price (CNY/kg)
Log of agricultural subsidies received (ha)	−0.000
	(0.001)
Years of experience in buckwheat production	−0.000
	(0.001)
Household head's age	−0.000
	(0.001)
Household head graduated from primary school (=1)	0.021
	(0.017)
Household head graduated from secondary school (=1)	0.007
	(0.018)
Household head graduated from high school, college, or university (=1)	0.022
	(0.016)
Had access to credit (=1)	0.002
	(0.011)
Index of livestock holdings	−0.003
	(0.004)
Conducting initial processing of buckwheat (=1)	0.030 *
	(0.016)
Sold buckwheat to wholesalers (=1)	0.008
	(0.015)
Sold buckwheat to processing firms (=1)	0.132 **
	(0.054)
Sold buckwheat to cooperatives (=1)	−0.035
	(0.044)
Baiwanzi township (=1)	−0.066 ***
	(0.013)
Yangjing township (=1)	−0.072 ***
	(0.019)
Jiban township (=1)	−0.022 *
	(0.012)
Hejuan township (=1)	−0.019
	(0.014)
Constant	0.282 ***
	(0.048)
Observations	262
R-squared	0.298

Robust standard errors are in parentheses. ***, **, and * indicate significance at 1, 5% and 10%, respectively.

6. Discussion

We discuss the main finding of our study and its interpretation and draw policy implications from our estimation results in this section.

6.1. How Can We Improve Buckwheat Productivity?

Using the multivariate OLS approach, this study first estimated the factors associated with buckwheat yield, revenue, and income. Our estimation results show that household labor was positively associated with the yield and revenue of buckwheat and that fertilizer costs and rental machine costs were negatively associated with buckwheat income. This may indicate that chemical fertilizers and machines may not have been optimized in the survey area. Additionally, only 9% of farmers applied manure, and none used agrochemicals or practiced mulching.

Efficient farming technologies have not yet been standardized in marginal and high-altitude areas in China for buckwheat farming. Additionally, there is a lack of good breeding systems and an insufficient supply of superior buckwheat varieties. Therefore, investments in the research and development of superior cultivars and the standardization of buckwheat cultivation technologies in rural and mountainous areas are strongly recommended.

Technological assistance that could help farmers disseminate desirable farming methods could also improve the productivity and profitability of buckwheat farming in China's marginal and mountainous areas. Support for credit access to purchase inputs may also be necessary [31].

6.2. How Can We Promote Market Participation of Buckwheat Farmers?

Secondly, this study quantified the factors associated with the market participation of buckwheat farmers using the double-hurdle model and the buckwheat selling price using the multivariate OLS approach. The results showed that the buckwheat-planted area, years of experience in buckwheat farming, and the selling price were positively and significantly associated with the decision to sell buckwheat and the quantity of buckwheat sold. The household head's school completion at the secondary or higher level was also positively related to the quantity of buckwheat sold. Offering a high selling price for buckwheat had the greatest coefficient among these factors. Thus, high selling prices could be the greatest driver of buckwheat farmers' market participation.

Then, how do farmers sell buckwheat at high prices? Our estimates indicate that the initial processing of buckwheat and selling of buckwheat to a processing farm could be one method. Buckwheat was generally sold raw in the survey area. The lack of processing technology results in limited value-adding opportunities to meet market demand. It is recommended to diffuse the initial processing technologies of buckwheat to farmers through extension services, which could encourage farmers to sell their buckwheat at high prices. The government could also assist buckwheat farmers in obtaining information regarding market channels and establishing online sales channels to reduce travel costs for farmers in remote areas. Food value chains have been developing rapidly in developing countries, and rural farmers are now being provided more opportunities to increase their income and profits [32,33]. Adding value to the harvested crop, responding to market demand, and identifying sales destinations with populations who would be willing to buy products with high prices are the recommended ways for rural farmers to participate in the buckwheat value chain, which could bring them high returns.

6.3. Importance of Education on Buckwheat Productivity and Market Participation

Our estimation results consistently show that the household head's educational attainment has a significant and positive association with buckwheat productivity and market participation. Primary education of the household head has a significant and positive relationship with buckwheat income. Secondary education of the household head had a positive and significant relationship with buckwheat yield, revenue, income, and quantity of buckwheat sold. Higher education of the household head, including high school, college, and university completion, is positively and significantly associated with the quantity of buckwheat sold.

However, only 35% of household heads had completed secondary school or higher in the survey area. The relationship between education and agricultural development has long been discussed, and it remains an important political issue in developing countries [34,35]. Although China is known globally for its education system, the gap in education between rural and urban areas is widening, and the poor in rural areas continue to be left behind [36,37]. Narrowing this educational gap and improving access to good education in rural and mountainous areas would increase the coarse grain land productivity in the long run in China.

7. Conclusions

We conducted a micro-empirical study to identify the factors associated with the land productivity of buckwheat, those associated with buckwheat farmers' decisions regarding market participation, and those associated with buckwheat prices, utilizing unique survey data collected from rural buckwheat farmers in China in 2016.

Our estimation results showed that fertilizer and rental machine costs were negatively associated with buckwheat income, indicating the sub-optimality of buckwheat farming

and the need for the development of superior cultivars and the standardization of buckwheat cultivation technologies. Farmers are likely to sell their buckwheat at high prices if they conduct the initial processing and sell it to processing firms. Providing technical training to buckwheat farmers regarding the initial processing as well as information on market channels could contribute toward efficacious policy interventions. The household head's educational attainment was positively associated with buckwheat productivity and market participation, indicating the importance of the effort to narrow the educational gap between urban and rural areas in China.

However, one of the limitations of this study is the lack of a causal analysis. A causal analysis could be a powerful tool for determining the most effective intervention to improve buckwheat farmers' yield, income, and profits. Therefore, further surveys and research conducting such causal analyses are required, which would enable us to discover technology that could increase land productivity as well as interventions through which farmers could raise income from buckwheat.

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Appendix A

To measure a household's wealth level, a wealth index is often constructed using principal component analysis (PCA) [38,39]. The PCA is a statistical procedure that converts a set of possibly correlated variables into a set of orthogonal components called principal components [40]. A component is a linear combination of possibly correlated variables, and the first component is constructed such that it has the greatest possible variance [41].

Following the literature, we generated an index measuring household wealth levels using livestock holding variables and the PCA method. We used this first component as the livestock holding index because it captures the greatest possible variance. The livestock owned in the survey area included adult and child sheep, pigs, donkeys, and cows. Appendix A Table A1 presents the mean number of livestock owned. Sheep were the livestock the most often owned in the survey area. Very few households had donkeys or cows.

This index, which measures household livestock holdings, was constructed using the following model [38]:

$$I_i = \sum_{k=1}^{8} F_k \left[\frac{(x_{ik} - X_k)}{S_k} \right] \quad (6)$$

where I_i is the index of livestock holdings of household i and is normally distributed with zero mean, F_k is the weight of variable k in the PCA model, x_{ik} is the value of variable k of household i, and X_k and S_k are the mean and standard deviation of variable k, respectively. We included eight livestock variables: the number of adult and child sheep, pigs, donkeys, and cows.

All the variables were loaded onto one factor that captured the greatest variance in the components. Appendix A Table A2 shows the factor loadings of the livestock holding

index. Factor loadings are the correlations between the explanatory variables and factors. Squared factor loadings indicate the percentage of variance in the explanatory variable explained by a factor. These were used as weights to compute the factors. The principal component explained 20% of the variance of the eight variables.

Table A1. Livestock holdings.

Livestock	Mean	S.D.
The number of adult sheep	8.06	21.41
The number of child sheep	4.30	12.23
The number of adult pigs	0.26	0.91
The number of child pigs	0.43	3.16
The number of adult donkeys	0.13	0.42
The number of child donkeys	0.01	0.13
The number of adult cows	0.02	0.25
The number of child cows	0.05	0.70

Table A2. Factor loadings for the livestock holding index.

	Factor Loadings
The number of adult sheep	0.65
The number of child sheep	0.71
The number of adult pigs	−0.01
The number of child pigs	0.25
The number of adult donkeys	−0.04
The number of child donkeys	0.04
The number of adult cows	0.11
The number of child cows	0.00
Proportion of variation explained	0.2006
Number of observations	303

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