Economic Analysis and Policy 80 (2023) 558–569

Contents lists available at ScienceDirect

Economic Analysis and Policy

journal homepage: www.elsevier.com/locate/eap

Analyses of topical policy issues

Impact of agricultural commercialization on dietary diversity and vulnerability to poverty: Insights from Chinese rural households☆

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ARTICLE INFO

Article history:
Received 29 June 2023
Received in revised form 8 August 2023
Accepted 6 September 2023
Available online 12 September 2023

JEL classification:
Q13
Q18
I32

Keywords:
Agricultural commercialization
Dietary diversity
Vulnerability to poverty
Rural households

ABSTRACT

In this study, we examine the role of agricultural commercialization in influencing rural households' dietary diversity and vulnerability to poverty. The instrumental variable (IV)-based approaches, including IV-Poisson and IV-Probit models, are employed to estimate the data collected through the China Land Economic Survey project. The results show that a higher level of agricultural commercialization is positively and significantly associated with higher dietary diversity and lower vulnerability to poverty. The poverty-reduction effect of agricultural commercialization is robust to the adjusted poverty line. Further analysis reveals that increasing the level of agricultural commercialization significantly increases the consumption levels of legumes, fruits, livestock meat, and poultry meat. The findings highlight the importance of linking farmers to markets for commercializing agricultural products, a practical way to improve rural household welfare and reduce the risk of falling into poverty.

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1. Introduction

Agricultural productivity and commercialization rate are crucial factors directly influencing farm income (Schulte et al., 2023; Tuni et al., 2022). The former determines the outputs of crops farmers can produce, while the latter affects the incomes they can obtain through marketing activities. Especially, commercializing agricultural products increases rural incomes directly (Luo et al., 2023). Therefore, farmers, non-government organizations, policymakers, and stakeholders have made great efforts to improve land productivity and accelerate agricultural commercialization (Aragiea et al., 2016).

Apart from its role in income generation, agricultural commercialization has been found to have multifaceted effects on different aspects of rural livelihoods. Extensive research has demonstrated that agricultural commercialization contributes to asset and livestock accumulation (Tabe Ojong et al., 2022), facilitates the adoption of sustainable agricultural practices (Benitez-Altuna et al., 2023), and increases household consumption (Cazzuffi et al., 2020). Agricultural commercialization catalyzes farmers to diversify their products, particularly when prioritizing market-driven and high-value commodities. This crop diversification creates opportunities for rural households to diversify their diets (Chegere and Stage, 2020), thereby enhancing food security and nutritional intake. Besides, by augmenting the capacity to generate income through

☆ Hongyun Zheng acknowledges the financial support from the National Natural Science Foundation of China (72303076), Fundamental Research Funds for the Central Universities (2023JGLW02; 2662022JGQD006), and National Social Sciences Foundation of China (18ZDA072).

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https://doi.org/10.1016/j.eap.2023.09.007
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agricultural commercialization, subsistence-oriented farming systems are transformed into commercial and market-oriented ones (Tabe Ojong et al., 2022). This transformation is expected to aid households in escaping poverty, ultimately leading to poverty eradication (Dey and Singh, 2023; Schulte et al., 2023).

This study's objective is to analyze the impact of agricultural commercialization on rural households' dietary diversity and vulnerability to poverty, using household data collected from China Land Economic Survey in Jiangsu province, China. Since previous studies have pointed out that rural households' decisions on commercializing their agricultural products tend to be self-determined (Cazzuffi et al., 2020; Rupa et al., 2019), this study employs instrumental variable (IV)-based strategies, namely the IV-Poisson and IV-Probit models, to address the endogeneity issue of agricultural commercialization.

The rest of this paper is as follows: In Section 2, we provide a literature review and identify research questions. The data collection and key variable measurements are presented in Section 3. Section 4 introduces the methodology employed for empirical analysis. Then, the results are presented and discussed in Section 5. Section 6 concludes the main findings and draws implications for policymakers.

2. Literature review

The literature has investigated the role of agricultural commercialization in affecting rural households' dietary diversity and underscores its significance (Carletto et al., 2017; Rupa et al., 2019; Zanello et al., 2019; Ochieng et al., 2020; Kihiu and Amuakwa-Mensah, 2021; Mulenga et al., 2021; Usman and Haile, 2022). Collectively, these studies concur that agricultural commercialization is pivotal in enhancing both food quality and the diversity of diets. For example, Ochieng et al. (2020) found that food crop commercialization significantly and positively influences rural households' dietary diversity in central Africa. In their study in Zambia, Mulenga et al. (2021) showed that agricultural market participation enhances household dietary diversity, and the effects increased from 2015 to 2019. Julius Chegere and Sebastian Kauky (2022) reported that agricultural commercialization significantly influences dietary diversity for the lower-income group in Tanzania.

The rise in income from agricultural commercialization also underscores agricultural commercialization's pivotal role in poverty alleviation. An interconnected body of research delves into the relationship between agricultural commercialization and poverty alleviation (Asfaw et al., 2012; Ogutu and Qaim, 2019; Birhanu et al., 2021; Etuk and Ayuk, 2021; Schulte et al., 2023; Dey and Singh, 2023). For example, Ogutu and Qaim (2019) suggested that agricultural commercialization reduces both income poverty and multidimensional poverty in Kenya. Dey and Singh (2023) found that participation in the vegetable market increases smallholders' income significantly. Schulte et al. (2023) reported that agricultural commercialization reduces multidimensional and structural poverty in rural Vietnam.

The two strands of literature discussed above offer valuable insights into the multifaceted role of agricultural commercialization in diversifying household diets and alleviating rural poverty. However, there exist two potential gaps that warrant further investigations. First, studies analyzing the effects of agricultural commercialization on dietary diversity have predominantly focused on African, Central Asian, and South Asian countries, like Malawi (Matita et al., 2021), Afghanistan (Zanello et al., 2019), and Vietnam (Rupa et al., 2019). Empirical evidence for China is currently absent. Exploring the association between agricultural commercialization and dietary diversity in the Chinese context would yield significant insights. Over the past nearly five decades, China's transition from a planned economy to a market-oriented one has facilitated farmers' commercialization of agricultural products (Huang and Shi, 2020). Concurrently, there have been notable changes in the food structure among Chinese rural households, characterized by an increase in high-fat and protein-rich foods (e.g., meat) and a decrease in fiber and carbohydrate-rich foods (e.g., cereal products) (Yu, 2018). In addition, limited knowledge exists regarding how agricultural commercialization influences the specific food consumption items that drive changes in dietary diversity.

Second, the literature points out that agricultural commercialization positively impacts poverty alleviation. However, prior studies have primarily relied on indicators such as income (Dey and Singh, 2023), poverty (Ogutu and Qaim, 2019), or multidimensional poverty (Schulte et al., 2023) when capturing poverty alleviation. While informative, these indicators alone do not provide insights into the future risk of falling into poverty. A non-impoverished household may become poor in the future. In other words, rural households are vulnerable to poverty. Therefore, it is more significant to investigate rural households' vulnerability to poverty rather than solely examining their current income or poverty status. Surprisingly, except for Birhanu et al. (2021), who analyzed how commercialization affects vulnerability to multidimensional poverty in Ethiopia, no previous studies have examined the influence of agricultural commercialization on vulnerability to poverty. Nevertheless, the analysis of Birhanu et al. (2021) only considered farmers' commercialization decisions regarding cereal crops and did not account for crop diversification. Furthermore, the vulnerability indicator they constructed did not incorporate income, a crucial determinant of rural poverty.

The existing research gaps motivate us to estimate the effect of agricultural commercialization on rural households' dietary diversity and vulnerability to poverty. The current research aims to make innovative contributions by addressing the following questions: (a) Does a high level of agricultural commercialization contribute to the diversification of dietary patterns among Chinese rural households? (b) How does agricultural commercialization affect the consumption levels of food items comprising dietary diversity? and (c) Does agricultural commercialization have the potential to reduce rural households' vulnerability to poverty? In other words, does the poverty-alleviation effect of agricultural commercialization persist when considering the risk of falling into poverty?

3. Data collection and key variable measurements

3.1. Data collection

Utilizing a multistage sampling approach, the 2021 CLES first selected two counties in 12 out of 13 municipalities in Jiangsu Province. Subsequently, two villages were chosen from each county. Face-to-face interviews were conducted with approximately 50 households in each selected village, yielding a comprehensive dataset that comprised 2420 rural households. It is important to note that some families did not engage in agricultural production activities. Consequently, the non-farming households were excluded during data cleaning. We further cleaned the data by eliminating observations with missing values and outliers that deviated significantly from expected values. Ultimately, the final dataset comprised 1529 households.

The CLES questionnaire encompassed various domains, covering agricultural production, food consumption behavior, household income and expenditure, finance and insurance, and local rural construction. In particular, the questionnaire meticulously captured detailed information on agricultural activities such as sown area, yields, sale volumes, and prices for each specific crop. Moreover, the questionnaire extensively captured household food consumption patterns, explicitly focusing on food items such as cereals, fruit, milk, and livestock meat. Respondents were required to report the frequency of consumption for each food item and the corresponding volumes. The questionnaire collected information on household income from diverse sources while accounting for the factors influencing income, including individual and household-level characteristics, household resource endowment, and the local infrastructure level.

3.2. Key variable measurements

3.2.1. Agricultural commercialization

In this study, agricultural commercialization refers to the ratio of the total value of crop output sold to the total value of all crops produced. The definition aligns with the existing literature (Abdul Mumin and Abdulai, 2022; Mulenga et al., 2021; Ochieng et al., 2020). Precisely, the agricultural commercialization index is calculated as follows:

$$AC_i = \frac{\sum_{c=1} P_{ci} S_{ci}}{\sum_{c=1} P_{ci} O_{ci}} \tag{1}$$

where AC_i refers to rural household i's agricultural commercialization level; P_{ci} is the sale price of crop c produced by household i; S_{ci} and O_{ci} represent the sold volume and total output of crop c produced by household i, respectively. Eq. (1) indicates that the agricultural commercialization index ranges from 0 to 1. The higher the index, the higher the commercialization level. The commercialization index in this study considers all produced crops, avoiding the potential bias raised when focusing on only one crop.

3.2.2. Dietary diversity

Dietary diversity is measured by the dietary diversity score. The CLES collected rural households' consumption of ten food items, including (1) Cereals, (2) Roots and tubers, (3) Legumes, (4) Vegetables, (5) Fruits, (6) Livestock meat, (7) Poultry meat, (8) Eggs, (9) Fish and aquatic products, and (10) Milk (see Table A.1 in the Appendix for a reference). Each item was counted once if it was consumed in the reference week. Then the counted score of each food item was aggregated as the dietary diversity score. Theoretically, the dietary diversity score takes the value from 0 to 10. The higher the dietary diversity score, the more varied household food consumption structure and a more diversified diet (Ma et al., 2022; Usman and Haile, 2022).

3.2.3. Vulnerability to poverty

Rural households' vulnerability to poverty can be measured in several ways, including vulnerability as the low expected utility (VEU) (Ligon and Schechter, 2003), vulnerability as uninsured exposure to risk (VER) (Zhang et al., 2022), and vulnerability as expected poverty (VEP) (Chaudhuri et al., 2002). The VEU relies on the subjective utility assumption, while the VER is usually used for regional vulnerability measurement (Wang and Fu, 2022). In comparison, the VEP approach, proposed by Chaudhuri et al. (2002), can foretell who will be poor and provide practical tools for policy design, and it is commonly used to capture households' vulnerability to poverty in the existing literature (Imai et al., 2015; Khosla et al., 2023; Phan et al., 2022). In addition, the VEP method can be estimated using both cross-sectional (Khosla et al., 2023; Wang and Fu, 2022) and panel data (Phan et al., 2022). Thus, we also employ the VEP method to measure rural households' vulnerability to poverty. It is estimated in three steps.

In the first step, the VEP method estimates a household income model, which can be expressed as:

$$lnY_i = \delta_i N_i + \pi_i \tag{2}$$

where lnY_i is the logarithmic form of per capita income of household i, N_i is a vector of variables that affects household income level and δ_i refers to a vector of corresponding parameters, π_i is an error term.

Following previous studies on measuring vulnerability to poverty (Biru et al., 2020; Imai et al., 2015; Khosla et al., 2023; Yang et al., 2023), we select various variables in N_i of Eq. (2). These include variables representing individual characteristics

(i.e., household head's age, sex, education, and health), household and farm-level characteristics (i.e., household size, the ratios of on-farm worker and off-farm worker, land, entrepreneur status), and regional characteristics (i.e., local industry, distance to bank, distance to bus stations, and city-level dummies). The definition and descriptive statistics of selected variables for the household income equation are presented in Table A.2 in Appendix. Eq. (2) can be estimated using the Ordinary Least Square (OLS) method, and meanwhile, the residuals are predicted at this stage.

In the second step, the residuals predicted from the first step are used to obtain an asymptotically efficient three-stage feasible generalized least squares (FGLS) estimate of the expected value ($\hat{E}[lnY_i|U_i]$) and variance ($\widehat{Var}[lnY_i|U_i]$) of household income (See detailed procedure in Chaudhuri et al. (2002).

In the third step, the vulnerability to poverty is calculated as follows:

$$\widehat{Vul}_i = \widehat{\Pr}(lnY_i \leq lnPoor) = \Phi\left(\frac{lnPoor - \hat{E}[lnY_i|U_i]}{\sqrt{\widehat{Var}[lnY_i|U_i]}}\right) \tag{3}$$

where $\widehat{Vul}_i$ refers to the ex-ante estimated vulnerability to poverty of household i. It indicates the probability ($\widehat{\Pr}$) that the logarithmic form of per capita income of household i (lnY_i) will fall below the logarithmic poverty line ($lnPoor$), where $Poor$ is the poverty line specified later. $\Phi(\cdot)$ is the cumulative function of normal distribution. In addition, we need to specify a threshold to distinguish whether rural households are vulnerable to poverty. Following the existing studies (Khosla et al., 2023; Yang et al., 2023; Zhang et al., 2022), the threshold is set as 0.5. In other words, when the estimated probability ($\widehat{\Pr}$) is larger than 0.5 for a household, the household would be considered vulnerable; otherwise, it is defined as non-vulnerable.

Eq. (3) highlights the significance of selecting an appropriate poverty line when estimating vulnerability to poverty. The selection of a poverty line directly affects the vulnerability assessment, with higher poverty lines indicating increased vulnerability to poverty. Previous studies have employed various poverty lines, such as the international absolute poverty line of USD 1.9 per capita per day (Zhang et al., 2022), the food poverty line as the expenditure required to deliver 2,100 calories/person/day (Phan et al., 2022), or the national level of 2,300 yuan/capita in 2010 in China (Yang et al., 2023). However, these poverty lines may not be suitable for the present study for two reasons. First, China has achieved its goal of eradicating absolute poverty by the end of 2020. Consequently, adopting an absolute poverty line does not align with the Chinese government's focus on addressing relative poverty. Second, The GDP per capita was 144,390 yuan (equivalent to 21,486 USD) in Jiangsu in 2022, positioning it as the third-highest among 31 provinces in mainland China (NBSC, 2023). Given these concerns, in this study, we consider 40% disposable income of rural residents at the municipal level as the poverty line. This approach enables us to capture the relative poverty status of rural residents in the context of Jiangsu province. Additionally, for comparative purposes, we also explore the poverty line set at 40% of the median disposable income of rural residents at the municipal level.

4. Methodology

4.1. Endogeneity issues

Our first objective is to analyze the influence of agricultural commercialization on dietary diversity. Dietary diversity, as discussed in Section 3.2.2, is measured as a count variable. Thus, we employ a Poisson model. Specifically, the Poisson regression gives the probability of observing a given value (the dietary diversity (DD_i) in this study):

$$\Pr(DD = DD_i|AC_i, Z_i) = \frac{\beta_i^{DD_i}\exp(-\beta_i)}{DD_i!}, DD_i = 0, 1, 2, \ldots, 10 \tag{4}$$

where DD_i is dietary diversity score of rural household i; AC_i refers to household i's agricultural commercialization level; Z_i is a vector of exogenous variables; β_i are unknown parameters to be estimated.

The second objective is to estimate the effect of agricultural commercialization on rural households' vulnerability to poverty. As discussed in Section 3.2.3, the vulnerability to poverty is measured as a dummy variable. Thus, a Probit model is employed to capture the influence of agricultural commercialization and control variables on rural households' vulnerability to poverty. The empirical specification is expressed as follows:

$$VEP_i^* = \gamma_1 AC_i + \gamma_{1+i} M_i + v_i \; with \; VEP_i = \begin{cases} 1 & if \; VEP_i^* > 0 \\ 0 & otherwise \end{cases} \tag{5}$$

where VEP_i^* represents the probability that household i falls into poverty in the future, and it is observed by VEP_i. Here, VEP_i takes the value of one if VEP_i^* is larger than zero, and zero otherwise; M_i refers to a vector of observed factors; γ_1 and γ_{1+i} are parameters to be estimated; and v_i refers to the error term.

If agricultural commercialization directly impacts dietary diversity and vulnerability to poverty, independent of any other channels, we could treat agricultural commercialization as exogenous variables and employ classical regression techniques to estimate Eqs. (4) and (5). However, it is crucial to acknowledge that rural households have the autonomy to make decisions regarding agricultural commercialization, which introduces a potential self-selection bias (Cazzuffi et al., 2020; Rupa et al., 2019). This self-selection bias renders agricultural commercialization variable endogenous, necessitating the adoption of instrumental variable-based methodologies to consistently estimate its effects on the outcome variables.

4.2. Instrumental variable-based methods

The instrumental variable-based method can be used to account for the endogeneity issue of agricultural commercialization. Given the count nature of dietary diversity and the binary nature of vulnerability to poverty, the IV-Poisson and IV-Probit models should be employed, respectively. Both the IV-Poisson and IV-Probit models involve a two-stage estimation process. In the first stage, rural households' decisions regarding agricultural commercialization, specifically the quantity of output to be sold in the market, are assumed to be influenced by observed factors X_i, and unobserved factors μ_i. Thus, the determinants of agricultural commercialization can be expressed as follows:

$$AC_i = \alpha_i X_i + \mu_i \tag{6}$$

where AC_i refers to rural household i's agricultural commercialization level; X_i is a vector of observed variables that affect households' decisions on agricultural commercialization; α_i are corresponding parameters to be estimated; μ_i refers to the error term with zero means.

In the second stage of the IV-Poisson model, the impact of agricultural commercialization on dietary diversity is estimated using Eq. (4); then, the IV-Poisson model employs the Generalized Method of Moments (GMM) estimator to estimate Eqs. (4) and (6) jointly. The effect of agricultural commercialization on vulnerability to poverty is estimated using Eq. (5) in the second stage of the IV-Probit model. Then, Eqs. (5) and (6) are jointly estimated using the maximum-likelihood estimator (MLE).

4.3. Instrumental variable selection

The estimation of IV-Poisson and IV-Probit models relies on a valid instrumental variable (IV). The IV should influence rural households' decisions on agricultural commercialization but not directly affect the dietary diversity and vulnerability to poverty theoretically. A valid IV should be included in X_i but not in Z_i and M_i. In this study, we employ a dichotomous variable reflecting whether the household head has received education or training in agricultural technology. On the one hand, technical training, specifically related to agricultural production and market decisions, is crucial in enabling rural households to participate in the market and engage in commercialization activities (Tuni et al., 2022). On the other hand, education or training in agricultural technology is less likely to directly affect diet structure and the risk of falling into poverty. Thus, the selected IV fits this study. In addition, the validity of the IV is also examined based on the falsification test (Di Falco et al., 2011; Ma et al., 2022). The testing results are presented in Table A.3 in Appendix. It shows that the association between selected IV and outcome variables (i.e., dietary diversity and vulnerability to poverty) is not statistically significant, while IV is significantly associated with the treatment variable (i.e., agricultural commercialization). The results support the validity of the selected IV.

5. Results and discussion

5.1. Descriptive results

Table 1 shows the definitions and descriptive statistics of the selected variables. On average, the sampled households consumed 7.6 types of food (out of 10) in the reference week. The mean of the estimated vulnerability to poverty is 0.137. This indicates that 13.7% of the sampled households are at risk of experiencing poverty, as defined by the chosen poverty line. Such vulnerability underscores the significance of exploring the connection between agricultural commercialization and the susceptibility to poverty. The average agricultural commercialization rate is 58.4%.

To better understand the components of dietary diversity, in Table A.1 in the Appendix, we demonstrate the summary statistics of the ten food items in detail. It shows that cereal food was consumed by almost all households (99.9%) during the survey reference week, with an average per capita intake of 5.913 kg. Cereals, rich in carbohydrates, are vital in providing energy for rural households. Roots and tubers were consumed by 62.5% of households, with a per capita intake of 0.672 kg. A majority of households consumed legumes (74.5%), vegetables (95.9%), and fruits (83.0%). Regarding meat consumption preferences, livestock meat was favored by 89.5% of rural households, surpassing poultry meat (54.1%). This echoes the findings of Ma et al. (2022) on China. The proportions of egg and fish and aquatic product consumers were 92.0% and 63.3%, respectively. The lowest proportion was observed for milk consumption, with only 51.7% of households including it in their diet.

As discussed earlier, agricultural commercialization is a synthesized index estimated based on the production and marketing information of all produced crops. To delve deeper into this index, we have selected seven major crops (wheat, maize, rice, soybean, peanut, vegetable, and rape) planted and commercialized by rural households and depicted their distributions of commercialization rates in Fig. 1. The figure shows that among cereal crop producers, wheat exhibits the highest commercialization rate (84.0%), followed by maize (64.6%). In contrast, despite being produced by 796 households (52%), rice has a comparatively lower commercialization rate, which is 57.6%. Soybean, peanut, vegetable, and rape display commercialization rates of 48.7%, 26.0%, 19.4%, and 17.6%, respectively. Fig. 1 thus confirms the substantial heterogeneity in commercialization rates across various crops, emphasizing the necessity of considering the commercialization behaviors for all crops produced by rural households.

Table 1
Variable definition and descriptive statistics.

Variables	Definition	Mean (S.D.)
Dependent variables		
Dietary diversity	The number of food items consumed by a household in the reference week (0–10)	7.664 (1.790)
Vulnerability to poverty	1 if the household is vulnerable to poverty, 0 otherwise	0.137 (0.344)
Agricultural commercialization	Ratio of the total value of crop output sold to the total value of all crops produced (0–1)	0.584 (0.439)
Independent variables		
Age	Age of household head (years)	62.898 (9.683)
Sex	1 if household head is male, 0 otherwise	0.931 (0.253)
Education	Educational experiences of household head (years)	7.390 (3.566)
Household size	Number of household members (persons)	3.094 (1.583)
Farm size	Total size of household's contracted land (mu)[a]	7.007 (28.562)
Child ratio	Ratio of the number of members aged 0–14 years to household size	0.085 (0.130)
Elder ratio	Ratio of the number of members aged 65 years and over to household size	0.306 (0.330)
Mobile phone	Number of mobile phones owned by household	3.056 (1.538)
Terrain	1 if the local village is in the hilly area, 0 is the plain area	0.154 (0.361)
Distance to township	Distance from village committee to township (km)	6.177 (6.455)
Distance to hospital	Distance from village committee to county hospital (km)	18.757 (15.050)
IV	1 if the household head has received education or training in agricultural technology, 0 otherwise	0.328 (0.470)
Observations		1529

Note: S.D. refers to the standard deviation.
[a] 1 mu = 1/15 hectare.

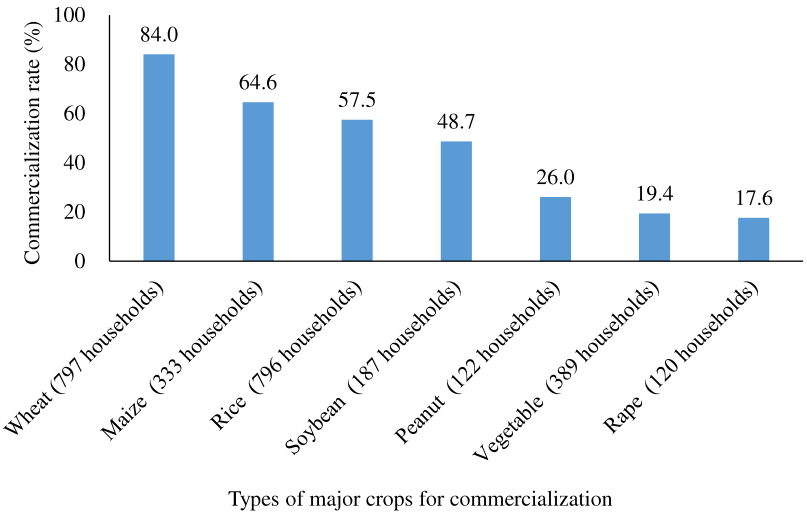

Fig. 1. Distributions of commercialization rates and number of planters of seven selected crops.

5.2. Empirical results

Table 2 presents the estimated results of the IV-Poisson and IV-Probit models. The first-stage estimations of both models yield similar results; thus, only one is reported in the second column of Table 2 for brevity. The results of the second stage of the IV-Poisson and IV-Probit models are presented in Columns 3 and 4, respectively.

5.2.1. Determinants of agricultural commercialization

The determinants of agricultural commercialization (column 2 of Table 2) are estimated using Eq. (6). We first looked at the relationship between IV and agricultural commercialization. It shows that the coefficient of IV is positive and statistically significant, suggesting that household heads' education or training experience in agricultural technology tends

Table 2
Impacts of agricultural commercialization on dietary diversity and vulnerability to poverty: IV-Poisson and IV-Probit model estimations.

Variables	First-stage	Second-stage	
		IV-Poisson	IV-Probit
	Agricultural commercialization	Dietary diversity	Vulnerability to poverty
Agricultural commercialization		0.378 (0.189)**	−1.772 (1.039)*
Age	−0.003 (0.001)**	0.000 (0.001)	0.005 (0.009)
Sex	0.063 (0.035)*	−0.063 (0.028)**	0.181 (0.176)
Education	−0.005 (0.003)	0.011 (0.002)***	−0.083 (0.023)***
Household size	0.011 (0.007)	0.016 (0.006)***	0.085 (0.041)**
Farm size	0.001 (0.000)***	−0.000 (0.000)	−0.002 (0.005)
Child ratio	0.025 (0.079)	0.049 (0.061)	0.074 (0.426)
Elder ratio	−0.011 (0.035)	0.005 (0.027)	1.250 (0.404)***
Mobile phone	−0.004 (0.007)	0.016 (0.005)***	−0.253 (0.079)***
Terrain	−0.016 (0.038)	0.068 (0.029)**	−0.115 (0.233)
Distance to township	0.003 (0.002)*	0.002 (0.001)	−0.009 (0.018)
Distance to hospital	0.004 (0.001)***	−0.001 (0.001)	0.012 (0.005)**
City-level dummy	Yes	Yes	Yes
Constant	0.255 (0.100)**	1.772 (0.104)***	−0.509 (0.802)
IV	0.071 (0.020)***		
Observations	1529	1529	1529

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. Standard errors are presented in parentheses.

to increase the agricultural commercialization. This finding aligns with the results of Tuni et al. (2022), who pointed out that the lack of technologies (e.g., post-harvest management and production technologies) is a primary barrier to commercializing agricultural products for smallholder farmers in Malawi. The age variable's coefficient is negative and statistically significant, suggesting that older farmers are less likely to engage in market transactions. This corresponds to a reduced agricultural commercialization level. In a study for Nigeria and Tanzania, Owusu and İşcan (2021) reported that the likelihood of market participation decreases as household heads' age increases.

The influence of the sex variable on agricultural commercialization is positive and statistically significant, meaning that male-headed households exhibit higher rates of agricultural commercialization than their female-headed counterparts. The findings may reflect women's lower access to resources and limited ability to accumulate resources (Croppenstedt et al., 2013). Previous studies also highlighted that female farmers tend to be marginalized from the agricultural market (Schulte et al., 2023; Sibande et al., 2017). The farm size variable exerts a positive and statistically significant impact on agricultural commercialization, suggesting that rural households with larger farm sizes have a higher probability of commercializing agricultural products. Nkegbe et al. (2022) reported a similar finding of the positive impact of farm size on market participation in Ghana. Two factors can explain the positive effects. Firstly, a larger farm size implies significant agricultural outputs that exceed self-sufficiency needs, necessitating sales rather than storage. Secondly, rural households relying on incomes generated from their land must participate in the markets to secure cash incomes that support their livelihoods.

5.2.2. Determinants of dietary diversity

The determinants of dietary diversity, estimated by the second stage of the IV-Poisson model, Eq. (4), are reported in Column 3 of Table 2. Notably, agricultural commercialization exerts a positive and statistically significant impact on dietary diversity. Specifically, rural households exhibit greater dietary diversity as the agricultural commercialization rate increases. The result of the positive relationship between agricultural commercialization and dietary diversity echoes the findings of existing studies on Tanzania (Julius Chegere and Sebastian Kauky, 2022), Ethiopia (Usman and Callo-Concha, 2021), and Vietnam (Rupa et al., 2019). The present study contributes to this body of literature by providing new empirical evidence from China. The results suggest that agricultural commercialization is valuable for enhancing household access to and affordability of a broader range of foods, ultimately improving dietary diversity among rural households.

The sex variable's negative and statistically significant coefficient indicates that male-headed households tend to have lower dietary diversity than their female-headed counterparts. This finding is similar to the findings found by Mulenga et al. (2021). Empowering females to assume the role of the household head can enhance their ability to manage intra-household tasks, such as cooking, which can contribute to a higher level of dietary diversity among female-headed households (Kassie et al., 2020). The education variable shows a positive and statistically significant effect on dietary diversity, a finding that echoes Ma et al. (2022). The finding suggests that the higher the education level of the household heads, the more diversified the diets. The coefficient of the household size variable is positive and statistically significant, implying that the larger the household size, the more food groups would be consumed. This finding aligns with the results reported by Usman and Haile (2022). The mobile phone variable's positive and statistically significant coefficient suggests that a higher ratio of mobile phone ownership is associated with increased dietary diversity. In a study in Kenya, Parlasca

et al. (2020) reported that mobile phone ownership and use are positively and significantly related to household dietary diversity. They argued that mobile phones improve rural households' accessibility to food markets and positively impact food diversity.

5.2.3. Determinants of vulnerability to poverty

We present the results on the determinants of vulnerability to poverty, estimated by the second stage of the IV-Probit model, in Column 4 of Table 2. The coefficient of agricultural commercialization is negative and statistically significant, indicating that households with higher commercialization rates are less vulnerable to poverty. To further examine the robustness of these results, we conducted a robustness check using an alternative poverty line, namely the 40% median disposable income of rural residents at the municipal level. The results of this sensitivity analysis are presented in Table A.4 in Appendix. Interestingly, the findings remain consistent with the results presented in Column 4 of Table 2, confirming the robustness of the finding reporting the negative association between agricultural commercialization and vulnerable to poverty.

Regarding control variables, we find that the education variable exerts a negative and statistically significant impact on vulnerability to poverty, suggesting that households with well-educated heads are less likely to be vulnerable to poverty. The finding aligns with Phan et al. (2022). Education equips household heads with the knowledge and skills necessary to access valuable information and make informed decisions, which reduces the likelihood of falling into poverty. The coefficient of the household size variable is positive and statistically significant, indicating that households with more members tend to fall into poverty in the future. Wang and Fu (2022) reported a similar finding in their investigation of the vulnerability to poverty among Chinese rural households. The positive and statistically significant coefficient of the elder ratio variable implies that more elders within the family are related to higher vulnerability to poverty. This finding echoes the results of Yang et al. (2023). Rural elderly individuals in China often lack access to pensions and medical insurance compared to their urban counterparts. As a result, households with more elderly members face reduced income-generating opportunities and an increased risk of illness, leading to a higher vulnerability to poverty.

The mobile phone variable's coefficient is negative and statistically significant, signifying that increased ownership of mobile phones within a household is associated with a reduced likelihood of falling into poverty. Mobile phones, as representative of modern information and communication technologies (ICTs), enable rural households to leverage the Internet and access valuable information, mitigating poverty vulnerability (Zhang et al., 2022). In contrast, Dzator et al. (2023) found that Internet and broadband penetration in sub-Saharan Africa increase poverty. The relationship between distance to a hospital and vulnerability to poverty is positive and statistically significant, meaning that a long distance to a hospital is associated with a higher vulnerability to poverty. The longer distance usually implies poor roads and medical infrastructure, making it hard for rural households to access affordable medical services.

5.2.4. Further analysis

While the findings in Column 3 of Table 2 demonstrate a positive relationship between agricultural commercialization and dietary diversity, there is still a need to explore the specific impact of agricultural commercialization on the quantities of food consumption groups. To address this gap, we examine the effects of agricultural commercialization on the quantities of food consumption items using the IV-Tobit model. This modeling approach is particularly suitable for investigating left-censored variables, as some food items may not be consumed by any households. The estimation results of the second stage of the IV-Tobit model are reported in Table 3.

Overall, the results show that the coefficients of agricultural commercialization are all positive for ten food consumption items. However, statistical significance is observed only for legumes, fruits, livestock meat, poultry meat, and fish and aquatic products. This suggests that agricultural commercialization primarily contributes to improved dietary diversity through increased consumption of legumes, fruits, livestock meat, poultry meat, and fish and aquatic products. These food items are known to provide higher levels of fat and protein rather than calories. This observation aligns with the tendency toward increased fat and protein consumption and decreased calorie consumption in rural China (Yu, 2018).

6. Conclusions and policy implications

Agricultural commercialization enables rural households to earn incomes from market transactions, facilitating access to more food types and eliminating vulnerability to poverty. Using the CLES survey data of 1529 households, this study analyzed the impact of agricultural commercialization on dietary diversity and vulnerability to poverty. We utilized the IV-Poisson and IV-Probit models to account for the endogeneity issue of agricultural commercialization. We also adjusted the poverty line to verify the robustness of the relationship between agricultural commercialization and vulnerability to poverty. Apart from the dietary diversity indicator, we further examined the influence of agricultural commercialization on ten food consumption items.

Three main conclusions can be drawn. First, the results from the first stage of IV-Poisson and IV-Probit models revealed that agricultural commercialization is negatively associated with the age of the household heads but positively related to the sex of household heads, farm size, and distances to township and hospital. Second, the results of the second

Table 3
Impact of agricultural commercialization on quantities of food consumption items: Second stage of IV-Tobit model estimations.

Variables	Food consumption items				
	Cereals	Roots and tubers	Legumes	Vegetables	Fruits
Agricultural commercialization	2.455 (3.140)	1.124 (1.479)	1.845 (1.052)*	1.677 (2.736)	5.966 (2.990)**
Control variables	Yes	Yes	Yes	Yes	Yes
City-level dummy	Yes	Yes	Yes	Yes	Yes
Constant	6.319 (1.446)***	−0.879 (0.683)	−0.968 (0.487)**	4.349 (1.260)***	2.143 (1.377)
Observations	1529	1529	1529	1529	1529
Variables	Food consumption items				
	Livestock meat	Poultry meat	Eggs	Fish and aquatic products	Milk
Agricultural commercialization	3.141 (1.172)***	2.192 (1.162)*	1.816 (1.545)	4.202 (1.469)***	2.703 (3.718)
Control variables	Yes	Yes	Yes	Yes	Yes
City-level dummy	Yes	Yes	Yes	Yes	Yes
Constant	0.739 (0.540)	0.259 (0.533)	−0.010 (0.711)	−0.100 (0.679)	−3.811 (1.709)**
Observations	1529	1529	1529	1529	1529

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. Standard errors are presented in parentheses. The results of the first-stage estimation are not presented for simplicity.

stage of the IV-Poisson model showed that an increase in the agricultural commercialization level significantly increases rural households' dietary diversity. Besides, we found that agricultural commercialization significantly increases the consumption of legumes, fruits, livestock meat, poultry meat, and fish and aquatic products, while its impact on cereals, roots and tubers, vegetables, eggs, and milk is insignificant. Third, the second stage of the IV-Probit model revealed that an increase in agricultural commercialization significantly reduces rural households' vulnerability to poverty. The robustness of this relationship is confirmed through analysis using adjusted poverty lines.

Our findings underscore the necessity of promoting agricultural commercialization to enhance diet quality and alleviate rural poverty. Policymakers should recognize different farmer groups' diverse needs and objectives rather than adopting a uniform approach. For example, we found that elders and females exhibit lower propensities to commercialize agricultural products. However, this does not imply their disinterest in participating in agricultural markets; instead, they often face marginalization compared to their younger and male counterparts. Considering this, the government can foster collective commercialization efforts by facilitating the establishment of farmer groups. In addition, households with a large farm size are more likely to have a higher commercialization rate. This observation highlights the vulnerability of smallholder farmers, who often possess limited bargaining power and face challenges in negotiating favorable terms. To address this, organizing smallholder farmers through agricultural cooperatives can bolster their collective market leverage and negotiation capabilities. Additionally, facilitating sales contracts between agricultural cooperatives and their members would further support their endeavors.

While the findings of this study provide crucial implications for diversifying rural households' diets and reducing vulnerability to poverty, two potential limitations exist. First, the CLES data was only collected from Jiangsu province in China. Although the findings of this study were quite interesting, they might not be generalized due to data limitations. Thus, more studies, focusing on other regions of China or even other developing countries, should be conducted to help improve our understanding. Second, the calculation of the dietary diversity score in this study was based on ten food items collected by the CLES, and the edible fungi and nuts and seeds were not included in the analysis. Thus, future research endeavors could develop an improved evaluation system that better captures the nuances of Chinese eating habits. This could involve expanding the range of food items or incorporating additional categories that reflect regional or cultural dietary preferences.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that support the findings of this study are available from Hongyun Zheng upon request.

Appendix

See Tables A.1–A.4

Table A.1
Definition and descriptive statistics of variables used to calculate dietary diversity.

Variables	Definition	% of consumer	Food intake per capita
Cereals	E.g., rice, wheat, and maize (kg/week)	99.9	5.913
Roots and tubers	E.g., potatoes, red kumara, purple kumara (kg/week)	62.5	0.672
Legumes	E.g., soybeans, tofu, bean sprouts, and other legumes (kg/week)	74.5	0.666
Vegetables	E.g., cauliflower, leaf vegetable, fruit vegetable, and other vegetables (kg/week)	95.9	4.237
Fruits	E.g., melons, oranges, and other fruits (kg/week)	83.0	1.881
Livestock meat	E.g., Beef, lamb, and pork (kg/week)	89.5	1.065
Poultry meat	E.g., chicken, duck, goose, and other poultry meat (kg/week)	54.1	0.521
Eggs	E.g., eggs and other egg foods (kg/week)	92.0	1.012
Fish and aquatic products	E.g., Fish, shrimp, and other aquatic products (kg/week)	63.3	0.600
Milk	E.g., milk (bottle/week)	51.7	1.754

Table A.2
Definition and descriptive statistics of variables used to estimate vulnerability to poverty.

Variables	Definition	Mean (S.D.)
Age	Age of household head (years)	62.898 (9.683)
Sex	1 if household head is male; 0 otherwise	0.931 (0.253)
Education	Educational experiences of household head (years)	7.390 (3.566)
Health	Health status of household head: 1 = disabled, 2 = bad, 3 = fair, 4 = good, 5 = great	4.010 (1.073)
Household size	Number of household members (persons)	3.094 (1.583)
Ratio of on-farm worker	Ratio of the number of members who worked on-farm last year to household size	2.881 (12.446)
Ratio of off-farm worker	Ratio of the number of members who worked off-farm last year to household size	0.389 (0.273)
Land	Size of contracted land per capita (mu/capita)[a]	0.486 (0.292)
Entrepreneur	1 if household has family entrepreneurship, 0 otherwise	0.111 (0.314)
Local industry	1 if the local village has rural industry, 0 otherwise	0.186 (0.390)
Distance to bank	Distance from village committee to the nearest bank outlets (km)	3.502 (3.299)
Distance to bus station	Distance from village committee to the nearest coach station (km)	18.512 (24.458)
Observations		1529

Note: S.D. refers to the standard deviation.
[a] 1 mu = 1/15 hectare.

Table A.3
Falsification test of instrumental variable.

Variables	Statistics
Dietary diversity	$\chi^2 = 1.92$; p-value = 0.166
Vulnerability to poverty	$\chi^2 = 1.41$; p-value = 0.235
Agricultural commercialization	$F\text{-}value = 13.32^{***}$; p-value = 0.001

Note: *** $p < 0.01$.

Table A.4
Impacts of agricultural commercialization on vulnerability to poverty: Second stage of IV-Probit model estimations.

Variables	Vulnerability to poverty (Adjusted poverty line)
Agricultural commercialization	−1.825 (1.023)*
Control variables	Yes
City-level dummy	Yes
Constant	−1.231 (1.062)
Observations	1,529

Note: *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$. Standard errors are presented in parentheses. The results of the first-stage estimation are not presented for simplicity.

References

Abdul Mumin, Y., Abdulai, A., 2022. Informing food security and nutrition strategies in Sub-Saharan African countries: An overview and empirical analysis. Appl. Econ. Perspect. Policy 44 (1), 364–393.

Aragiea, E.A., Baliéb, J., McDonaldc, S., 2016. Investment in agricultural productivity vs rural commercialization: Which way to rapid poverty reduction in Ethiopia? FAO.

Asfaw, S., Lipper, L., Dalton, T.J., Audi, P., 2012. Market participation, on-farm crop diversity and household welfare: Micro-evidence from Kenya. Environ. Dev. Econ. 17 (5), 579–601.

Benitez-Altuna, F., Materia, V.C., Bijman, J., Gaitán-Cremaschi, D., Trienekens, J., 2023. Farmer–buyer relationships and sustainable agricultural practices in the food supply chain: The case of vegetables in Chile. Agribusiness (March) 1–28.

Birhanu, F.Z., Tsehay, A.S., Bimerew, D.A., 2021. The effects of commercialization of cereal crops on multidimensional poverty and vulnerability to multidimensional poverty among farm households in Ethiopia. Dev. Stud. Res. 8 (1), 378–395.

Biru, W.D., Zeller, M., Loos, T.K., 2020. The impact of agricultural technologies on poverty and vulnerability of smallholders in Ethiopia A panel data analysis. Soc. Indicators Res. 147 (2), 517–544.

Carletto, C., Corral, P., Guelfi, A., 2017. Agricultural commercialization and nutrition revisited: Empirical evidence from three african countries. Food Policy 67, 106–118.

Cazzuffi, C., McKay, A., Perge, E., 2020. The impact of agricultural commercialisation on household welfare in rural Vietnam. Food Policy 94 (2019), 101811.

Chaudhuri, S., Jalan, J., Suryahadi, A., 2002. Assessing household vulnerability to poverty from cross-sectional data: A methodology and estimates from Indonesia. World 0102–52 (April), 36.

Chegere, M.J., Stage, J., 2020. Agricultural production diversity, dietary diversity and nutritional status: Panel data evidence from Tanzania. World Develop. 129 (2019), 104856.

Croppenstedt, A., Goldstein, M., Rosas, N., 2013. Gender and agriculture: Inefficiencies, segregation, and low productivity traps. In: World Bank Research Observer.

Dey, S., Singh, P.K., 2023. Role of market participation on smallholder vegetable farmers' wellbeing: Evidence from matching approach in Eastern India. Agribusiness (2021), 1–21.

Di Falco, S., Veronesi, M., Yesuf, M., 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. Am. J. Agric. Econ. 93 (3), 825–842.

Dzator, J., Acheampong, A.O., Appiah-Otoo, I., Dzator, M., 2023. Leveraging digital technology for development: Does ICT contribute to poverty reduction? Telecommun. Policy 47 (4), 102524.

Etuk, E.A., Ayuk, J.O., 2021. Agricultural commercialisation, poverty reduction and pro-poor growth: Evidence from commercial agricultural development project in Nigeria. Heliyon 7 (5), e06818.

Huang, J., Shi, P., 2020. Regional rural and structural transformations and farmer's income in the past four decades in China. China Agric. Econ. Rev. 13 (2), 278–301.

Imai, K.S., Gaiha, R., Thapa, G., 2015. Does non-farm sector employment reduce rural poverty and vulnerability? Evidence from Vietnam and India. J. Asian Econ. 36, 47–61.

Julius Chegere, M., Sebastian Kauky, M., 2022. Agriculture commercialisation, household dietary diversity and nutrition in Tanzania. Food Policy 113 (2021), 102341.

Kassie, M., Fisher, M., Muricho, G., Diiro, G., 2020. Women's empowerment boosts the gains in dietary diversity from agricultural technology adoption in rural Kenya. Food Policy 95 (July), 101957.

Khosla, S., Jena, P.R., Rahut, D.B., 2023. Can rural livelihood programs enhance capabilities and reduce vulnerability to poverty? Evidence from a tribal region of eastern India. Econ. Anal. Policy 77, 85–98.

Kihiu, E.N., Amuakwa-Mensah, F., 2021. Agricultural market access and dietary diversity in Kenya: Gender considerations towards improved household nutritional outcomes. Food Policy 100 (2019), 102004.

Ligon, E., Schechter, L., 2003. Measuring vulnerability. Econ. J. 113 (486), C95–C102.

Luo, Y., Huang, D., Han, Y., Wu, L., 2023. Storage losses, market development and household maize-selling decisions in China. China Agric. Econ. Rev. 15 (1), 78–94.

Ma, W., Vatsa, P., Zheng, H., Guo, Y., 2022. Does online food shopping boost dietary diversity? Application of an endogenous switching model with a count outcome variable. Agric. Food Econ. 10 (1), 30.

Matita, M., Chirwa, E.W., Johnston, D., Mazalale, J., Smith, R., Walls, H., 2021. Does household participation in food markets increase dietary diversity? Evidence from rural Malawi. Global Food Secur. 28 (2020), 100486.

Mulenga, B.P., Ngoma, H., Nkonde, C., 2021. Produce to eat or sell: Panel data structural equation modeling of market participation and food dietary diversity in Zambia. Food Policy 102 (2020), 102035.

NBSC, 2023. China Statistical Yearbook. China Statistics Press, Beijing (in Chinese).

Nkegbe, P.K., Araar, A., Abu, B.M., Alhassan, H., Ustarz, Y., Setsoafia, E.D., Abdul-Wahab, S., 2022. Nonfarm activity and market participation by farmers in Ghana. Agric. Food Econ. 10 (1), 1–23.

Ochieng, J., Knerr, B., Owuor, G., Ouma, E., 2020. Food crops commercialization and household livelihoods: Evidence from rural regions in Central Africa. Agribusiness 36 (2), 318–338.

Ogutu, S.O., Qaim, M., 2019. Commercialization of the small farm sector and multidimensional poverty. World Dev. 114, 281–293.

Owusu, O., İşcan, T.B., 2021. Drivers of farm commercialization in Nigeria and Tanzania. Agric. Econ. (United Kingdom) 52 (2), 265–299.
Parlasca, M.C., Mußhoff, O., Qaim, M., 2020. Can mobile phones improve nutrition among pastoral communities? Panel data evidence from Northern Kenya. Agric. Econ. (United Kingdom) 51 (3), 475–488.
Phan, C.T., Vo, T.T., Vo, D.T.H., 2022. Can microcredit reduce vulnerability to poverty? Evidence from rural Vietnam. Rev. Dev. Econ. (2021), 1–22.
Rupa, J.A., Umberger, W.J., Zeng, D., 2019. Does food market modernisation lead to improved dietary diversity and diet quality for urban Vietnamese households? Australian J. Agric. Resour. Econ. 63 (3), 499–520.
Schulte, O., Mumber, J., Nguyen, T.T., 2023. Agricultural commercialisation, asset growth and poverty in rural Vietnam. Australian J. Agric. Resour. Econ. (April), 1–29.
Sibande, L., Bailey, A., Davidova, S., 2017. The impact of farm input subsidies on maize marketing in Malawi. Food Policy 69, 190–206.
Tabe Ojong, M.P.J.R., Hauser, M., Mausch, K., 2022. Does agricultural commercialisation increase asset and livestock accumulation on smallholder farms in Ethiopia? J. Dev. Stud. 58 (3), 524–544.
Tuni, A., Rentizelas, A., Chipula, G., 2022. Barriers to commercialise produce for smallholder farmers in Malawi: An interpretive structural modelling approach. J. Rural Stud. 93 (May), 1–17.
Usman, M.A., Callo-Concha, D., 2021. Does market access improve dietary diversity and food security? Evidence from southwestern Ethiopian smallholder coffee producers. Agric. Food Econ. 9 (1).
Usman, M.A., Haile, M.G., 2022. Market access, household dietary diversity and food security: Evidence from Eastern Africa. Food Policy 113 (2021), 102374.
Wang, X., Fu, Y., 2022. Digital financial inclusion and vulnerability to poverty: Evidence from Chinese rural households. China Agric. Econ. Rev. 14 (1), 64–83.
Yang, B., Wang, X., Wu, T., Deng, W., 2023. Reducing farmers' poverty vulnerability in China: The role of digital financial inclusion. Rev. Dev. Econ. (2022), 1–36.
Yu, X., 2018. Engel curve, farmer welfare and food consumption in 40 years of rural China. China Agric. Econ. Rev. 10 (1), 65–77.
Zanello, G., Shankar, B., Poole, N., 2019. Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan. Food Policy 87 (June), 101731.
Zhang, G., Wu, X., Wang, K., 2022. Research on the impact and mechanism of internet use on the poverty vulnerability of farmers in China. Sustainability (Switzerland) 14 (9), 1–16.