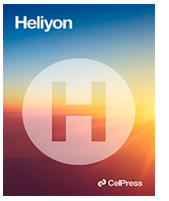
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Unravelling the influence and mechanism of agricultural inputs on rural poverty vulnerability: Evidence from China

Xu Li, Xiaobing Peng *, Yu Peng

School of Public Policy and Administration, Chongqing University, Chongqing, 400044, China

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ABSTRACT

Agricultural inputs have a significant catabatic effect on rural poverty at present. However, few studies have assessed whether agricultural inputs inhibit the intending probability of being vulnerable to rural poverty, referred to as poverty vulnerability. Poverty vulnerability studies, which focus on the likeli-hood of poverty among households in the future, have forward-looking and prognostic features in poverty research. Such research provides essential tools for describing mechanisms that can eradicate poverty. This study investigates the impact of agricultural inputs on rural poverty vulnerability and the mechanisms of action, using data from the 2015 China Household Finance Survey (CHFS). The empirical results show that agricultural inputs significantly suppress the probability of rural poverty vulnerability. The results hold after replacing the poverty criterion, poverty vulnerability criterion, and core explanatory variables. To overcome the endogeneity problem created by possible reverse cau-sality and omitted variables in the baseline model, this study uses the instrumental variables method to test endogeneity. The study also applies a treatment effects model and propensity score matching method to estimate and address any endogeneity problems due to explanatory variables. The findings also remain robust and significant after addressing the endogeneity problem. Further analyses indicate that the inhibitive effect of agricultural inputs on rural poverty vulnerability is mainly achieved through increased agricultural yields, improved physical health, and increased opportunities for entrepreneurial behavior. A heterogeneity analysis finds that the inhibitive effect of agricultural inputs on poverty vulnerability is more pronounced in Midwest China, in households with physically healthy household heads, and in families whose leaders have risk preferences. Our findings provide empirical evidence that can help inform forward-looking and prognostic policies for developing countries when formulating anti-poverty strategies.

1. Introduction

1.1. Research background

Reducing poverty is crucial for developing countries, including the world's largest developing country, China [1]. Since 2013, the Chinese government has implemented comprehensive and targeted poverty alleviation policies. In February 2021, China achieved a significant victory in eradicating poverty, eliminating poverty for 98.99 million rural poor people, 832 poor counties, and 128,000

* Corresponding author.
E-mail address: pxbmx@cqu.edu.cn (X. Peng).

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poor villages when comparing levels against current standards. This illustrates that the problem of overall regional poverty has been largely resolved. However, poverty-causing and poverty-returning factors remain prevalent in rural areas, and may counter poverty reduction efforts and exacerbate the marginalization of vulnerable rural households. Existing studies have underscored that health burdens [2], natural disasters [3,4], and fragile ecological environments [5] serve as pivotal contributors to poverty in rural areas. Vulnerable rural families may also return to poverty due to these risk shocks. Subsequent to China's comprehensive achievement in poverty alleviation, a report disseminated by the State Council Information Office of China indicates that, as of the end of September 2021, approximately 5 million individuals were under dynamic monitoring for potential re-entry into poverty, with a concerning 24 % still facing the risk of reverting back to impoverished conditions [6]. Hence, sustained attention and rigorous research into poverty are not only relevant but also essential. There is a compelling need to delve deeper into the factors leading to poverty and its recurrence.

To shift from eliminating absolute poverty to reducing relative poverty, China faces two significant challenges: consolidating poverty alleviation achievements in poor rural areas; and avoiding a return to poverty in poor areas. The conventional approach to measuring poverty is welfare, and the standard poverty measure is an ex-post indicator of welfare [7]. It reflects the poverty status of the poor at a specific point in time, but does not consider future risks [8]. When faced with a lack of stable income and uncertain future risks, rural households that escape poverty may have a higher probability of falling back into poverty. This leads to poverty vulnerability and hinders the sustainability of poverty reduction efforts. The critical point for alleviating future poverty in rural China is to establish coping mechanisms to reduce poverty vulnerability, to prevent rural households that have escaped poverty from returning to it [9,10]. This requires identifying rural households and their vulnerability to poverty. More specifically, this task requires identifying the current poverty situation of rural households and their risk and likelihood of falling into poverty in the future. By identifying the characteristics of families likely to fall into poverty and measuring the probability of this occurrence, we can identify target groups in advance for formulating and implementing poverty reduction policies and projects [11].

On a related topic, China is currently engaged in achieving a "Green Revolution", which requires a more significant application of modern agricultural technologies and inputs. Many countries that have adopted these technologies have achieved record harvests [12, 13]. China, is a predominantly agricultural country and is a significant player in agriculture. China's agriculture has been a consistent essential support for the country's economic development, and agricultural inputs are critical for agricultural production. Agricultural inputs, including fertilizers, seeds, and pesticides, significantly increase agricultural productivity, affecting poverty reduction, economic growth, and food security [14]. China's agriculture is clearly characterized by having high inputs and output [15]. Since the reform and opening, Chinese agriculture has rapidly developed based on continuously strengthening agricultural inputs [16]. The ultimate goal of applying agricultural products is maximizing productivity and economic returns [17]. The productivity-enhancing effect of agricultural inputs helps to increase rural household income; helps ensure improvements in the quality of life of households; and helps households avoid falling into poverty. This makes inputs an essential industrial influence for rural revitalization in China.

1.2. Research gap and research contributions

Both theory and practice have verified that agricultural inputs increase agricultural output. Research on whether agricultural inputs can curb rural poverty vulnerability has reference value for China, which is implementing a rural revitalization strategy, and for other developing countries engaged in poverty reduction efforts. China has alleviated absolute poverty, but there remain prominent regional problems of unbalanced and insufficient development [18,19]. Few studies have explored whether agricultural inputs suppress or inhibit current and future poverty by increasing agricultural output; nor has research determined whether agricultural inputs affect dynamic poverty. It is important to study whether agricultural inputs can stop the negative impact of rural poverty vulnerability. This clarity may help provide more targeted agricultural policies and anti-poverty strategies to support households at risk of future poverty.

The main contributions of this study are as follows. First, rural poverty vulnerability is influenced by rural households' agricultural inputs. Scholars have studied financial transactions [20], climate [21], informal social support [22], human capital [23], and disease [24]. However, few studies have explored the positive role played by agricultural inputs in curbing poverty vulnerability. Using cross-sectional data from the 2015 China Household Finance Survey, this study empirically analyzes the impact of agricultural inputs on poverty vulnerability in rural China. It provides a new perspective on the problem of rural poverty and poverty vulnerability; and broadens the scope of research in the area of agricultural inputs and poverty vulnerability. Second, compared with past studies on the relationship between agricultural inputs and poverty, this study focuses special attention on the probability of future poverty. This study concludes that agricultural yields, health levels, and entrepreneurial behavior mediate mechanisms by which agricultural inputs help mitigate rural poverty vulnerability. This provides a forward-looking and prognostic policy reference for developing countries to formulate anti-poverty strategies.

The rest of the study is organized as follows. Section 2 presents a literature review. Section 3 introduces the theoretical background and research hypotheses. Section 4 describes the data and methodology. Section 5 describes the empirical analysis. Section 6 presents the mechanism test and heterogeneity analysis. Section 7 concludes the study and discusses theoretical and practical implications.

2. Literature review

2.1. Poverty vulnerability

Conventional measurements and definitions related to poverty provide a static analysis of the level of welfare of a household or

individual at a point in time [25]. These conventional approaches do not predict future poverty status and are ex-post indicators. The World Bank defines poverty vulnerability as the probability of being poor or poorer in the future; vulnerability is the exposure of households or individuals to various risk shocks, and the likelihood that income will be lost or quality of life will fall below the poverty line as a result of the shock [26]. Different academics have interpreted the concept of poverty vulnerability differently. Gallardo (2020) described poverty vulnerability as the ability of a household or individual to resist or withstand uncertain external risks, and the household's perception of external risks [27]. Pritchett et al. (2000) define poverty vulnerability as the probability that a family will become poor in the next few years [28]. Chaudhuri et al. (2002) define a household's poverty vulnerability at time T as its probability of being poor at time T+1 [29].

In different specific studies, scholars have focused on the impact of public policy, economic and social behavior, and the natural environment on poverty vulnerability. For example, influencing factors in the area of public policy include land transfer [30], subsistence allowance (livelihood subsidies/income) [31], education expenditure [32], and poverty alleviation and relocation [33]. In contrast, the factors affecting economic and social behavior include financial transactions [20], human capital [23], wage level [34], and informal social support [35]. Influencing factors related to the natural environment include spatial patterns [36] and climate [21, 22].

There are three main theoretical approaches to measuring poverty vulnerability: Vulnerability as Uninsured Exposure to Risk (VER) [37], Vulnerability as Low Expected Utility (VEU) [38], and Vulnerability as Expected Poverty (VEP) [29]. Of these, the VER measure proposed by Dercon and Krishnan (2000) defines poverty vulnerability as the sensitivity of household consumption levels to changes in income [37]. The VEU measure proposed by Ligion and Schechter (2003) defines poverty vulnerability as the expected utility of household consumption levels less than the poverty line [38]. This approach emphasizes that vulnerability is the loss of welfare at the household level due to risk. The VEU measure uses a single utility function; it does not consider individual (household) diversity preferences, which is somewhat unrealistic [29]. The VEP measure estimates and predicts poverty vulnerability in the next period, using a single period of cross-sectional data with a limited number of periods. In contrast to other methods, VEP considers the heterogeneity associated with individuals (households) and poverty's dynamic and forward-looking nature. It is effective for research methods that use cross-sectional data; can address the problem of insufficient data in developing countries; and has more robust applicability [39,40].

2.2. Agricultural inputs

Agriculture is an input-intensive sector; those inputs are a driving force for increasing agricultural production and promoting economic transformation [41]. Agricultural improvements can be achieved by introducing improved land management technologies and agricultural inputs [42]. External inputs to agricultural production systems include mineral fertilizers, such as urea, ammonium nitrate, sulfates, and phosphates; organic fertilizers, such as animal manure, compost, and biosolids; other organic products, such as humic acids and microbial inoculants; and pesticides, including herbicides, pesticides, and fungicides. These agricultural products are applied to maximize agricultural productivity and economic returns [17]. Ozturk (2016) noted that, among different material inputs to agricultural production, fertilizer and agricultural machinery use contribute the most to production value [43]. McArthur and McCord (2017) estimated the role of agronomic inputs in increasing cereal yields and their impact on the process of structural change in each country, concluding that fertilizer, modern seeds, and water have a significant role in increasing yields [41]. Duan et al. (2015) argued that the total amount of freshwater consumed and polluted during crop production depends mainly on agricultural inputs, rather than regional climate and its variability [44]. Amber et al. (2014) analyzed gender differences in the use, access, and adoption of non-land agricultural inputs in developing countries. They found that men generally use more inputs than women [45]. Finally, Pingali (2015) noted that agricultural inputs remain centered on staple grains and do not promote sufficient diversified production to meet demand [46].

Studies have shown that modern agricultural inputs (including fertilizers and improved seeds) can lead to profitability, but not for all households [47]. In response to the low profitability associated with using agricultural inputs, some governments use large-scale subsidies to reduce the market price of those inputs [48]. To respond to a significant shortage in public agricultural extension services given so many small and dispersed agriculture households, grassroots dealers provide agricultural technical services when selling agricultural products to farmers [49]. With the gradual concurrent popularization of agricultural insurance, some studies have found that the amount of fertilizer inputs significantly increases the demand for agricultural insurance [50]. In addition, those who purchase agricultural insurance are generally more active in using agricultural technology and increasing agricultural inputs [51].

2.3. The relationship between agricultural inputs and poverty vulnerability

Poverty is a needed focus in discussions on social and economic policies, welfare systems, and prospects for sustainable growth [52, 53]. Agricultural sector development is a top factor and contributor that may alleviate poverty [54]. Most of the poor live in rural areas, where people depend heavily on crops for their productive livelihoods [55]. Using inorganic fertilizers is an essential solution to the productivity challenge [56], and can be combined with improved seeds to increase crop yields and eradicate poverty [57]. In addition, agrochemicals can compensate for workforce shortages and challenges related to soil erosion in the agricultural sector, while providing food security [58]. Shankar and Poole (2019) argue that investments and policies focused on the "Green Revolution" input package have increased productivity, reduced poverty, promoted food security, and reduced hunger with respect to South Asia's staple foods [59]. Murgai (2001) argues that increasing agricultural productivity is an effective policy tool for eradicating poverty [42]. Agricultural inputs can significantly increase agricultural yields and incomes, reducing poverty among rural households [41]. Song

et al. (2022) argue that agricultural labor, technology, and land factor endowments significantly impact rural poverty [60]. Parikh et al. (2013) found that improved agricultural input efficiency increases agricultural productivity; this, in turn, affects poverty reduction and food security in India [61]. Agricultural input subsidies are a form of social protection, and are an essential way to increase agricultural productivity and achieve pro-poor economic growth in low- and middle-income countries [62,63].

Extant literature has seen numerous scholars utilizing rural China as a case study to explore the mitigative effects of agricultural investments on rural poverty vulnerability. Through these case studies on rural China, scholars have discerned that significant reductions in rural poverty and concomitant promotion of sustainability both at the rural and national levels can be achieved via initiatives such as augmenting rural road infrastructure investments [64], advancing the adoption of novel rural family energy solutions [65], leveraging rural clan networks [66], integrating digital finance [1], and enhancing major illness insurance and its coverage [67]. Such insights proffer invaluable lessons for countries globally, particularly for developing nations, in their poverty alleviation endeavors and strategies to curb poverty. Specifically addressing the issue of alleviating rural poverty vulnerability through agricultural investments, rural China presents replicable paradigms. Research by Song et al. (2022) underscores that agricultural factor investments can effectively ameliorate relative poverty in China's rural areas, primarily through augmenting cash and savings [60]. Shenggen et al. (2005) found that escalating investments in rural infrastructure in China notably suppresses the onset of rural poverty, a finding that remains salient even in densely populated rural India [68]. Contrarily, Chen et al. (2023) offer a counter-narrative on the effects of agricultural investments on poverty reduction. They contend that in Chinese households experiencing farmland transitions, those relinquishing their farmlands tend to allocate more labor to agricultural production, subsequently increasing agricultural investments. However, these investments do not necessarily diminish their vulnerability to poverty [69]. This study offers a fresh perspective on the long-term implications of farmland transitions and agricultural investments on rural poverty.

Studies on agricultural inputs and poverty have systematically explained the relationship between agricultural inputs and poverty in terms of theoretical and empirical studies. However, in general, studies have focused on ex-post assessments, including the impact of agricultural inputs on current poverty status. Few studies have focused on the impact of agricultural inputs on the risk of possible future poverty. In addition, studies have focused on the impact of conventional agricultural input methods on household income and poverty suppression. Few studies have focused on the impact of vehicles on poverty, which are becoming popular in rural areas. Existing studies centered on rural China, which explore factors curbing the onset of rural poverty and the impact of agricultural investments in alleviating rural poverty vulnerability, offer significant insights for vulnerability research in other countries and regions. Nevertheless, direct investigations into the relationship between agricultural investments and poverty vulnerability are notably limited. Given this, this study uses the 2015 China Rural Household Finance Survey (CHFS) data to measure the probability of future poverty using the VEP measure of poverty vulnerability. The study also assesses the impact of agricultural inputs on vulnerability to rural poverty in terms of both conventional agricultural input methods and whether a household owns vehicles. This study also includes endogeneity tests, robustness tests, and heterogeneity analysis to examine the effectiveness of the impact on poverty reduction.

3. Theoretical background and research hypothesis

3.1. Theoretical background

Our understanding of the concept of poverty has evolved as society has developed. Poverty theory developed from the concept of absolute poverty, initially proposed by Booth; to the concept of relative poverty, from the perspective of resource allocation, proposed by Townsend (1979) [70]; and relative poverty, from the standpoint of rights deprivation, proposed by Sen (1981) [71]. The concept of poverty has also evolved from a single perspective to a single view, and has undergone changes from single-income poverty to multidimensional poverty. As poverty theory has developed, scholars have gradually shifted their attention from observing to predicting poverty and exploring poverty vulnerability [72]. Poverty vulnerability measures the likelihood of rural households falling into poverty based on the uncertainty of future household income and risk [73,74]. Academia has not reached a unified metric of poverty vulnerability. The most widely accepted approach to measuring poverty vulnerability is VEP (Vulnerability to Expectation), which is a forward-looking projection of a household's future welfare status. Household agricultural inputs, a major rural production factor, may inhibit the likelihood of rural poverty vulnerability. Agricultural inputs may reduce the probability of poverty vulnerability by increasing agricultural production, growing entrepreneurial opportunities, and improving physical health.

3.2. Research hypothesis

Research has shown that increasing agricultural productivity is an important policy tool for curbing poverty; however, few studies have examined the impact of agricultural inputs on poverty vulnerability. Developing countries have fought poverty to improve people's livelihoods and living standards. There are two significant challenges to poverty reduction: identifying the poor, and preventing those who have escaped poverty from falling back into it. As a significant factor of production in rural areas, agricultural inputs are essential to raising rural income and improving a household's quality of life, making them a crucial vehicle for curbing the occurrence of poverty vulnerability. This background leads to the following hypothesis.

H1. *Household agricultural inputs can significantly curb the occurrence of rural poverty vulnerability.*

Agricultural products, such as pesticides and fertilizers, are an integral part of modern agriculture to improve crop yields [75]. Due to the relative scarcity of land, the agricultural sector has replaced land reclamation with agricultural products, such as pesticides and fertilizers, to increase productivity [76]. The combination of pesticides and mineral fertilizers has enabled modern intensive

agriculture, mitigating the trend of agricultural area expansion [77]. As many rural households' primary mode of production, agricultural production is the foundation and immediate activity associated with rural areas. Increasing such production is a fundamental need for rural homes and the agricultural sector. It plays an essential institutional role in suppressing the occurrence of rural poverty vulnerability by agricultural inputs. Given this background, this study proposes the following hypothesis.

H2. *Household agricultural inputs curb the incidence of rural poverty vulnerability by increasing agricultural production.*

Health is determined by many social, economic, and environmental factors [78]. Poor health constitutes a cause of poverty itself. Sen explains poverty in terms of "Viable Capabilities", arguing that good health is a condition for individuals to develop other likely and viable capabilities [79]. Improved health also alleviates health-related poverty, and facilitates the satisfaction of other needs [80]. Phoumin et al. (2019) analyzed data from the 2015 Cambodia Socio-Economic Survey (CSES) and found a negative relationship between multidimensional energy poverty and household health in Cambodia [81]. The purchase of a vehicle by rural households can reduce the spatial distance between rural and urban areas, and increase the possibility of accessing urban healthcare resources, based on the function of transporting agricultural products. This can effectively curb the occurrence of rural poverty vulnerability. Given this background, the study proposes the following hypothesis.

H3. *Household agricultural inputs curb rural poverty vulnerability by improving physical health.*

Agriculture is a way of life and a form of business that transforms rural living conditions. From a practical perspective, entrepreneurship is widely recognized as a potential way to help individuals escape poverty [82] and is a mechanism to reduce and eventually eradicate poverty in developing and developed economies. In China's new normal, farmer entrepreneurship is a new strategy to promote rural urbanization, revitalize the rural economy, and address poverty [83]. Poor households can start formal or informal enterprises, creating self-employment opportunities, and opportunities for others. Rural households' agricultural inputs significantly increase the scale of agricultural production and gradually increase the likelihood that households undertake entrepreneurial behavior related to agricultural production, which is a transition to progressive entrepreneurship. Through entrepreneurial behavior, rural households can further increase their household income and resilience to uncertainty risks, and reduce the likelihood of rural poverty vulnerability. This background leads to the following hypothesis.

H4. *Household agricultural inputs inhibit the incidence of rural poverty vulnerability by increasing opportunities for entrepreneurial behavior.*

4. Data and methodology

4.1. Data description

The sample for this study comes from the China Household Finance Survey (CHFS) database (https://chfs.swufe.edu.cn/), organized and managed by the China Household Finance Survey and Research Center of Southwest University of Finance and Economics in 2015. The survey adopts a three-stage stratified sampling method proportional to population size, covering 29 provinces, 355 counties (districts and county-level cities), and 1428 village (residence) committees. Study data include micro information on essential characteristics, social security, assets and liabilities, income and expenditure, and agricultural production of the sample households. A data review indicated it has good representativeness and high data quality. For this study, data covering agricultural inputs are selected from the historical CHFS data for analysis, specifically cross-sectional data for 2015. Based on study needs, the study combines datasets at household, individual, and regional levels. Rural household data with complete information yielded 7840 rural household samples after removing invalid information samples, and samples with missing relevant variables.

4.2. Model specification

This study examines the impact of agricultural inputs on rural poverty vulnerability using the Logit model to answer the following three questions. First, do agricultural inputs inhibit the occurrence of rural poverty? Second, what is the mechanism of action of agricultural inputs on rural poverty vulnerability? Third, is the impact of agricultural inputs on rural poverty vulnerability heterogeneous? The baseline model (Model (1)) is set as follows.

$$VEP_i = \alpha + \beta_1 AMi + \beta_2 X_i + \varepsilon_i \tag{1}$$

In Model (1), VEP_i denotes the poverty vulnerability of household i; AM_i denotes the agricultural input of family i; X_i denotes the control variables; α denotes the constant term of the regression equation; β_1 denotes the degree of impact of agricultural input on rural poverty vulnerability; and ε_i is the random error term.

4.3. Variables selection

4.3.1. Dependent variables

This study uses the VEP measure based on the definition of expected poverty proposed by Chaudhuri et al. (2002) [29]. This measure defines a rural household as being vulnerable to poverty if the probability of poverty in the future exceeds the predetermined vulnerability. The basic equation is expressed as follows:

$$VEP_{it} = Pr\left(Y_{i,t+1} \leqslant Z\right) \tag{2}$$

In Model (2), VEP_{it} represents the poverty vulnerability of family i in period t; $Pr(\ .)$ is the probability that the per capita consumption of family i in period $t+1$ is less than or equal to the poverty line; $Y_{i,t+1}$ represents the welfare status (household per capita consumption, which is calculated as the total household expenditure divided by the number of household members) of sample i in period $t+1$; and Z represents the poverty line. A sample household is defined as poor and vulnerable if its future per capita consumption expenditure is below the poverty line.

First, this study uses the logarithm of per capita household consumption as the explanatory variables. The characteristics of household heads and the household itself that affect per capita household consumption are used as explanatory variables for the ordinary least squares (OLS) estimation (Model 3). The squared residuals obtained from the regression are used as consumption fluctuations to re-estimate the OLS (Model 4).

$$Ln\ Y_i = X_i\beta + e_i \tag{3}$$

$$Ln\ \widehat{e}_i = X_i\rho + \varepsilon_i \tag{4}$$

Second, the obtained fitted values are used to construct weights for the feasible generalized least squares (FGLS) estimation to obtain valid, consistent estimates for ρ and β , denoted as $\widehat{\rho}_{FGLS}$ and $\widehat{\beta}_{FGLS}$, respectively. The expected value and variance of the logarithm of the per capita household consumption are calculated using Models (5) and (6).

$$\widehat{E}(Ln\ Y_i|X_i) = X_i\widehat{\beta}_{FGLS} \tag{5}$$

$$\widehat{V}(Ln\ Y_i|X_i) = \widehat{\sigma}^2_{e,i} = X_i\widehat{\rho}_{FGLS} \tag{6}$$

Finally, based on Christiaensen and Subbarao (2005), assuming that the logarithm of household consumption per capita follows a normal distribution, the poverty vulnerability of the sample household i is calculated by selecting the poverty and vulnerability lines [40].

$$\widehat{Vul}_{\ h}\ Pr(Ln\ Y_i \leqslant LnZ|X_i) = \varphi\left(\frac{\mathrm{LnZ\text{-}X_i\widehat{\beta}_{FGLS}}}{\sqrt{\mathrm{X_i\widehat{\rho}_{FGLS}}}}\right) \tag{7}$$

In 2011, the World Bank defined the extreme poverty line as being $1.9 per day based on purchasing power parity. The poverty line determined by median per capita consumption in other developing countries was defined as $3.1 per day. This study establishes $3.1 as the poverty line criterion, and $1.9 as the poverty line criterion for robustness testing, to eliminate measurement error due to income data. The selection of the vulnerability line criterion is key to defining whether poverty is vulnerable; this study draws on both Günther and Su. This study establishes a 50 % vulnerability line criterion for analysis. The 29 % vulnerability line is used for the robustness test, identifying chronically poor households, while also identifying poor households due to consumption fluctuations.

4.3.2. Core explanatory variables

This study uses two indicators to measure household conventional agricultural product inputs and whether the household owns a car. The questionnaire enables the construction of a household conventional agricultural product input indicator based on the

Table 1
Variables descriptive statistics.

Variables Type	Variables	Obs	Mean	Std.Dev.	Min	Max
Dependent variables	1.9 dollars 50 % vulnerability line	7752	0.238	0.426	0	1
	3.1 dollars 50 % vulnerability line	7752	0.650	0.477	0	1
	1.9 dollars 29 % vulnerable line	7752	0.378	0.485	0	1
	3.1 dollars 29 % vulnerable line	7752	0.837	0.369	0	1
Core explanatory variables	Conventional agricultural products (¥)	7840	0.560	4.549	0	310
	Vehicles (Yes/No)	7837	0.128	0.334	0	1
Household Head characteristic variables	Age	7840	55.026	11.875	17	80
	Gender	7840	0.877	0.328	0	1
	Marriage	7840	0.896	0.305	0	1
	Education level	7836	2.504	0.978	1	7
	Physical Condition	7806	3.152	0.990	1	5
	New Agricultural Cooperative Medical Insurance (Yes/No)	7795	0.889	0.314	0	1
	Type of pension insurance	7706	3.985	1.790	1	7
Family characteristic variables	Member Size	7840	4.352	0.953	2	13
	Family Accident Protection	7840	0.945	0.265	0	3
	Family Retirement Protection	7840	0.731	0.460	0	2
	Family Relationship Network	7832	2.714	1.114	1	4
	Members' medical insurance accounts (Yes/No)	7098	0.513	0.500	0	1
	Member chronic diseases (Yes/No)	7787	0.466	0.499	0	1
	Overall Financial Literacy	7840	0.543	0.756	0	3
	Home Based Business (Yes/No)	7840	0.107	0.309	0	1
	Household debt (¥)	7840	2.343	9.544	0	500

household's previous year's spending on purchasing seeds, seedlings, seedlings, seedlings, pesticides, growth agents, fish medicine, herbicides, fertilizers, baits, agricultural films, small agriculture machinery, and other agricultural products. This indicator includes spending on leasing agriculture machinery and agriculture transport vehicles. In addition to travel, a large part of the function of a rural household's vehicles purchase is to transport agricultural products. Therefore, this study's questionnaire asked, "Does your family have vehicles? This question includes common cars, buses, and trucks". The response is another indicator of household agricultural inputs. Existing research has convincingly demonstrated that agricultural inputs, such as pesticides and fertilizers [75], as well as seeds of modern varieties [41] are pivotal factors for product growth. Furthermore, with the gradual improvement of transportation infrastructure, the role of automobiles in facilitating the consistent and rapid movement of goods and in enhancing labor productivity has been empirically substantiated [84]. Consequently, employing conventional agricultural products and vehicles as compositional indicators for household agricultural inputs provides a robust foundation for exploring their impact on VEP.

4.3.3. Control variables

Based on previous studies, this study selects control variables from the categories of household head characteristics and household characteristics. The 16 variables include age, gender, marriage, education level, physical condition, new agricultural cooperative medical insurance, type of pension insurance, member size, family accident protection, family retirement protection, family relationship network, members' medical insurance accounts, member chronic diseases, overall financial literacy, home based business, and household debt. Table 1 lists the descriptive results of all variables.

Table 1 summarizes the statistics of the variables. On average, the VEP with $3.1 per day and 50 % vulnerability line criterion in 2015 was 0.650, the household conventional agricultural product input was 5600 yuan, and the ratio of purchasing vehicles accounted for 12.8 %. These figures suggest that most Chinese rural households were more likely to be falling into poverty in the future, and had a low level of investment in agricultural products. Moreover, the remainder of Table 1 presents the descriptive statistics of the control variables.

When analyzing the spatial distribution of household poverty vulnerability in the sample, households in the eastern coastal region have a lower probability of falling into poverty in the future. In comparison, the western region and relatively economically underdeveloped provinces have a higher probability of falling into poverty in the future. Fig. 1 shows the specific spatial distribution of poverty vulnerability in four distinct categories: 1.9 dollars 50 % vulnerability line (Fig. 1a); 3.1 dollars 50 % vulnerability line (Fig. 1b); 1.9 dollars 29 % vulnerable line (Fig. 1c); and 3.1 dollars 29 % vulnerable line (Fig. 1d), highlighting where the more significant proportions of households with poverty vulnerability are seen.

5. Empirical analysis

5.1. Baseline regression results

This section applies a logit model to examine the impact of agricultural inputs on rural poverty vulnerability. Using the $3.1 poverty line, Table 2 reports the results of the baseline regression of agricultural inputs on rural poverty vulnerability. After gradually increasing the core explanatory variables, household head characteristics variables, household characteristic variables, and province fixed effects, the results indicate household conventional agriculture product inputs and vehicles purchases are significantly and negatively associated with rural poverty vulnerability. Agricultural inputs inhibit the occurrence of rural poverty vulnerability. In Table 2, column (5), the probability of poverty vulnerability is expected to be reduced by 1.7 % for each 1-unit increase in conventional agriculture product inputs of rural households; vehicles ownership by an agriculture household is expected to minimize the probability of poverty vulnerability by 10 %. These results indicate that agricultural inputs can reduce the likelihood of rural households falling into poverty vulnerability. The above results verify Hypothesis 1.

In addition, the gender of the household head, marital status and education level, household accidental and old-age security, relationship network, overall financial literacy, household entrepreneurship, and household indebtedness has significant adverse effects on rural household poverty vulnerability. However, the age of household head, new agricultural cooperative medical insurance participation, and household size have a significant positive impact on rural household poverty vulnerability. With respect to NHI participation, while this variable is associated with risk transfer and reducing household medical expenditure, it increases the

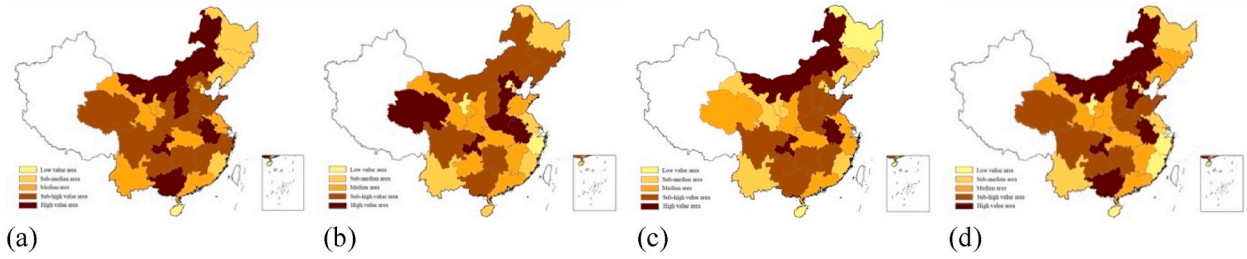


Fig. 1. Spatial distribution patterns of rural poverty vulnerability. (a) 1.9 dollars 50 % vulnerability line; (b) 3.1 dollars 50 % vulnerability line; (c) 1.9 dollars 29 % vulnerable line; (d) 3.1 dollars 29 % vulnerable line.

Table 2
Baseline regression results.

Variables	Poverty Vulnerability (For Each Study Model)				
	(1)	(2)	(3)	(4)	(5)
Conventional agricultural products	−0.050***	−0.040***	−0.018***	−0.016***	−0.017***
	(0.006)	(0.006)	(0.004)	(0.002)	(0.002)
Vehicles		−0.371***	−0.223***	−0.103***	−0.100***
		(0.013)	(0.012)	(0.010)	(0.010)
Age			0.017***	0.014***	0.014***
			(0.000)	(0.000)	(0.000)
Gender			−0.058***	−0.055***	−0.057***
			(0.016)	(0.012)	(0.012)
Marriage			−0.386***	−0.361***	−0.356***
			(0.028)	(0.022)	(0.021)
Education level			−0.087***	−0.082***	−0.080***
			(0.004)	(0.004)	(0.004)
Physical Condition			−0.019***	−0.004	−0.004
			(0.004)	(0.004)	(0.004)
New Agricultural Cooperative Medical Insurance			0.046***	0.193***	0.186***
			(0.013)	(0.016)	(0.016)
Type of pension insurance			0.005**	−0.014*	−0.011
			(0.002)	(0.007)	(0.007)
Size of family members				0.228***	0.227***
				(0.008)	(0.008)
Family Accident Protection				−0.200***	−0.206***
				(0.045)	(0.043)
Family Retirement Protection				−0.064**	−0.058**
				(0.029)	(0.028)
Relationship Network				−0.092***	−0.091***
				(0.002)	(0.002)
Family members' medical insurance accounts				−0.000	0.005
				(0.006)	(0.006)
Chronic illness of family members				0.012	0.009
				(0.007)	(0.007)
Overall family financial literacy				−0.011***	−0.013***
				(0.004)	(0.004)
Home Based Business				−0.405***	−0.393***
				(0.014)	(0.014)
Household debt				−0.003***	−0.003***
				(0.001)	(0.001)
Householder control variables	No	No	Yes	Yes	Yes
Home control variables	No	No	No	Yes	Yes
Provincial control effects	No	No	No	No	Yes
Observations	7752	7749	7659	6967	6967
Pseudo R2	0.010	0.074	0.376	0.667	0.684

Notes: Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

possibility of rural households falling into poverty vulnerability. This is due to the weaker risk compensation function and lower household precautionary saving characteristics.

5.2. Coping with endogeneity due to reverse causality and omitted variables: instrumental variables approach

This study's two core explanatory variables, household conventional agriculture product inputs and the purchase of vehicles, may have endogeneity problems caused by reverse causality and omitted variables. To assess the endogeneity problem, the instrumental variables for household conventional agricultural product inputs include: the presence of electricity supply measures near arable land and the proximity of arable land to a mechanized road. The instrumental variables for the household purchase of vehicles include: proximity of arable land to a mechanized road and the presence of drainage facilities on arable land. Electricity supply measures near the cultivated land, the cultivated land adjacent to the mechanized road, and the drainage facilities of the cultivated land are inherent local infrastructures and do not directly affect the probability of poverty vulnerability of agriculture households. These variables show significant homogeneity and are significantly correlated with household conventional agriculture product inputs and vehicles purchases for agricultural production and are suitable as instrumental variables. Specifically, whether it's the measures for cultivated land power supply, the proximity of cultivated land to machine-accessible roads, or the availability of drainage measures, all pertain to the fundamental infrastructure development in rural areas. Specifically, whether it's the measures for cultivated land power supply, the proximity of cultivated land to machine-accessible roads, or the availability of drainage measures, all pertain to the fundamental infrastructure development in rural areas. Public infrastructure investments influence individual or household inputs, and this holds true in rural settings as well. Such infrastructure directly impacts the agricultural products of rural households or individuals. Such infrastructure directly impacts the agricultural products of rural households or individuals. The two-step method was used to estimate

the model. Table 3 shows the correlation test results that assess the validity of the model's endogeneity and instrumental variables.

The estimation results from the Wald test indicate that the original hypothesis that the core variables are exogenous is rejected at the 1 % level. This indicates there is no weak instrumental variables problem. Among the two-stage estimation results, the F-test values in the first stage were 16.89 and 57.78, respectively, corresponding to p-values of 0.0000.

The instrumental variables estimation results show that the coefficients of the effects of conventional household inputs of agricultural products and purchase of vehicles on rural poverty vulnerability are −0.612 and −13.774, respectively, both significant at the 1 % level. This indicates that agricultural inputs significantly reduce the likelihood of rural households falling into poverty vulnerability. Comparing the results of the instrumental variables approach with those of the benchmark model shows a significant difference between the two results, indicating that the endogeneity problem of the benchmark model significantly impacts the findings.

5.3. Coping with the endogeneity problem caused by self-selection: dealing with the effects model

In addition to the possible endogeneity problem caused by reverse causality and omitted variables in the baseline model, agricultural input behavior may also have a self-selection problem. This study uses a treatment effects model to mitigate the estimation bias caused by this problem. The household purchase of conventional agricultural products (representing inputs) is a continuous variable; as such, its proxy is set as the binary dummy variable of whether the household purchases conventional agricultural products or not. Whether or not the household purchases vehicles is a binary dummy variable, both of which apply to the treatment effect model. In this study, the immediate vicinity of the mechanized road is selected as the instrumental variable. Table 4 reports the results of the two-step estimation of the treatment effect model.

The estimation results show that the effective coefficient of the instrumental variable cultivated land adjacent to a machine road is significant at the 1 % level in the first stage of the probit regression. This indicates that the instrumental variable is significantly correlated with the endogeneity variable. In this study, endogeneity tests using the method of excellent likelihood estimation (MLE) and Wald tests reject the original hypothesis that the model does not have an endogeneity problem at the 1 % level. This indicates that household agricultural inputs do have an endogeneity problem. In contrast, household purchases of conventional agriculture products and vehicles significantly negatively and more robustly affect poverty vulnerability. The results of the treatment effects model further support the result that household agricultural inputs negatively impact rural poverty vulnerability.

5.4. Coping with endogeneity problems due to self-selection: propensity score matching

Propensity score matching (PSM) also somewhat mitigates estimation bias from the self-selection problem. In this study, propensity scores are estimated using conducting logit regressions, selecting variables such as age, gender, marriage, education, physical status, participation in NPS medical and in pension insurance categories, household accident and pension protection, relationship network, household health insurance account, chronic household disease, and overall household financial literacy of the household head. PSM results were obtained by performing propensity score nearest neighbor matching and kernel matching. Table 5 shows the matching results. The average treatment effects of the household purchase of conventional agricultural products and vehicles in the nearest neighbor matching and kernel matching are −3.9 %, −23.4 %, −4.9 %, and −24 %, respectively. The results are significant, indicating that the study's results are robust. Fig. 2 shows the distribution of PSM (nearest neighbor matching) for households purchasing conventional agricultural products (Fig. 2a) and vehicles (Fig. 2b).

5.5. Robustness test

To verify the reliability of the regression results, this study conducts robustness tests by replacing the poverty criteria, poverty

Table 3
Impact of agricultural inputs on rural poverty vulnerability: an instrumental variables approach.

Variables	Rural Poverty Vulnerability	
	(1)	(2)
Conventional agricultural products	−0.612***	
	(0.181)	
Household Vehicles		−13.774***
		(4.214)
Householder control variables	Yes	Yes
Home control variables	Yes	Yes
Observations	5927	5922
First stage F-test value	16.89	57.78
First stage F-test p-value	0.0000	0.0000
Instrumental variables t-value		
Cultivated land power supply measures	−2.84	
The cultivated land is adjacent to the machine farming road	−1.68	−1.68
Availability of drainage measures		−2.80
Wald test Chi2	15.51	42.18
(*P*-value)	0.0001	0.0000

Table 4
Impact of agricultural inputs on rural poverty vulnerability: treatment effects model.

Variables	Rural Poverty Vulnerability	
	(1)	(2)
Conventional agricultural products	−1.228**	
	(0.586)	
Household Vehicles		−0.642*
		(0.323)
Householder control variables	Yes	Yes
Home control variables	Yes	Yes
Observations	4869	5931
Wald test Chi2	70.82	1038.31
(*P*-value)	0.0000	0.0000
Estimation of instrumental variable coefficients for the maximum likelihood estimation (MLE)		
The cultivated land is adjacent to the machine farming road	−0.301***	−0.134***
	(0.099)	(0.042)
Pseudo R2	0.0139	0.0023

Table 5
Propensity score matching results.

Matching method	Explanatory variables	Experimental group	Control group	ATT	Std.Dev.	t-value
Nearest Neighbor Matching	Conventional agricultural products	0.535	0.574	−0.039*	0.020	−1.91
	Vehicles	0.266	0.500	−0.234***	0.024	−9.71
Nuclear Matching	Conventional agricultural products	0.535	0.584	−0.049***	0.015	−3.31
	Vehicles	0.266	0.506	−0.240***	0.017	−14.48

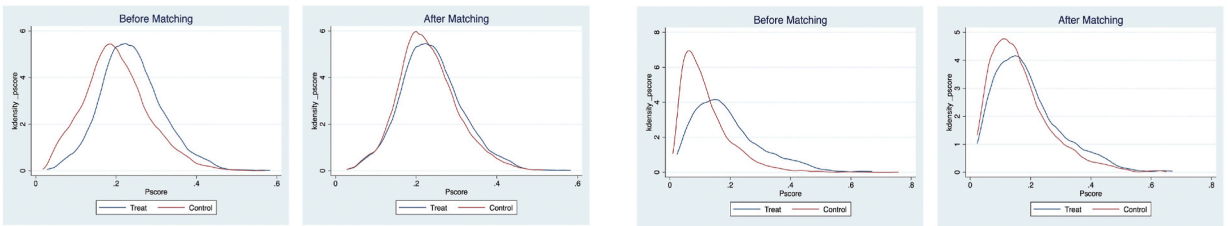


Fig. 2. Propensity score matching distribution (Near-Neighbor Matching). (a) Propensity score matching distribution of conventional agricultural products; (b) Propensity score matching distribution of vehicles.

Table 6
Robustness test results.

Variables	Replacement of the poverty standard ($1.9 standard)			Replacement of the poverty vulnerability line (29 % poverty line)			Replacement of explanatory variables		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Conventional agricultural products	−0.092*	−0.147***	−0.144***	−0.043***	−0.069***	−0.079***			
	(0.050)	(0.037)	(0.040)	(0.013)	(0.019)	(0.022)			
Vehicles	−1.426***	−1.615***	−1.934***	−1.913***	−1.438***	−1.477***	−1.473***	−1.571***	−1.511***
	(0.192)	(0.380)	(0.489)	(0.088)	(0.128)	(0.136)	(0.197)	(0.203)	(0.204)
Fertilizer input							−0.941***		
							(0.183)		
Pesticide input								−1.166***	
								(0.284)	
Seed input									−0.768***
									(0.247)
Householder control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Home control variables	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Provincial fixed effects	No	No	Yes	No	No	Yes	Yes	Yes	Yes
Observations	7659	6967	6967	7659	6967	6967	4692	4335	4345
Pseudo R2	0.509	0.846	0.855	0.321	0.610	0.627	0.674	0.674	0.676

vulnerability line, and explanatory variables. First, a robustness test is conducted that replaces the poverty criterion. In the baseline regression, the poverty criterion of $3.1 per capita daily household consumption (published by the World Bank) is used as the poverty line indicator to calculate poverty vulnerability. To avoid the problem of differences in the benchmark regression results caused by different poverty line selection criteria, the poverty standard of $1.9 per capita daily household consumption is selected as the new poverty line, and the poverty vulnerability indicator is measured again. Table 6, columns (1), (2), and (3) report the stepwise regression results of the robustness test. The effect of agricultural inputs on rural poverty vulnerability remains significantly negative after replacing the poverty line criterion. This indicates that this study's empirical results are robust, and changing the poverty criterion does not affect the estimated results.

Second, a robustness test is conducted that replaces the vulnerability line criterion. The 50 % poverty vulnerability line criterion is used in the baseline regression. To avoid differences in the empirical results caused by vulnerability criteria selection, the poverty vulnerability line is replaced with the 29 % vulnerability line. Table 6, columns (4), (5), and (6) show the stepwise regression results of the robustness test. The results show that the outcome that agricultural inputs suppress rural poverty vulnerability remains robust after replacing the poverty vulnerability line criterion.

Third, the core explanatory variables are replaced. The core explanatory variables of household purchase of conventional agricultural products is the sum of all conventional agricultural products purchased by households in the previous year. The model is then re-estimated using only the separate inputs of fertilizer, pesticides, and seeds purchased by rural households in the last year, rather than the sum of conventional agricultural products. Table 6, columns (7) (8) and (9) report that after replacing the core explanatory variables, household purchases of fertilizer, pesticide, and agricultural seed products all have a significant adverse effect on rural poverty vulnerability at the 1 % level. This indicates that the model's outcomes after replacing the core explanatory variables are consistent with the baseline regression model and the results remain robust.

6. Mechanism testing and heterogeneity analysis

6.1. Mechanism test

Rural household poverty vulnerability is a dichotomous variable and cannot be tested for mechanisms that are characteristic of continuous variables. This study uses generalized structural equation modeling (GSEM) to complete a mediating effects analysis, to explore how agricultural inputs affect rural poverty vulnerability. Table 7 shows the mediating effects are all significant at the 1 % level, and the test results of the mediating effects are robust. For the mechanism test, in which the explanatory variable is the household purchase of conventional agricultural products, the mediating results through agricultural production output and entrepreneurial behavior are −0.0005 and −0.0018, respectively; the total impacts of household purchase of agricultural products on rural poverty vulnerability are both −0.0064, with the mediating effects accounting for 8.43 % and 28.79 % for agricultural production output and entrepreneurial behavior, respectively. For the mechanism test, where the explanatory variable is having household vehicles, the mediating results through entrepreneurial behavior and physical status are −0.1381 and −0.0311, respectively. The total effects of having household vehicles on the impact of rural poverty vulnerability are −0.4298 and −0.4294, respectively, with the mediating effect shares of 32.12 % and 7.25 %, respectively.

The results show that the household purchase of conventional agricultural products first affects rural poverty vulnerability by increasing agricultural production yields. This in turn affects household poverty vulnerability by acting on disposable income. Second, households purchasing conventional agricultural products affect rural poverty vulnerability by strengthening entrepreneurial behavior. Purchasing these products can effectively increase the scale of agricultural production and encourage operators to gradually engage in entrepreneurship related to agricultural production. This, in turn, inhibits the occurrence of rural poverty vulnerability by improving household production and living standards. Third, having household vehicles affects rural poverty vulnerability by strengthening entrepreneurial behavior. Having vehicles improves the transportation efficiency of agricultural production and business operations, enhances interaction with the outside world, and improves access to entrepreneurial information and behavioral participation. This reduces the probability of rural poverty vulnerability by increasing the coverage of household relationship networks and income levels. Fourth, having household vehicles affects rural poverty vulnerability by improving physical status. By shortening the medical distance between the household and the city, having vehicles increases the possibility of accessing urban medical resources and reduces the probability of that members of the household experience a physical decline. This, in turn, inhibits the occurrence of

Table 7
Mechanism test results.

Variables	Intermediate variables	Coefficient	Standard error	95 % confidence interval	*P*-value	Intermediary effect as a percentage
Conventional agricultural products	Agricultural production	−0.0005	0.0001	[-0.0008,-0.0003]	0.000	8.43 %
	output	−0.0064	0.001	[-0.0087,-0.0041]	0.000	
	Entrepreneurial behavior	−0.0018	0.0004	[-0.0027,-0.001]	0.000	28.79 %
		−0.0064	0.001	[-0.0087,-0.0041]	0.000	
Vehicles	Entrepreneurial behavior	−0.1381	0.007	[-0.1514,-0.1248]	0.000	32.12 %
		−0.4298	0.015	[-0.4601,-0.3995]	0.000	
	Physical Condition	−0.0311	0.003	[-0.0377,-0.0246]	0.000	7.25 %
		−0.4294	0.015	[-0.4597,-0.399]	0.000	

rural poverty vulnerability. These results verify hypotheses 2, 3, and 4.

6.2. Heterogeneity analysis

There are significant differences in characteristics between households, and the impact of household agricultural inputs on rural poverty vulnerability may differ between families with different features. This study examines household heterogeneity in the effects of agricultural inputs on rural poverty vulnerability, and further tests the robustness of the estimation results.

6.2.1. Regional differences

To examine regional heterogeneity, sample households are divided into eastern, central, and western regions based on location, using the conventional regional division method. The regression results in Table 8, columns (1), (2), and (3) show that the impact of agricultural inputs on rural poverty vulnerability is more significant for rural households in the west. The effect is weakest in the east. This may be because the overall economic and social development level of rural areas is higher in the eastern region. As such, agricultural inputs may not have as significant an impact on rural poverty vulnerability. In contrast, rural households in the west have a relatively low economic level, and increasing agricultural inputs can significantly raise household income levels, substantially inhibiting the occurrence of rural poverty vulnerability.

6.2.2. Differences in physical status

Table 8, columns (4) and (5) report the heterogeneous characteristics of the physical quality of rural household heads. Agricultural inputs inhibit rural poverty vulnerability, regardless of whether the pastoral household head is physically healthy. In contrast, the inhibitive effect of agricultural inputs on rural poverty vulnerability is more substantial in households with a healthy household head. This may be because health risk is an essential risk that can lead marginalized families to fall into poverty vulnerability, and the head of household is an important influence on the home. Homes with healthy heads are more likely to increase household income and quality of life by improving agricultural inputs, inhibiting household poverty vulnerability.

6.2.3. Risk preference differences

Table 8, columns (6) and (7) report the heterogeneous characteristics of risk preferences of rural household heads. Agricultural inputs inhibit rural poverty vulnerability, regardless of whether the household head is a risk taker. The regression results show that the inhibitive effect of agricultural inputs on rural poverty vulnerability is more significant for households whose head is a risk taker. This may be because households willing to accept risk generally show more positive attitudes in the face of expected uncertainty, and respond more effectively to the stresses and problems in agricultural production and agricultural inputs. These attitudes have a more substantial inhibitive effect on rural poverty vulnerability.

7. Discussions and conclusions

7.1. Discussions

Poverty is constantly challenging for human sustainability [85]. Accordingly, poverty alleviation is a common concern of all nations [86,87]. From the perspective of poverty reduction [88,89], this study discusses the impact and potential mechanisms of agricultural inputs on rural household poverty vulnerability. This offers an exploratory contribution to poverty research and studies on sustainable development. The empirical results show that agricultural inputs significantly suppress the probability of rural poverty vulnerability. Agricultural investments can address challenges posed by labor shortages and soil fertility depletion, subsequently ensuring food security [59]. Concurrently, existing studies have demonstrated that the utilization of inorganic fertilizers, improved seeds, and other such agricultural interventions can significantly boost crop yields and alleviate poverty [56]. Research into how agricultural investments mitigate rural poverty vulnerability serves as a vital augmentation and refinement of the current literature.

Table 8
Heterogeneous effects of agricultural inputs on rural poverty vulnerability.

Variables	Regional Heterogeneity		Physical condition heterogeneity			Risk appetite heterogeneity	
	East	Middle	West	Health	Unhealthy	Open to Risk	Risk Averse
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Conventional agricultural products	−0.233**	−0.265***	−0.412***	−0.430**	−0.264***	−0.319***	−0.263***
	(0.092)	(0.039)	(0.129)	(0.182)	(0.035)	(0.070)	(0.040)
Vehicles	−1.472***	−1.748***	−1.442***	−1.096**	−1.627***	−1.586***	−1.536***
	(0.257)	(0.317)	(0.277)	(0.474)	(0.173)	(0.190)	(0.309)
Householder control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Home control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provincial fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2102	2578	2287	1714	5253	5553	1414
Pseudo R2	0.689	0.692	0.679	0.724	0.674	0.688	0.673

McArthur and McCord (2017) suggest that agricultural investments can influence a nation's structural changes by enhancing crop yields [41]. Similarly, Murgai (2001) posits that augmenting agricultural productivity stands as an effective policy tool to eradicate poverty [42]. Building on this, this article specifically addresses the role of agricultural inputs in mitigating poverty, delving deeper into the relationship between the two. We find that agricultural inputs effect rural household poverty vulnerability mainly by increasing agricultural production yields, strengthening entrepreneurial behavior, and enhancing physical health based on the industrial-technological [88] and production efficiency [89] characteristics of agricultural inputs. This conclusion serves as a crucial validation and supplement to the research of Yang et al. (2022), Michael et al. (2020), and Xavier et al. (2001). Yang et al. (2022) found that the accumulation of health human capital and enhancing individual agency can effectively alleviate poverty [80]. Michael et al. (2020) recognized the pivotal role of entrepreneurship in addressing poverty issues [82]. Xavier et al. (2001), through cross-national estimations between agricultural yield per unit area and poverty indices, underscored the significance and value of agricultural growth in reducing poverty [90]. These findings offer innovative insights into the processes and mechanisms by which agricultural inputs suppress vulnerability to poverty.

7.2. Theoretical implications

Most previous literature has focused on the impact of agricultural inputs on the current state of poverty, arguing that agricultural inputs are important means of agricultural productivity [41], raising rural household income [91] to curb poverty. However, the measurement of poverty is an ex-post indicator and lacks predictive analysis of future poverty status. It has certain limitations. And the existing indicators on the composition of agricultural inputs are mainly the analysis of single agricultural inputs such as fertilizers [92] and seeds [47], lacking a comprehensive exploration of the overall agricultural inputs of households. This study finds that agricultural inputs significantly suppress rural household poverty vulnerability based on the data from a large sample in China. It provides new empirical evidence that higher agricultural inputs can play a positive role in suppressing rural poverty. It extends the analysis of a comprehensive set of indicators for agricultural inputs and strengthens the understanding of agricultural inputs on the likelihood of future poverty among rural households. Based on the poverty vulnerability theory [93], households need to strengthen their ability to resist and withstand the risk of external uncertainty. It includes improving household income and raising households' perceptions of external risks. In addition, we find that agricultural inputs suppress rural household poverty vulnerability by increasing agricultural yields, enhancing physical health, and increasing opportunities for entrepreneurial behavior. It provides valid evidence for understanding the impact mechanisms and behavioral processes of agricultural inputs.

7.3. Practical implications

The evidence presented in this study suggests that increasing agricultural inputs significantly curbs rural poverty vulnerability. It further illustrates the need for policy efforts. The public sector should focus on the role of agricultural inputs in improving the quality of life of rural households and curbing rural poverty vulnerability, and develop more targeted and complementary policies that are tailored to the characteristics of rural households and the agricultural industry. Thus, the practical implications of this study include the following. First, agricultural inputs are the main component of rural households' agricultural production and the pivotal factor that influences rural households to increase agricultural production and expand the scale of their industries. Therefore, strengthening financial subsidies and product preferences for rural households, enabling them to purchase conventional agricultural products and vehicles can help reduce the input costs of rural families from both the production and consumption sides. Second, poverty vulnerability arises from the risk of uncertainty external to the household. While enhancing the level of external risk resistance of rural households, the public sector should also strengthen assistance to the endogenous capacity of rural households, such as enhancing the physical health of rural household members from the perspective of improving medical coverage and enhancing the entrepreneurial awareness and entrepreneurial behavior protection of rural households from the perspective of strengthening entrepreneurial training and introducing agricultural insurance. Thirdly, the focus of this study is on rural households in China, a nation with vast rural areas and a large rural population. The governance measures and pathways developed in this research to mitigate vulnerability to poverty can offer valuable insights for other countries and regions. However, the reasons for poverty or its recurrence vary across different countries and regions. When formulating public policies aimed at mitigating poverty, it's imperative to consider the specific circumstances of the respective region, ensuring the policy reflects targeted and differentiated characteristics. Furthermore, there should be a comprehensive integration of short-term and long-term strategies to ensure a synergistic approach to alleviating poverty and promoting sustainable development.

7.4. Limitations and future research directions

Like all articles, this one has some limitations, with a point to the need for future research in the following areas. First, we considered the impact of agricultural inputs on rural poverty vulnerability in the context of China. The economic and social development environments vary between countries. Therefore, extending this research to other countries in the form of comparative studies could help achieve a higher generalization. Second, the data on household agricultural inputs in the Chinese Household Finance Survey database is only available in cross-sectional data for 2015. Data over multiple years are needed to facilitate a more systematic research framework to observe the impact of household agricultural inputs on rural poverty vulnerability over time. Thirdly, given the various categories available for measuring agricultural investments and poverty vulnerability, this study acknowledges certain limitations in its choice of proxy variables or constituent indices, resulting in a lack of comprehensiveness. Future research can consider

employing alternative proxy variables or indices to validate the relationship between agricultural investments and poverty vulnerability. These limitations present crucial opportunities for future research.

7.5. Conclusions

This study leverages data from the 2015 China Household Finance Survey to analyze the processes and mechanisms through which agricultural investments impact rural poverty vulnerability. By regressing the poverty vulnerability dependent variable against the indices of conventional agricultural products and vehicles within the composition of agricultural investments, and subsequently conducting endogeneity checks using instrumental variables method, treatment effects model, and propensity score matching, along with robustness checks for alternative poverty benchmarks, poverty vulnerability criteria, and core explanatory variables, we discern that agricultural investments significantly mitigate the onset of rural poverty vulnerability. Further analysis indicates that the dampening effects of agricultural investments on rural poverty vulnerability are chiefly realized by augmenting agricultural yields, enhancing physical health, and amplifying entrepreneurial opportunities. Heterogeneity analyses reveal that the mitigating effects of agricultural investments on poverty vulnerability are notably pronounced in the central and western regions of China, in households where the head maintains good health, and in households led by those with a risk-taking propensity. These empirical findings furnish valuable insights for developing nations in crafting forward-looking and targeted poverty alleviation policies.

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Data availability statement

Sharing research data helps other researchers evaluate your findings, build on your work and to increase trust in your article. We encourage all our authors to make as much of their data publicly available as reasonably possible. Please note that your response to the following questions regarding the public data availability and the reasons for potentially not making data available will be available alongside your article upon publication.

Has data associated with your study been deposited into a publicly available repository? Yes. The data that support the findings of this study are available from the corresponding author, upon reasonable request. Additionally, it is directly accessible through the China Household Finance Survey database (https://chfs.swufe.edu.cn/).

CRediT authorship contribution statement

Xu Li: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Xiaobing Peng:** Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Conceptualization. **Yu Peng:** Writing – review & editing, Writing – original draft, Software, Data curation, Conceptualization.

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.

Appendix

Table A1
Description of variables.

Variables Type	Variables	Variables Definition
Dependent variables	1.9 dollars 50 % vulnerability line	Calculated based on the daily poverty thresholds of $1.9 and $3.1, along with vulnerability to poverty criteria of 50 % and 29 % respectively.
	3.1 dollars 50 % vulnerability line	
	1.9 dollars 29 % vulnerable line	
	3.1 dollars 29 % vulnerable line	
Core explanatory variables	Conventional agricultural products	Expenditure on conventional agricultural inputs encompasses items such as seeds, seedlings, pesticides, growth agents, fish medicine, herbicides, fertilizers, baits, agricultural films, small agricultural machinery, and other related agricultural products. (¥)
	Vehicles	Expenditure on vehicles, which includes common cars, buses, and trucks. (¥)
Household Head characteristic variables	Age	Respondent's age (in years)
	Gender	0: Female, 1: Male

(*continued on next page*)

Table A1 (*continued*)

Variables Type	Variables	Variables Definition
	Marriage	0: Single, 1: Married
	Education level	1: No formal education, 2: Primary school, 3: Middle school, 4: High school, 5: Vocational high school, 6: Vocational college, 7: University degree
	Physical Condition	1: Very Poor, 2: Poor, 3: Average, 4: Good, 5: Very Good
	New Agricultural Cooperative Medical Insurance	Participation in a specific rural medical insurance scheme? (Yes/No)
	Type of pension insurance	1: Public sector pension, 2: Urban employee insurance, 3: New rural pension scheme, 4: Urban resident insurance, 5: Urban-rural resident insurance, 6: Others, 7: None
Family characteristic variables	Member Size	Number of family members
	Family Accident Protection	Number of family members with accident coverage
	Family Retirement Protection	Number of family members with retirement protection
	Family Relationship Network	Number of blood relatives
	Members' medical insurance accounts	Enrollment in a medical insurance account by family members? (Yes/No)
	Member chronic diseases	Presence of chronic diseases among family members? (Yes/No)
	Overall Financial Literacy	0: Low, 1: Average, 2: High, 3: Very High
	Home Based Business	Presence of home-based business ventures among family members? (Yes/No)
	Household debt	Total household debt amount (¥)

Table A2
OLS regression results for the natural logarithm of per capita household consumption and its squared residuals as a measure of consumption volatility (VEP)

Variables	OLS regression results for the natural logarithm of per capita household consumption			OLS regression results using the squared residuals as a measure of consumption volatility		
	Coefficient	Std. err.	t	Coefficient	Std. err.	t
Age	0.018***	0.006	3.030	0.016	0.017	0.960
Age^2	−0.0003***	0.0001	−5.580	−0.00004	0.0002	−0.250
Sex	0.049	0.030	1.640	−0.121	0.083	−1.460
Marriage	0.334***	0.032	10.350	−0.173*	0.090	−1.930
Education level	0.073***	0.010	7.190	−0.058**	0.028	−2.050
Physical Condition	−0.004	0.010	−0.430	−0.072***	0.027	−2.680
Size of family members	−0.239***	0.011	−22.550	−0.057*	0.029	−1.950
Family Relationship Network	0.077***	0.008	9.180	0.051**	0.023	2.200
New Agricultural Cooperative Medical Insurance	−0.169***	0.039	−4.330	0.248**	0.109	2.280
Total Assets	0.0000002***	0.00000001	16.970	0.0000002***	0.00000004	4.580
Total Revenue	0.0000002*	0.0000002	1.660	0.0000001	0.0000004	0.320
Home Based Business	0.387***	0.031	12.360	−0.083	0.087	−0.950
Family Accident Protection	0.273***	0.048	5.740	−0.21	0.132	−1.590
_cons	8.727***	0.182	47.960	−1.913***	0.507	−3.780
Observations	7752			7752		
Pseudo R2	0.293			0.012		

Table A3
Results from the FGLS regression analysis (VEP).

Variables	Natural logarithm of per capita household consumption		
	Coefficient	Std. err.	t
Age	0.015***	0.006	2.690
Age^2	−0.0003***	0.0001	−5.370
Sex	0.048	0.031	1.550
Marriage	0.325***	0.034	9.470
Education level	0.062***	0.010	6.470
Physical Condition	−0.008	0.009	−0.850
Size of family members	−0.225***	0.010	−22.130
Family Relationship Network	0.068***	0.008	8.360
New Agricultural Cooperative Medical Insurance	−0.135***	0.034	−3.990
Total Assets	0.0000004***	0.00000002	19.900
Total Revenue	0.0000007***	0.0000002	3.280
Home Based Business	0.310***	0.030	10.500
Family Accident Protection	0.228***	0.042	5.380
_cons	8.795***	0.168	52.500
Observations	7752		
Pseudo R2	0.294		

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