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Corn Grain or Corn Silage: Effects of the Grain-to-Fodder Crop Conversion Program on Farmers' Income in China

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Abstract: The Grain-to-Fodder Crop Conversion Program (GCCP) in China mainly promotes the green and sustainable development of grain crops, economic crops, and silage crops by subsidizing livestock farms to encourage farmers to plant silage crops, such as corn silage and alfalfa silage. In this context, this study assesses the impact of planting silage crops on farm household income. Based on a survey of 495 households in Henan and Hebei Provinces, China, we first constructed a theoretical model of the program's effect on farmers' income, and then used an ordinary least squares (OLS) method to estimate the magnitude of the GCCP on farmers' income. To identify endogeneity and further test the stability of the results, we adopted instrumental variable estimation, subsample estimation, and matching methods. The GCCP significantly increased smallholder farm income. Compared with growing corn grain, corn silage increased income by approximately CNY 101/mu. Meanwhile, corn silage reduced the capital input cost of farmers by 10.71% per mu and labor input by 26.6% per mu. Heterogeneity analysis revealed that farmers who plant corn silage on a large scale, closer to dairy farms, have higher incomes. Few scholars have empirically analyzed the impact of GCCP on farm household income from a micro-farm household perspective. This study enriches the empirical literature on the effects of the GCCP on farmers in China, which can help policymakers understand policy implementation.

Keywords: Grain-to-Fodder Crop Conversion Program; corn silage; farmers' income; China

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1. Introduction

As a result of its large population and limited arable land and water resources, the Chinese government has always been concerned about food security [1–3]. To encourage food production, the government introduced various subsidy policies, such as the agriculture direct subsidy program [4], minimum procurement prices for rice and wheat [5,6], and a temporary storage program for maize, soybean, and rapeseed [7]. These policies have significant effects on guaranteeing national food safety and increasing farmers' incomes [8,9]. According to data from the National Statistics Bureau, in 2021, China's food output reached 682.85 million tons, 2.24 times its output at the beginning of China's "reform and opening up" program in 1978; this represents an annual average growth rate of 1.89%. However, many problems arose as a result of increases in food output in China, such as high grain production costs [10–12], increasing agricultural product price differences between China and the world's major agricultural nations [13,14], conflicts with World Trade Organization (WTO) policies [15], and large amounts of grains stored in state warehouses [16–18]. These problems are even more serious for China's corn production. The volume of corn imports continuously increased since the trade gap in 2010. The net corn import volume increased to 8.079 million tons, 12.2% higher than the 2020 total import tariff quota (7.2 million tons).

Owing to the limitations of China's quota system, Chinese enterprises import considerable amounts of wheat, oats, and sorghum each year as substitutes for corn [19,20].

With the continuous growth in Chinese consumer demand for animal by-products and nutrient-rich foods, the livestock industry increased its demand for feed grains [21,22]. In particular, the consumption of meat, eggs, and milk products increased. According to *China's Food Safety*, a white book published by the Chinese government in October 2019, the per capita quantities of meat (including pork, beef, and mutton), aquaculture products, and milk consumed in China increased by 35.7%, 55.0%, and 72.5%, respectively, between 1996 and 2019. Increased demand for animal by-products drives the expansion of the livestock industry in China, further increasing the demand for fodder grasses [23]. However, China's silage supply is insufficient to meet the demand for livestock breeding. Therefore, accelerating the transformation of agricultural cultivation structure and sustainable development (especially ensuring the security of feed grains) and considering China's food security from a larger food security perspective become more significant.

To solve this supply-demand disparity, the government of China issued a subsidy policy called the Grain-to-Fodder Crop Conversion program (GCCP) in 2015. Livestock farms that use corn silage for feed receive financial subsidies from the government. Driven by subsidy funds, farmers near livestock farms began to plant corn silage. Through this program, the Chinese government aimed to adjust crop structures and increase potential income sources for farmers. To study the income influences of the GCCP, a few case studies compared the cost-benefit relationship between corn silage and corn grain [24–26]. There are few empirical studies using micro-survey data to assess the impact of the GCCP on farmers' income evolution. Towe and Tra's [27] study evaluated the influence of increased demand from U.S. ethyl alcohol companies on crop structures and farmers' income after the implementation of the *U.S. Energy Act*. In contrast, the GCCP provides policy support and financial subsidies to livestock farms, which are encouraged to use more corn silage to feed livestock, leading to more farmers producing corn silage. In addition, agricultural technology is also an important factor causing income inequality [28,29]. Although the GCCP is an agricultural support subsidy, to a certain extent it can assist farmers in adopting new technologies to plant more silage corn varieties, thereby obtaining a higher income. For example, corn silage requires a higher level of mechanization, and farmers with a larger arable land area are more likely to grow this crop, and their income may be higher. This paper conducts a heterogeneity analysis on the impact of farmer incomes from the perspective of the scale of cultivated land. In this study, we used unique survey data from 495 households in Hebei and Henan provinces in China to quantitatively analyze the effects of the GCCP on farmers' incomes. We also analyzed heterogeneity in terms of both the area of cultivated land and the distance to livestock farms receiving agricultural subsidies. This study enriches the empirical literature on the effects of the GCCP on farming households in China.

This paper is organized as follows. Section 2 introduces the GCCP and analyzes its mechanisms. Section 3 presents data, variables, and the research method. Section 4 presents the estimation results and endogenous identification strategy. Section 5 analyzes the influence of corn silage on the production input of farming households and the heterogeneity of the GCCP. Section 6 presents conclusions and implications.

2. Policy Review and Mechanism Analysis

2.1. The Grain-to-Fodder Crop Conversion Program

The Chinese government and scholars have discussed subsidy policies related to corn production in China [20,30,31]. In 2008, China initiated a temporary storage program that determined the purchase price of corn with regard to China's and other countries' market demands and market prices. In the early stage of the temporary storage program, there were positive effects on farmers' income, grain yield, and market stabilization [32]. However, many problems began to occur in the late stage, such as continuous increases in corn inventory and an inverted price gap between China and other countries [17]. To accelerate reform on the corn supply side, destocking, and adjusting the planting structure, the No.1 *Central Document* proposed the GCCP for the first time in 2015. This policy regulates support for planting silage crops, such as corn silage and alfalfa silage, and promotes the agricultural green and sustainable development of grain, cash and fodder crops. Financial subsidy funds from the central government are primarily used to facilitate high-quality fodder crop harvesting and storage. This promotes the transformation of the livestock farming industry and improves farmers' income from growing crops. These subsidies are mainly provided to (1) scaled grass-feeding livestock farms that have a high-quality fodder crop harvest, storage, and usage functions, (2) professional harvesting and storage enterprises or cooperatives that have stable supply and marketing orders for fodder crops, and (3) socialized service organizations that provide harvesting and storage services. Among the subsidy recipients, scaled grass-feeding livestock farms are predominant, especially dairy farms in livestock farms. According to a questionnaire survey of 25 dairy farms, they received an average subsidy of CNY 58/ton (USD 1 = CNY 6.90 in 2019) to harvest and store corn silage.

Subsidy coverage areas increased after the implementation of the GCCP. In 2015, the central government provided CNY 300 million for pilot programs in 30 counties across 10 provinces. In the same year, the *13th Five-Year Plan* for National Economic and Social Development, five successive *No. 1 Central Documents,* and many important conference documents from 2016 to 2020 emphasized the importance of the GCCP in adjusting plant structures. The scope and subsidy amounts expanded continuously. In 2019, the scope of the GCCP pilot program was expanded to 629 counties in 17 provinces. The regions involved extended from the original agro-pastoral ecotone in Northeast, North, and West China to those of East, Southwest, and South China. The central government input a cumulative subsidy of CNY 7.3 billion by June 2019.

2.2. Mechanism of Influence of the GCCP on Farmers' Income Growth

The GCCP mainly influences corn silage prices and farmers' income by influencing corn silage demand on livestock farms [33]. Concerning the local market supply-demand equilibrium model, this study analyzed the influence of the GCCP on farmers' income. Since there are many scattered producers and consumers in the agricultural product market in China, the corn silage market can be viewed as a perfect competition market [34]. As shown in Figure 1, under the original condition without subsidies, the intersection between the equilibrium price and quantities of corn silage was the point of B at market-clearing. Currently, equilibrium price and quantity are P_0 and Q_o, respectively. In the initial state, livestock farmers' marginal cost is equal to marginal revenue. Specifically, the marginal cost is the purchase price of corn silage, and marginal revenue is the marginal output value of corn silage. After obtaining subsidies, livestock farms increased their demand for corn silage. As a result, the demand curve moves rightward from D_0 to D_1, with the new equilibrium price and quantity moving upward and intersecting at point C. As the price of corn silage increases, farmers begin to plant more, and a new equilibrium point E is reached. Currently, equilibrium price and quantity are P_2 and Q_2, respectively. The degree of market demand and the production level of farmers' households determine the amplitude of the movement of the supply-demand curve. After obtaining subsidies, livestock farms increase their scale, machinery equipment, and technical efficiency, making the demand curve move rightward more than the supply curve. The supply curve moves slightly rightward because farmers' households use new varieties and slowly improve production technologies.

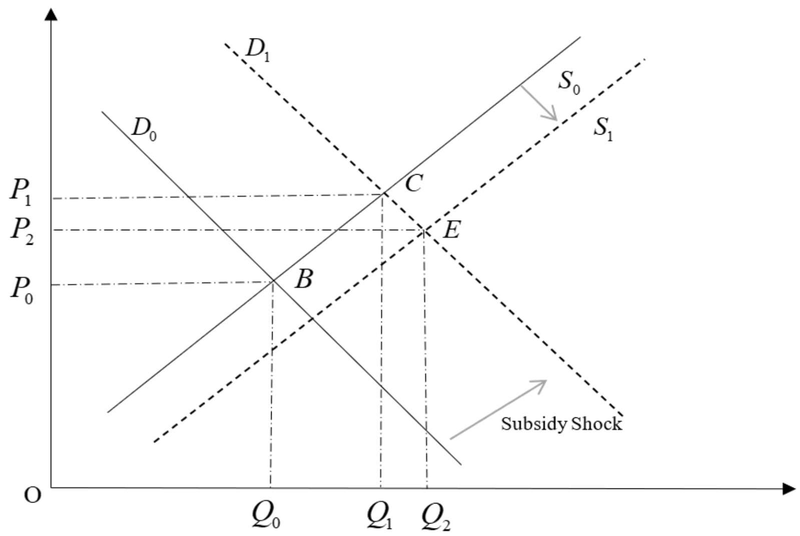

Figure 1. Effects of the GCCP on household farmers' income.

According to the perfect competition market hypothesis, the supply curve of farmers is the marginal cost curve of agricultural production, and the total cost is the area below it. Hence, the region above the supply curve in the OQ_0BP_0 and OQ_2EP_2 areas (Figure 1) represent the surplus of household farmers. The slope of the supply curve is related to the production period, which is adjusted by farmers according to the market price. A shorter adjustment time makes it more difficult to change the inputs of fixed production factors such as land and machines, and the supply curve becomes increasingly vertical. If the adjustment time is longer, the farmers' input of fixed production factors will be adjusted, and the supply curve tends to be horizontal. As shown in Figure 1, the new market equilibrium price declines with increases in the production period. No matter how long the policy intervention, the equilibrium price is always between points *B* and *C*. The quantity and price of corn silage will be higher than in the early stage, so the farmers' net income increases. However, the increase in income from corn silage will prompt farmers to change from corn silage to corn grain, and the farmers will change their land use, machinery capital and other fixed factors of production inputs, and eventually reach a new balance between the income from corn silage and corn grain. At this time, farmers in the same areas with GCCP subsidies will have an equal income from growing corn silage and corn grain. However, in the short term, it will be difficult for some farmers to change their crop structure due to differences in production habits, land endowment, and technical conditions, and the income from corn silage will be higher than corn grain. Based on the above analysis, it can be speculated that farmers' incomes from corn silage will increase after implementing the subsidy program in the short term.

2.3. Heterogeneity Analysis of Scale and Distance Effects

The influence of land scale on production efficiency differs significantly among crops [35–37]. Since the environments required for the growth of corn grain and silage differ to some extent, their scale effects might also differ [38]. Compared with corn grain, corn silage requires large professional machines during harvesting, thus imposing higher requirements on the land scale. The main purpose of the subsidy program is to motivate the surrounding farming households to produce corn by providing subsidies to livestock farms and increasing their feed demand. As a result of traffic costs, livestock farms first consider purchasing corn silage from nearby livestock farmers. Hence, farmers closer to livestock farms are more obviously affected by the policy, and their incomes increase more significantly than farmers farther away. Based on this, we tested the heterogeneity of grain and corn silage in terms of scale and distance effects.

3. Data and Research Method

3.1. Data

Stratified random sampling was used to survey counties, villages, and farming households. All the GCCP pilot program's county-level districts in Henan and Hebei provinces were divided into high-level, mid-level, and low-level groups. One or two county-level districts were chosen from each group. Five dairy farms with at least 100 cows were then randomly chosen from each selected county, or all dairy farms were investigated if there were fewer than five farms. The GCCP project is mainly aimed at dairy farms in livestock farms, so we chose to survey farmers near dairy farms. At the same time, we tried to exclude the situation where there are other subsidy targets in the vicinity. After dairy farms were selected, two villages were chosen near each dairy farm. One was the dairy farm's village, and the other was the next closest village. After the sample villages were determined, the investigators randomly selected ten households that planted corn from a list provided by village cadres. Farm household surveys in the Hebei and Henan provinces were conducted in 2018 and 2019, respectively. The investigated regions are shown in Figure 2. Hebei and Henan are the main provinces producing corn in China. In 2018, Hebei Province sowed 3654.4 thousand hectares, accounting for 55.9% of the total sown area of grain crops in the province and 8.8% of the total corn sown area in China. In 2019, Henan Province sowed 3801.3 thousand hectares of corn, accounting for 35.4% of the total sown area of grain crops in the province and 9.2% of the total sown area of maize in China. Therefore, the farmers in Hebei and Henan provinces were chosen for this paper.

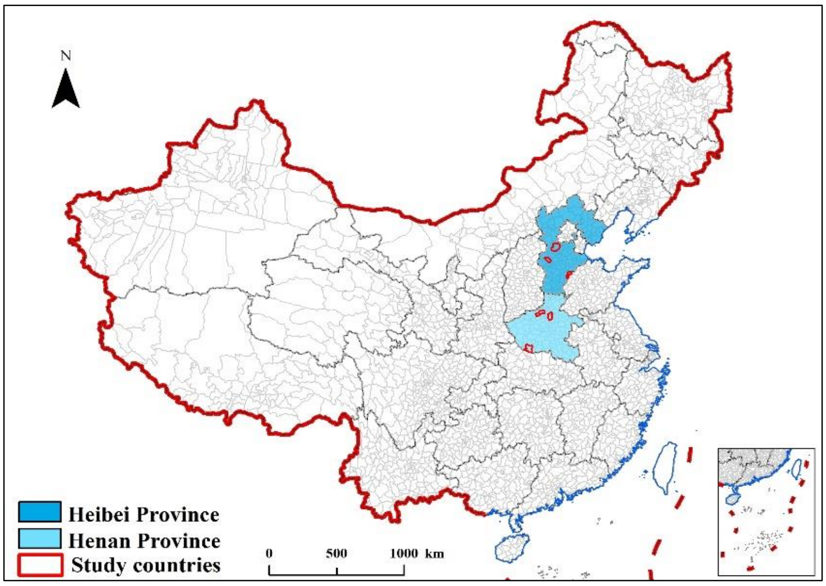

Figure 2. Locations of the surveyed households.

The survey involved face-to-face interviews with the participants, and 507 questionnaires were collected. In Hebei province, we investigated 253 farming households in 26 villages, 13 dairy farms, and three counties. In Henan Province, we investigated 254 farming households in 26 villages, 13 dairy farms, and four counties. Finally, 495 effective samples were retained after deleting missing and discrete values.

3.2. Empirical Model

In this section, we use an econometric model to estimate the effect of corn silage on farm household income shown in Equation (1).

$$Y_{ik} = \beta_0 + \beta_1 B_{ik} + \beta_2 C_{ik} + \beta_3 F_i + \beta_4 H_{ik} + \varepsilon_{ik} \quad (1)$$

Model (1) is the benchmark model used, where Y_{ik} refers to the income of the ith farmer from the kth crop (k = 1 or 2, representing corn grain and corn silage, respectively). B_{ik} is a key variable in the model and refers to whether the kth crop planted by the ith farmer is corn silage. C_{ik} represents control variables at the crop level and refers to whether the kth crop suffered disasters, irrigation conditions, or land scale. F_i represents household-level control variables indicating the number of members of the ith farmer's household, and whether the household was in a village where a dairy farm was located. H_{ik} represents control variables indicating the household head's educational level, health status, Communist Party of China (CPC) membership status, off-farm work status, and ε_{ik} is an error term.

Given the differences in terrain and fertility between different areas, county-level dummy variables were included in the model. In addition, considering that the surveys were conducted in Hebei and Henan provinces in 2018 and 2019, respectively, time dummy variables were also included in the model.

3.3. Variable Definitions and Descriptive Statistical Analysis

In this study, farmers' income refers to the net income from corn planting. Therefore, farmers' income = sales revenues − capital input; and sales revenues = sales volume × sales price. The sale price of corn within a village has little variation; therefore, discrete or missing sales price values were replaced by the average price for the village. Capital input is the sum of production material cost and socialized service cost. The former refers to the total cost of seeds, pesticides, fertilizers, and irrigation. The latter mainly refers to the expenses for machinery services for plowing, sowing, pesticide application, fertilization, irrigation, harvest, and transportation. Labor input is the sum of a family's labor during the corn production process from tillage to harvest.

The descriptive statistical analysis of all control variables is presented in Table 1. It mainly shows the means, mean differences between corn grain and corn silage, and variable definitions. Farmers of planted corn silage accounted for 35.8% of all samples, and the average farmers' income from corn per mu was CNY 391. The incomes from corn grain and silage were CNY 356/mu and CNY 453/mu, respectively; hence, the average income from corn silage planting was CNY 97 higher per mu than from corn grain. It can be seen that farmers who planted their main crop as corn silage had a higher corn income than farmers whose main crop was corn grain.

Table 1. Descriptive statistics and variable definitions.

Variable	Full Sample	Corn Grain	Corn Silage	Difference (*t* Test)	Definition or Unit
Income	0.391	0.356	0.453	−0.097 ***	Sales revenues minus capital input (CNY 1000/mu).
Corn silage	0.358	-	-	-	1 = yes; 0 = others
Sales revenue	0.803	0.784	0.836	−0.052 *	Corn price multiplied by yield (CNY 1000/mu).
Capital input	0.412	0.430	0.382	0.048 ***	Total expenses other than the input of their own labor (CNY 1000 /mu).
Labor input	3.181	3.377	2.829	0.548	The sum of one's own family labor inputs (day/mu). One day = 8 h.
Instrumental variable					
Corn silage varieties	0.437	0.380	0.538	−0.159 ***	Whether it is easy to purchase corn silage varieties in the village (1 = yes; 0 = no).
Slope degree	0.077	0.091	0.053	−0.039 ***	The slope degree is extracted through the 3D analyst tool of ArcGIS software using elevation data with a resolution of one km.

Table 1. *Cont.*

Variable	Full Sample	Corn Grain	Corn Silage	Difference (*t* Test)	Definition or Unit
		Crop characteristics			
		Irrigation			
Groundwater	0.784	0.818	0.722	0.096 **	1 = yes; 0 = others
Surface water	0.128	0.091	0.194	−0.104 ***	1 = yes; 0 = others
Groundwater and surface water	0.078	0.078	0.078	0.001	1 = yes; 0 = others
Rainwater	0.010	0.013	0.006	0.007	1 = yes; 0 = others
Farm size	87.606	51.581	152.093	−100.512 ***	Mu
Disaster	0.385	0.412	0.337	0.0747 *	1 = yes; 0 = others
		Household characteristics			
Household size	4.438	4.506	4.315	0.191	Total number of permanent family members
	Household income (CNY)				
≤15,000	0.208	0.241	0.149	0.092 **	1 = yes; 0 = others
(15,000, 35,000]	0.212	0.219	0.199	0.020	1 = yes; 0 = others
(35,000, 60,000]	0.184	0.170	0.210	−0.040	1 = yes; 0 = others
(60,000, 95,000]	0.196	0.204	0.182	0.021	1 = yes; 0 = others
>95,000	0.200	0.167	0.260	−0.093 **	1 = yes; 0 = others
Dairy farm location	0.454	0.385	0.575	−0.190 ***	Is there a dairy farm in the village? 1 = yes; 0 = others
		Head of household characteristics			
Gender	0.073	0.086	0.050	0.036	1 = female; 0 = male
Age	54.717	55.448	53.409	2.039 **	Year
Education level					
Illiteracy	0.063	0.065	0.061	0.004	1 = yes; 0 = others
Primary school	0.204	0.201	0.210	−0.009	1 = yes; 0 = others
Junior high school	0.525	0.497	0.575	−0.078 *	1 = yes; 0 = others
Senior high school	0.208	0.238	0.155	0.083 **	1 = yes; 0 = others
Health	0.842	0.833	0.856	−0.023	1 = yes; 0 = others
CPC membership	0.196	0.216	0.160	0.056	1 = yes; 0 = others
Non-agricultural employment	0.469	0.444	0.514	−0.069	1 = yes; 0 = others

Notes: Robust t-statistics in parentheses; * significance at 10%; ** significance at 5%; *** significance at 1%; 1 Mu = 1/15 Ha; and CNY is the currency of China (USD 1 = CNY 6.90 in 2019). Capital input refers to the production cost other than labor input, including the total cost of pesticides and fertilizers, irrigation, seeds, purchase of machinery and services, etc. (unit: CNY 1000/mu). Labor input is the sum of one's own family labor inputs in the production process of corn from tillage to harvest.

Various control variables are chosen based on the household decision-making model [39,40]. The average household size was 4.4 persons, the average household head's age was 54.7 years, and 46% of household heads were engaged in non-agricultural employment. Most household heads had a junior high school education level. These household and individual characteristics were consistent with those described in the existing literature [41–43]. It is worth noting that there were significant differences between corn silage and corn grain in terms of irrigation mode, farm size, whether they had suffered disasters, dairy farm location, and household head age. The above is only a comparative analysis of grain and corn silage income. Nevertheless, many other factors can influence farmers' decision making. Therefore, it is necessary to conduct an empirical analysis based on an econometric model to control these factors.

4. Results and Discussion

4.1. Empirical Results

Table 2 reports the benchmark results using the OLS estimation method. Although the R-squared figures are relatively small, the estimated results of the foul models are robust. The disaster and irrigation conditions and the county dummy variables all had relatively strict exogeneity. Regarding the research method of Mishra et al. [44], the model robustness was tested by eliminating the exogenous variables one by one. In Table 2, Model 4 shows the estimation results of the benchmark model, while Models 1, 2, and 3 show results after eliminating crop disaster, irrigation conditions, and county dummy variables. The estimation results of the benchmark model were robust after eliminating exogenous variables one-by-one and only differed slightly. Therefore, based on the estimates of Model 4, we conclude that growing corn silage can increase farmers' income significantly compared to growing corn grain. The average income of farmers sowing silage maize increased by CNY 76.8 more than corn grain and revealed a highly significant difference (at the 5% level). If this is calculated according to the average income from corn grain (CNY 356/mu), planting corn silage can increase farmers' incomes by 21.6%.

Table 2. The results of corn silage on farmers' income.

Variable	Model 1	Model 2	Model 3	Model 4
Corn silage	0.0963 ***	0.0823 **	0.0676 *	0.0768 **
	(2.608)	(2.269)	(1.926)	(2.101)
Irrigation (base period = groundwater)				
Surface water	0.0101		−0.0126	0.0096
	(0.163)		(−0.270)	(0.156)
Groundwater and surface water	0.0104		0.0507	0.0061
	(0.191)		(1.116)	(0.110)
Rainwater	0.0902		−0.2430	0.0929
	(0.911)		(−0.812)	(1.082)
Disaster		−0.1173 ***	−0.1337 ***	−0.1152 ***
		(−3.580)	(−4.653)	(−3.447)
County dummy variable	yes	yes		yes
Crop characteristics	yes	yes	yes	yes
Household characteristics	yes	yes	yes	yes
Head of household characteristics	yes	yes	yes	yes
Time dummy variable	yes	yes	yes	yes
Constant	0.3656 **	0.4141 **	0.3700 ***	0.4005 **
	(2.140)	(2.444)	(2.609)	(2.335)
Observations	489	495	495	489
R-squared	0.060	0.083	0.070	0.081

Notes: Robust t-statistics in parentheses; * significance at 10%; ** significance at 5%; and *** significance at 1%.

4.2. Identification Strategy and Discussion

The following two situations may lead to the endogeneity of the benchmark model. The first is self-selection bias, where the higher income received by farmers of silage maize is likely due to a higher agricultural production capacity rather than the crop type itself. The second issue may be sample selection bias, where farmers sowing corn silage were more likely to be in our sample. To address this issue and check the stability of the fundamental model, we use two methods.

The first is an instrumental variable method. During the survey, we asked village cadres, "Is it easy for farmers in this village to buy corn silage varieties? (Defined as corn silage variable)". After implementing the GCCP, corn silage varieties sold in the market began to increase, and the yield of corn silage varieties was higher than that of corn grain varieties if farmers eventually harvested the corn silage. Both corn silage and corn grain varieties can be harvested for corn silage, with the former having a higher yield and the latter having less market risk. If a farmer grows corn grain varieties, the farmer can harvest corn grain when the market price of corn silage is low, but if the farmer grows corn silage, he or she can only harvest corn silage. Whether it is easy to buy corn silage in the market is a market behavior that is strictly exogenous to the farm household income, and it is directly related to whether farmers planted corn silage. Therefore, we selected the corn silage variable at the village level as an instrumental variable for corn silage.

The estimated results are presented in the second and third columns of Table 3. The second column shows the results of the first step of the regression of the instrumental variables method, that is, the effect of instrumental variables on whether farmers plant corn silage. It can be seen that the variable of corn silage varieties at the village level significantly affects whether farmers plant corn silage; it is significant at the 1% level. Therefore, we can conclude that the instrumental variables are reasonable in the model. The third column of Table 3 shows that the income of farmers who plant corn silage can increase to CNY 93.6/mu, increasing farmers' incomes by 26.3% per mu. This result is generally consistent with those obtained using the OLS method in the benchmark model; the difference between the two results was only CNY 16.8/mu.

Table 3. The estimation results using instrumental variable and sub-sample methods for regression.

Variable	First Stage	Second Stage	Sub-Sample
	Corn Silage	Farmers' Income	Farmers' Income
Corn silage varieties	0.1637 ***		
	(−3.596)		
Corn silage		0.0936 *	0.0714 *
		(−1.946)	−1.663
County dummy variables	yes	yes	yes
Crop characteristics	yes	yes	yes
Household characteristics	yes	yes	yes
Head of household characteristics	yes	yes	yes
Time dummy variables	yes	yes	yes
Constant	0.4404 **	0.3087 *	0.3534 **
	(−2.091)	(1.774)	(−2.114)
Observations	494	494	244
R-squared	0.0862	0.0264	0.0744

Notes: Robust t-statistics in parentheses; * significance at 10%; ** significance at 5%; and *** significance at 1%. We also removed exogenous variables such as irrigation, disease, and county dummy variables separately in the sub-sample, as we did in Table 2; the estimation results remained robust.

The above instrumental variable may represent the opinion of village cadres, which it is not really an objective measure. To test the robustness of the results, we selected the slope degree at the village level as an instrumental variable. Harvesting silage corn requires large mechanical equipment which requires that the silage not be lodged. The flatter the local terrain, the easier it is to use mechanization, and the less likely it is that corn is planted. The terrain is also an objective exogenous variable, which has little to do with the income of growing corn. The indicators of the slope degree of the land surface at the village level are calculated using elevation data with a resolution of one km. The Resource and Environment Science and Data Centre (https://www.resdc.cn/, accessed on 1 July 2019) provided the elevation data. The slope degree is extracted using the 3D analyst tool of ArcGIS software. The estimated results are presented in Appendix A. The first step of the instrumental variable regression passed the test (see the second column of Table A1), and the results of the second step were also significant at the 10% level (see the third column of Table A1), indicating that the value of planted corn silage was CNY 164.5 per mu higher than corn grain maize. This was higher than the result from using "Corn silage varieties" as the instrumental variable by CNY 70.9 per mu.

The second method selects subsamples that do not have endogeneity to check for stability. When we conducted the questionnaire survey, we found that most farmers had not decided whether to sell corn silage or corn grain at sowing. Generally, if farmers plant corn silage varieties, they have no choice but to harvest corn silage. Conversely, farmers who plant corn grain varieties can choose to harvest corn grain or silage. Therefore, most farmers prefer to plant corn grain varieties and decide whether to harvest corn grain or silage according to market prices during the harvest period. Market prices are completely exogenous; therefore, it is difficult for farmers to predict the price of either type of corn in the current year. Based on this, if we only sample those using corn grain varieties, the self-selection problem is eliminated. Therefore, corn grain farmers can be used to check the robustness of the full sample results. Unfortunately, we only collected the corn varieties grown by farmers in Hebei province in 2018; we modified the questionnaire in Henan province in 2019. As it was found that there were too few farmers planting corn silage varieties in Hebei province, we only investigated the form of farmers' harvested corn (that is, whether it was corn silage or corn grain) in Henan province. Hence, we only used farmers of corn grain varieties in Hebei province for the regression analysis.

According to our survey data, 90.1% of farmers in Hebei Province grew corn varieties. Next, we use only the farmers in the Hebei province sample who grow grain varieties for the regression analysis; the results are shown in the third column of Table 3. The regression results are very close to those of the full sample. It can be seen that corn silage can increase farmers' income by CNY 71.4/mu, which is only CNY 5.4/mu lower than the full-sample regression result and is significant at the 10% level. In addition, we tested the robustness of the results by using the propensity score matching (PSM) method [45]. The estimation results are shown in the Appendices B and C. Table A2 shows the results of the parallelism test, and Table A3 shows the final estimation results. The results show that corn silage increased farm income by CNY 101/mu on average; the estimation results were similar to those of the previous methods, further indicating the robustness of the estimation results.

Using the estimation results of the different methods mentioned above, we can conclude that planting corn silage can increase income by CNY 76.8–164.5 per mu compared to planting corn grain, with an average of CNY 101.6 per mu.

5. Further Analysis

5.1. Effects of Corn Silage on Production Cost

Corn silage requires significantly different agricultural production techniques and management than corn grain. First, the harvest times are different; the optimal harvest time of corn silage is earlier than that of corn grain. Second, the harvest requirements are different. Corn silage has requirements related to stubble height, moisture content, and dry matter content at harvest. Moreover, small farmers do not have special machinery for harvesting corn silage and, in most cases, need to purchase machinery services from large farmers or livestock farms. Therefore, farmers may make corresponding adjustments to production management, the input of production materials, labor input, and socialized service purchasing after changing corn silage planting, thus influencing their production costs. Therefore, an increase in the net income of farming households may be caused by a decrease in production costs. To verify this, we selected farmers' capital inputs and labor inputs as proxy variables for production costs and used OLS models to study the effect of growing corn silage on the production cost of growing maize. In this study, production costs mainly refer to capital and labor inputs. The former mainly covers farmers' expenditures for seeds, fertilizers, pesticides, and purchasing machinery services. The latter mainly covers the total input of labor by family members.

Table 4 shows the regression results. The second column in Table 4 shows the estimated effect of corn silage on capital costs. The results show that corn silage decreased the capital cost of farmers by 10.71%, on average, compared to corn grain, with the result being highly significant at the 1% level. According to the calculation of capital input for corn grain (CNY 412/mu), corn silage decreased capital input by CNY 44/mu. The third column in Table 4 shows the estimated effect of silage on labor input. The results show that corn silage decreased labor input by an average of 26.62% compared to corn grain. According to the average labor input for corn grain (3.37 days), corn silage can save approximately 0.90 days of labor input, on average, per mu. The costs of capital and labor are almost the entire input cost for a farmer. The two estimates above show that farmers can significantly reduce the cost of sowing corn silage compared with corn grain.

Table 4. Effects of corn silage on farmers' production cost.

Variable	Capital Cost	Labor Cost
Corn silage	−0.1071 ***	−0.2662 ***
	(−2.641)	(−2.761)
Crop characteristics	yes	yes
Household characteristics	yes	yes
Head of household characteristics	yes	yes
County dummy variables	yes	yes
Time dummy variables	yes	yes
Constant	−1.0014 ***	1.5269 ***
	(−5.492)	(3.414)
Observations	499	491
R-squared	0.097	0.531

Notes: Robust t-statistics in parentheses; *** significance at 1%. Capital input refers to the production cost other than labor input, including the total cost of pesticides and fertilizers, irrigation, seeds, purchase of machinery and services, etc. (unit: CNY 1000/mu). Labor input is the sum of one's family labor inputs in the production process of corn from tillage to harvest (unit: day/mu; 1 day = 8 h). The capital cost and labor cost are taken logarithmically.

5.2. Heterogeneity Analysis: Farm-Scale and Distance to a Dairy Farm

Farm size affects the technical efficiency of production and income [43,46,47], and is referred to as the scale effect in agricultural economics. Compared with corn grain, corn silage requires large professional machines during harvesting, thus imposing higher requirements on the land scale. We wanted to determine whether the effect of corn silage on income has a scale effect at different sowing sizes; that is, do farms with a larger sowing area experience a greater effect of corn silage on income? To explore this question, we divided the farmer samples equally into three groups according to the sowing area of corn. Farmers with less than or equivalent to 12 mu of corn planting were defined as the small-scale group. Farmers with 12–26 mu of corn planting were defined as the mid-scale group. Farmers with 27 mu or more of corn planting were defined as the large-scale group. The effects of corn silage on the incomes of the different groups were estimated using an OLS model.

Columns 2−4 of Table 5 report the results of the impact of corn silage on income at small, medium, and large scales, respectively. The results show that the effect of corn silage on farmers' income varies according to farm scale. Corn silage increased the income of the large-scale group by 29.9%, which is significant at the 10% level. However, the income growth of the small-scale and mid-scale groups was not significant. Therefore, we can conclude that farmers who plant corn silage on a large scale are more affected by the GCCP.

The main purpose of the subsidy program is to motivate farming households near livestock farms to produce corn silage by providing subsidies to livestock farms and increasing their feed demand. As a result of traffic and information gathering costs, livestock farms first consider purchasing corn silage from nearby farmers. After dairy farms receive financial subsidies, their demand for corn silage inevitably increases. Therefore, farmers who are closer to dairy farms are more affected by policy interventions. To test this hypothesis, we divided all samples into two groups: (1) farmers whose villages contained dairy farms (Group A), and (2) those whose villages did not (Group B). We estimated the effect of corn silage on income separately for these two groups using OLS models.

Table 5. Estimated effects of corn silage on farmers' income at different scales.

Variable	Small-Scale	Mid-Scale	Large-Scale
Corn silage	0.304	−0.065	0.299 *
	(−1.458)	(−0.467)	(−1.676)
Crop characteristics	yes	yes	yes
Household characteristics	yes	yes	yes
Head of household characteristics	yes	yes	yes
County variables	yes	yes	yes
Time dummy variables	yes	yes	yes
Constant	−0.330	−0.310	0.032
	−0.330	−0.310	0.032
Observations	173	156	159
R-squared	0.206	0.315	0.198

Notes: Robust t-statistics in parentheses; * significance at 10%.

Table 6 presents the estimated results. The second and third columns in Table 6 show the estimates for groups A and B, respectively. Corn silage increased the income of group A by 31.4%, which was highly significant at the 5% level. However, income growth was not significant in Group B. Therefore, we conclude that farmers closer to dairy farms have a more obvious overflow effect from the GCCP and obtain a higher income.

Table 6. Estimated effects of corn silage on income at different distances to dairy farms.

Variable	Group A	Group B
Corn silage	0.314 **	−0.027
	(−2.106)	(−0.241)
Crop characteristics	yes	yes
Household characteristics	yes	yes
Head of household characteristics	yes	yes
County dummy variables	yes	yes
Time dummy variables	yes	yes
Constant	−1.127 **	−1.062 ***
	(1.982)	(2.982)
Observations	203	232
R-squared	0.107	0.123

Notes: Robust t-statistics in parentheses; ** significance at 5%; and *** significance at 1%.

6. Conclusions and Implications

Based on a survey of GCCP pilot areas in Hebei and Henan provinces, China, we conducted a detailed analysis of the impact of farming corn silage on farmers' income. Further, we explored the impact of corn silage on farmers' production costs, as well as heterogeneity in terms of both the size of corn farms and their distance from a dairy farm. Three major conclusions were drawn. First, compared to corn grain, corn silage can significantly increase farmers' income. According to the estimation results of the different methods, corn silage can increase farmers' corn income by approximately CNY 101 per mu. Thus, from an income perspective, the GCCP achieved one of its policy objectives. Second, corn silage can lower farmers' production costs more significantly than corn grain. Heterogeneity analysis demonstrated that corn silage can decrease capital input and labor input. This finding is consistent with observations made during our survey that the field management required for growing corn silage is relatively simple, and that farmers do not need to make significant investments in capital and labor. Farmers in China cultivate relatively small areas of arable land, and most do not earn much from corn cultivation. Thus, many farmers plant corn silage to save labor on other jobs. In addition, corn silage depends more on large machinery, which can further reduce a farmer's labor input. Third, farmers with large farms and those near livestock farms are influenced more significantly by the GCCP.

The GCCP encourages farmers to grow corn silage by subsidizing farmers, which is important for the adjustment of planting structure and the green transformation and sustainable development of agriculture in China. In this study, we found that farmers' income increase is the main reason they adjust their planting structures to plant silage maize. Based on the above conclusions, we have three suggestions. First, the GCCP should be continuously promoted, especially in areas with large livestock farms. Second, the scale effect can be improved by encouraging farmland transfers near livestock farms. Third, support should be given to the research and development of high-quality corn silage varieties. At present, the proportion of Chinese farmers that grow corn silage varieties is relatively low.

It should be noted that this study only measured the direct influence of corn silage on farmers' incomes from growing corn. The GCCP might have an indirect influence on farmers' income. For example, corn silage can decrease labor input and thereby promote labor transfer of farmers to increase the non-agricultural income of farming households. Such indirect effects require further discussion and are beyond the scope of this study.

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Appendix A

Table A1. The estimation results using topographic slope at the village-level as an instrumental variable.

Variable	First Stage	Second Stage
	Corn Silage	Farmers' Income
Slope degree	−1.718 ***	
	(−5.58)	
Corn silage		0.1645 *
		(−1.906)
County dummy variables	yes	yes
Crop characteristics	yes	yes
Household characteristics	yes	yes
Head of household characteristics	yes	yes
Time dummy variables	yes	yes
Constant	0.647 **	0.295 **
	(−3.04)	(2.04)
Observations	483	483
R-squared	0.1433	0.00558

Notes: Robust t-statistics in parentheses; * significance at 10%; ** significance at 5%; and *** significance at 1%.

Appendix B

Table A2. The sample mean difference of control variables before and after matching.

Variable	Before			After		
	Control Group	Treatment Group	Difference (*t*-Test)	Control Group	Treatment Group	Difference (*t*-Test)
Disaster	0.337	0.413	−1.670 *	0.353	0.335	0.34
Farm size	3.432	2.84	5.200 ***	3.239	3.32	−0.65
Household size	4.298	4.498	−1.29	4.27	4.527	−1.3
Gender	0.051	0.085	−1.42	0.054	0.024	1.41
Age	53.517	55.448	−2.030 **	54.036	54.593	−0.54
Primary school	0.208	0.202	0.16	0.222	0.15	1.69
Junior high school	0.573	0.498	1.6	0.569	0.641	−1.34
Senior high school	0.157	0.237	−2.090 *	0.15	0.18	−0.74
Health	0.854	0.833	0.61	0.85	0.88	−0.8
CPC membership	0.157	0.211	−1.47	0.138	0.108	0.83
Non-agricultural employment	0.506	0.451	1.17	0.491	0.509	−0.33
Dairy farm location	0.478	0.274	4.640***	0.449	0.377	1.33
County dummy variable		Omitted			Omitted	

Notes: * significance at 10%; ** significance at 5%; and *** significance at 1%.

Appendix C

Table A3. The results of average treatment effects.

Matching Method	Control Group	Treatment Group	Difference	Standard Deviation	*t*-Value
Nearest-neighbor matching (one-to-one matching)	0.447	0.347	0.101	0.046	2.180
Nearest-neighbor matching (one-to-three matching)	0.447	0.342	0.105	0.044	2.420
Kernel matching (bandwidth = 0.06)	0.447	0.351	0.096	0.042	2.280

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