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Does the Agricultural Productive Service Embedded Affect Farmers' Family Economic Welfare Enhancement? An Empirical Analysis in Black Soil Region in China

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Abstract: The modernization of agriculture in China has begun to take shape, but some groups of farmers still have relatively weak access to welfare and live in poverty, which is closely related to national food security and sustainable agricultural development. Based on survey data from northeastern China, this study analyzes the logical framework of "Agricultural Productive Services (APS) Embedded—Farmers' Family Economic Welfare Enhancement" by the endogenous switching regression model. The main findings are as follows. First, the purchase of APS brings a significant positive impact on farmers' family economic welfare improvement, mainly through the income effect and the substitution effect. Second, with the income effect, there are significant differences in the strength of the "pulling power" of different forms of APS for farmers' family economic welfare. Compared with farmers who purchase APS for the entire production chain, farmers who purchase only some of the services are more likely to increase their welfare in the later stages. Third, with the substitution effect, the re-employment behavior of the rural surplus laborers who are "squeezed out" under the embedding of APS is promoted, which makes farmers' income channels, income types, and income opportunities diversify, and their welfare will be more obviously strengthened after purchasing services. In order to enhance farmers' welfare more efficiently and meet their needs for a better life, this study suggests a combination of farmer information archiving and labor market information transparency to reduce service risks, expand employment channels, and enhance the effectiveness of the linkage between farmers and service providers.

Keywords: APS embedded; farmers' welfare; endogenous switching regression model; agricultural sustainability

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1. Introduction

The level of welfare is an important evaluation basis for measuring whether a country or region's economic growth is effectively translated into people's well-being, and is a key factor in maintaining peace, stability, and sustainable development [1–3]. Since China's reform and opening up in 1978, the country has experienced 44 years of breakthroughs in total economic output and a significant increase in comprehensive national power, with total GDP growing rapidly from 367.87 billion yuan in 1978 to 113,323.98 billion yuan in 2021, and the international ranking of total economic output has also improved [Source: Statistical Yearbook of the National Bureau of Statistics]. However, behind this "super-speedy" development, the social problems hidden under the surface of economic prosperity are more worthy of attention. The inequality between the urban and rural economy [4,5], the widening income gap [6], the rough economic growth [7], the deterioration of the ecological environment, and a series of other problems have come to the fore [8,9], and the quality and efficiency of development are difficult to balance effectively, meaning the welfare situation of this group of Chinese farmers still has more outstanding problems. China is a large agricultural country and small-scale farmers are the basic unit of agricultural

operation [10]. By the end of 2020, China announced that all rural poor under the current standard will be out of poverty, which marks that absolute poverty and regional poverty have been effectively addressed, but there are still relative poverty and marginalized people. Moreover, China's Gini coefficient in 2020 has reached 0.468, the highest value since 2015 [Source: Statistical Yearbook of the National Bureau of Statistics], exceeding the internationally accepted alert line for fair income distribution [11]. The problems of urban–rural income inequality and excessive income disparity still exist. Labor mobility for the purpose of working is an important way to strengthen the self-reliance and endogenous development motivation of rural families. However, whether the redistribution of rural labor resources is conducive to the improvement of welfare levels and whether it can play a role in promoting sustainable income growth needs to be further verified.

With the development of industrialization and urbanization, quality labor can receive more pay for working in cities than in farming, and the employment market of secondary and tertiary industries in China is more attractive to young laborers from rural areas [12–14]. However, due to the high degree of land fragmentation, low level of education, and lack of capital flow that prevails in rural areas of China, too much of the labor force is "fixed" in agricultural activities, depriving them of certain opportunities to expand their sources of income [15,16]. In addition, agricultural production is an important means of sustaining livelihoods for a relatively low-quality group of farmers who lack skill-based knowledge and are in poor health. Although it is difficult for this group of farmers to earn off-farm income, the labor substitution effect generated in the process will increase their overall "leisure" time and effectively reduce the burden of living as APS become more embedded. In this dilemma, the development of the APS industry has enhanced the value-addedness and divisibility of each link in the agricultural industry chain, deepened the division of labor in the agricultural field, and can effectively solve the two major problems of economy of scale and labor redistribution [17–20]. In recent years, the release of a number of policy documents has released the government's determination to support the development of the APS industry. In 2019, the "No. 1 Document" of the Central Government clearly proposed to promote farmers' income with APS; in 2021, the Ministry of Agriculture and Rural Affairs issued the "Guidance on Accelerating the Development of APS", which once again clearly pointed out that the development of APS is an important initiative to enhance farmers' family economic welfare and social and ecological welfare.

At present, the existing academic literature on farmers' welfare studies mainly focuses on the following aspects. First, several scholars have constructed appropriate indicator systems to integrate the inter-relationships among economic, ecological, and social subsystems to comprehensively measure farmers' welfare levels [21]. However, there is no unified view on the measurement of welfare and, in general, it can be classified from two perspectives: macroscopic, which usually uses GDP indicators to refer to the level of socioeconomic welfare, and microscopic, which usually uses indicators such as income, consumption levels, and food expenditure ratios to measure [22–26]. Second, studies on the factors influencing farmers' welfare are mainly multidimensional, taking into account the role of environmental, economic, and social life aspects in a comprehensive manner. The results show that factors such as labor market development, regional economic status, residential ecology, poverty status, psychological status, nutritional intake, government transfer payments, financial constraints, and production methods all have an impact on the welfare level of individuals and the country as a whole [27–31]. Third, theoretical studies on welfare have focused on the perspectives of "income", "utility", and "function and capacity", covering a wide range of economic, psychological, and ecological fields [32,33]. Fourth, in terms of the use of research methods, existing studies mostly use correlation analysis or general simple linear regression models for analysis, while some studies also use randomized experimental control methods for research [34,35]. Using data from Bangladesh, Ahmed et al. analyzed the impact of labor allocation on income and profitability, concluding that machinery substitution enhances the impact of income effects and increases farmers' income [36]. Huang et al. verify that urbanization development

raises farmers' income by increasing wage income through driving labor allocation based on panel data from China [37].

From the summary and generalization of the existing literature, it is found that the existing studies do not go deep enough into the factor of labor allocation, which is an important and non-negligible role in exploring the influence of APS embedding on farmers' family economic welfare and is a research topic that needs to be discussed in depth. Therefore, this paper makes marginal contributions in the following areas. First, this study highlights the importance of labor allocation in the process of farmers' welfare level improvement and verifies the substitution role of labor redistribution that occurs within families. It also provides further insight into how the effect of whether or not the purchase of external services brings about the level of economic welfare under the influence of interventions in the distribution of labor within farmer families. Second, unlike the simple linear regression model used by most previous scholars, this study incorporates the issue of endogeneity into the econometric analysis. This is due to the fact that the effect of APS on economic welfare inherently has the problem of sample self-selection, and the counterfactual state is difficult to obtain [38]. Applying traditional econometric regression models and quantitative analysis is difficult to reflect this counterfactual state scientifically and needs to be considered in combination with methods that can deal with endogeneity.

Therefore, a more in-depth exploration of whether APS can improve the level of farmers' family economic welfare from the perspective of labor allocation will not only help clarify the formation mechanism and constraints of the economic level, but also help promote the formulation and promotion of more targeted APS industry-related policies, and help promote sustainable agricultural development and stable and healthy national economic development. This study will construct the theoretical logic of "APS embedding—farmers' family economic welfare enhancement" based on the farmers' family model theory and biased technological progress theory, reveal the heterogeneous effects of different forms of APS on welfare enhancement, and discuss the path process of labor allocation stimulation of welfare growth under the influence of APS—generated intervention. Among them, the farmer's family model theory can clearly explain the impact of the income effect on welfare, and the biased technological progress theory can explain the effect of APS on welfare driven by labor allocation from the perspective of substitution, and the use of these two theories can better uncover the inner mechanism in the impact path and better clarify the connection between the three terms of "service, labor, welfare". Therefore, this study uses empirical analysis of farmer data obtained from field research in three major grain-producing provinces in northeastern China to construct counterfactual predictions of the effects on welfare levels, and uses Stata SE16.0, a statistical econometric software, to conduct treatment effects analysis. Theoretically, this study enriches the research on farmers' welfare, extends the application of the theory of biased technological progress, and extracts the intervention factor of APS from the complex correlated elements for analysis, providing new reference implications for later research on farmers' welfare.

2. Theoretical Analysis

The theory of the farmers' family model, which mainly describes the correlation between the general and individual behavior of farmers, is similar to the principle of the general equilibrium model and was first proposed by Russian agricultural economist A.V. Chayanov. Kennedy further integrates the theory of biased technological progress with related theories and proposes a two-factor model with constant relative prices, which will lead to a reallocation of labor and capital factors to reach an equilibrium when the allocation ratio between the two factors is out of equilibrium [39]. Specifically, the farmers' model theory has been applied to the impact of external interventions on farmers' interests and behaviors, and the impact of external interventions on farmers' "spillover effects" with other sectors [40,41]. Worldwide, academic research with reference to the analytical framework of the biased theory of technological progress has been widely applied to sociological issues, economics, biology, agronomy, and other interdisciplinary disciplines [42–45]. Existing

studies have achieved many valuable academic results by applying the theory of the farmers' family model and the theory of biased technological progress, which have laid a solid foundation for this study. On this basis, this study constructs a two-level theoretical analysis framework of "APS embedding—impact mechanism—farmers' family economic welfare enhancement" based on the income effect and substitution effect, as shown in Figure 1.

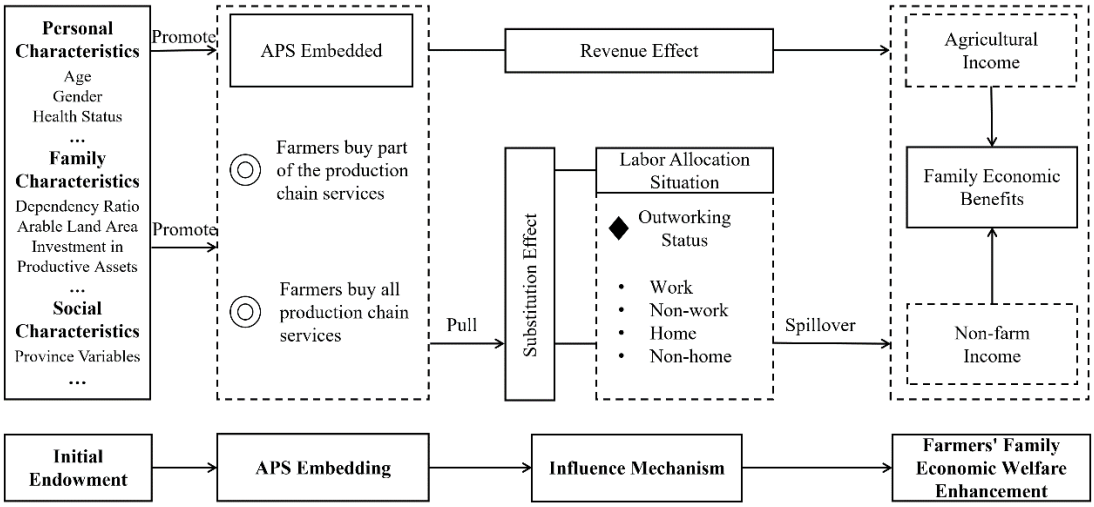

Figure 1. A two-level theoretical framework for "APS embedding—farmers' family economic welfare enhancement".

2.1. Analysis of the Revenue Effect Level of "Agricultural Productive Services Embedding—Farmers' Family Economic Welfare Enhancement"

Farmers' family economic welfare mainly includes basic agricultural production and operation income, wage income, property income, and transfer income obtained from government transfer payments. Combining the idea of general equilibrium in the theory of the farmers' home model and the view of finite rational actors, farmers spontaneously choose whether to purchase APS, with the ultimate goal of improving economic utility and maximizing total family income and welfare level through resource allocation renewal [46–49]. Drawing on Chayanov's equilibrium equation of farmers' labor—consumption and the farmers' family model, this study develops the following analysis of the income effects [50,51]. For the purpose of the analysis, this study assumes that farmers face a well-established regional factor market and simplifies its objective to maximize the returns to agricultural production and operation. In addition, it is also assumed that farmers only engage in agricultural production, leaving off-farm employment out of the equation for the time being, and does not distinguish between types of agricultural crops. The improvement of agricultural production and operation income brought on by farmers' purchase of APS can be clarified mainly from the following perspectives. First, farmers will save agricultural production costs and improve production efficiency after purchasing APS. The main reason is that the servicer provides supporting transportation services, distribution services, etc., which save the input of agricultural production materials and labor. In addition, through the input of agricultural machinery, it can have faster work efficiency compared to manual labor. The crop production process has strict requirements for farming time, and traditional human sowing and harvesting are gradually eliminated in the process of agricultural mechanization, which has higher time and efficiency guarantees than manual labor. Second, APS interventions are also a process of "unconscious" dissemination and diffusion of knowledge, information, and technology. In the process of providing APS, service providers bring to farmers the use of technologies such as seed selection and soil testing and fertilization, which improve agricultural productivity and increase farmers' income. Based on the above analysis, Hypothesis 1 is proposed:

Hypothesis 1. *The purchase of APS had a significant direct positive impact on farmers' family economic welfare enhancement.*

2.2. Analysis of the Substitution Effect Level of "Agricultural Productive Services Embedding—Farmers' Family Economic Welfare Enhancement"

The theoretical framework of biased technological progress provides an assumption that innovation is propensity-based, and Acemoglu and Restrpo combine this theory with the "task approach" to give the framework a more rigorous mathematical form [52]. This analytical framework has been applied to research areas such as energy processing, carbon emissions and efficiency, and worker income issues in the digital economy [53–56]. In the agricultural sector, the purchase of APS by farmers in the process of agricultural production is essentially a technological substitution, a change in the way production factors is combined [57,58]. After purchasing APS, farmers are stimulated by labor market price signals to redistribute the surplus labor "squeezed out" by the use of agricultural machinery, freeing up family labor and facilitating the redistribution of work hours and types of work within farmers' families. That is, the embedding of APS allows families with diverse labor resources to expand their sources of wage income and have more opportunities to upgrade their farmers' family economic welfare. Farmers can choose to purchase and use services in different production stages before, during, and after production. For rural families with a part-time nature, who prefer to invest their labor capital in the more remunerative non-agricultural sector, the embeddedness of APS provides them with greater convenience. This study builds on previous academic literature and adopts a biased technological progress theoretical framework under which farmers' purchase of APS is considered as a technological innovation. On this basis, this study explores the substitution effect of APS intervention on labor allocation and the impact on farmers' family economic welfare enhancement. Based on the above theoretical analysis, Hypothesis 2 was formulated:

Hypothesis 2. *Labor allocation has a significant direct positive effect on farmers' family economic welfare levels.*

3. Materials and Methods

3.1. Study Areas

To validate the two-level analytical framework of "APS embedding—farmers' family economic welfare enhancement", the research team conducted a survey of maize-based farmers in northeastern China in July and August 2018. This study area was selected for the following reasons (see Figure 2). First, it is the main distribution area of black soil in China. In 2017, China's Ministry of Agriculture, National Development and Reform Commission, and Ministry of Finance jointly issued the Guidance Opinions on Accelerating the Development of the APS Industry. The Opinions point out that the development of the APS industry has a significant role in promoting the modernization of agricultural production and operation and the integration of rural industries [59]. The APS industry has been developed in the northeastern region, which is a typical "one-year maturity zone", with corn, rice, and soybeans being the main crops, and is an important commodity grain-production base in China, coupled with the advantage of plain terrain. Second, in Liaoning and Jilin provinces, for example, the annual per capita disposable income and annual per capita consumption expenditure of farmers in rural areas are generally in a state of imbalance, and the expenditure on agricultural production and operation accounts for a low proportion of total expenditure, which indicates that the overall welfare level is poor, the efficiency of agricultural production has not been well released, and the farmers' family economic welfare level still needs further improvement. Third, from the annual statistics made public by the Liaoning Provincial Bureau of Statistics, farmers' annual non-farm employment length basically remains at 9–10 months, and their non-farm income also shows a trend of increasing year by year, from 6905 dollars in 2009 to 15,740 dollars in

2020, which is a common status quo in the rural areas of northeast China. The emergence and development of the APS industry in the main grain-producing areas of northeastern China are an important grasp to alleviate agricultural production problems, such as labor turnover, and an effective means to improve agricultural production efficiency. Fourth, as one of the three major black soil distribution areas in the world, the black soil area in northeastern China includes all of Heilongjiang and Jilin provinces, the northern part of Liaoning province, and a few eastern parts of Inner Mongolia. This type of soil is rich in organic matter and can provide enough nutrients for the growth of crops. Therefore, this agricultural region has a collection of ecological and economic advantages, and the investigation activities based on this region can better clarify the ideas of farmers' family economic welfare level improvement and provide help for the healthy development of the agricultural economy.

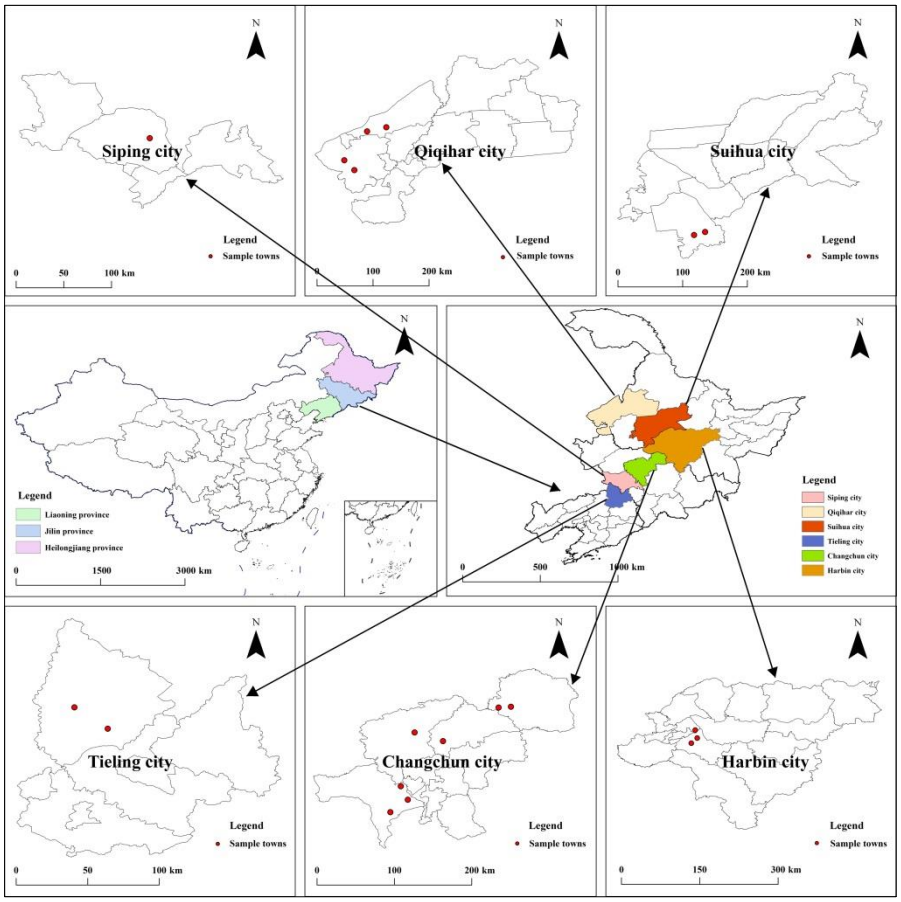

Figure 2. Map of the study area and spatial distribution of the sample villages.

3.2. Data Collection and Processing

In order to ensure the rigor, science, and credibility of the sampling process, this study has undergone in-depth discussion and consideration on the process design, questionnaire design, and sampling method design of each step in the survey process. In the design process of the pre-study, the research team was all based on the objectives, theories, and logical framework of this study as the main clues, and also took into account the sample characteristics of the research area, the level of economic development, the characteristics of the ecological resources, and the differences in geographical location and other influencing factors, and carried out the preparation of the research in a comprehensive manner. During the spring of 2018, in order to verify the adequacy of the research preparation, the research team selected rural areas in Tieling City, Liaoning Province, to conduct a small-scale pre-survey. The research team promptly revised and improved the inappropriately phrased

questions through feedback and went through another round of expert discussions to form the final version of the research questionnaire. The questionnaire survey designed for this study was conducted from both village collective and farmer perspectives, and the survey mainly included basic information on family demographics, family production and operation, agricultural production chain, APS selection, and family income structure of the sample farmers. The research method is adopted in the form of offline research, and the one-on-one interview method of "entering the house to take samples" is chosen to avoid the drawback of high "misreporting" of the online questionnaire. The entire survey process upholds the principle of rigor, the investigators are scientifically trained, strictly avoiding induced questions and other "noise" prone survey methods, to maintain the integrity of the questionnaire information obtained and the scientific nature. The survey was conducted using a stratified sampling method, and the sampling process was as follows. First, the sampling method was determined after meeting discussions by combining the agricultural production statistics released by the National Bureau of Statistics and the accumulated expertise within the discipline. Second, the typical agricultural production areas of Harbin City, Heilongjiang Province, Siping City, Jilin Province, and Tieling City, Liaoning Province (see Figure 2) were selected as the research provinces among the provincial administrative regions in China. Third, the sample was selected by a combination of typical sampling methods and random sampling, and each sample municipality collected 2–3 townships with relatively active APS industries, and a total of 16 sample townships and 43 villages were selected (see Table 1).

Table 1. Selection of research areas for the sample of farmers.

Province	City	County	Samples (n)	Proportion (%) [a]
Heilongjiang	Harbin	Acheng	46	68.6
		Daowai	21	31.4
	Qiqihaer	Longjiang	104	65.0
		Gannan	56	35.0
	Suihua	Zhaodong	125	100.0
Jilin	Siping	Lishu	96	52.1
		Gongzhuling	102	34.0
	Changchun	Dehui	80	26.6
		Jiutai	74	24.6
		Yushu	44	14.8
Liaoning	Tieling	Changtu	234	100.0
Total			982	

[a]: The formula for calculating the proportion in the table is (number of samples at the county level/number of samples at the municipal level × 100).

In conducting the questionnaire design session, the research team focused on extracting farmers' personal characteristics, family production and business characteristics, information on inputs of production materials in the maize-growing process, as well as farmers' purchase of APS and farmers' family economic welfare status according to the theoretical analysis framework of this study. We also categorized the forms of services purchased by farmers into growing their own, outsourcing part of the process, and outsourcing all of the process, and presented detailed information on farmers' purchases of APS. Among the 982 samples studied, 954 valid samples were finally obtained by removing samples with missing data and outliers. The basic characteristics of the farmers are shown in Table 2.

Table 2. Basic characteristics of sample (Unit: farmer, %).

Index	Value	Freq	Prop	Index	Value	Freq	Prop
Gender	Male	903	94.60	Service Purchase	Signed	790	82.81
	Female	51	5.40		Unsigned	164	17.19
Age	18–40 years old	75	7.87	Professional Skills	Possession	194	20.34
	41–63 years old	644	67.50		None	760	79.66
	64–86 years old	235	24.63	Family Welfare Level	≤CNY10,000	320	33.54
Education	No degree	459	48.11		CNY10,000–20,000	341	35.74
	Primary school	417	43.71		CNY20,000–30,000	170	17.82
	Secondary schools	73	7.65		>CNY30,000	123	12.90
	Bachelor's Degree	5	0.53	Number of Areas Affected	0 Times	122	12.79
Health Status	Extremely unhealthy	15	1.58		1 Times	261	27.36
	Relatively unhealthy	86	9.01		2–5 Times	569	59.64
	Ordinary state	115	12.05		5 Times or More	2	0.21
	Relatively healthy	493	51.68	Agricultural Machinery Situation	Possess	508	53.25
	Extremely healthy	245	25.68		Not owned	446	46.75

3.3. Research Methods

3.3.1. Endogenous Switching Regression Model

The endogenous switching regression model proposed by Maddala has several advantages over other econometric models, such as simple linear regression models and structural equation models, in dealing with selectivity bias and endogeneity [60–62]. First, it can realize the construction of unobservable factors in the counterfactual analysis process. In the process of acquiring sample data, it is often difficult for us to observe the sample situation on the spatial and temporal layers when the event has not occurred. The endogenous switching regression model can focus on the sample situation in two states at the same time, which makes up for the deficiency that Heckman and other regression models can only analyze the relationship between variables from the perspective of the observed terms. Second, this model can perform great likelihood estimation under full information conditions and obtain consistent standard errors. Unlike the traditional maximum likelihood estimation and two-stage least squares method, the endogenous switching regression model can estimate both the binary choice model and the continuous numerical model, which in turn improves the validity of the parameters and enhances the scientific validity of the study. Third, in this study, the farmers' purchases of APS are immediate behaviors, which are counterfactual in character at a point in time. Using endogenous switching regression for welfare effects analysis can effectively address the self-selection problem and endogeneity of the sample, taking into account the effects brought on by both observable and unobservable factors. This advantage compensates for the lack of the counterfactual analysis capability of models such as structural equations, which have a more rigorous character.

Endogenous switching regression models generally include two stages of estimation [63–65]. In the first stage, the Probit model is used to estimate the farmers' choice equation for purchasing APS, which in turn is used to identify the major factors that determine the farmers' purchase of APS. Our estimation of the choice equation is as follows:

$$D_i = \gamma Z_i + KI_i + \mu_i \quad (1)$$

where D_i is a binary variable that takes the value of 1 if the farmer purchases APS and 0 otherwise; Z_i is a vector of exogenous variables that influence the farmers to make purchase decisions; I_i is a vector of instrumental variables to ensure the identifiability

of the model; and γ is a vector of coefficients, μ_i is a disturbance term with zero mean and constant variance. It is worth noting that the ease of the farmers' access to APS at the regional scale was selected as an instrumental variable in this study and included in the model of the farmers' product service decisions because this variable only affects the farmers' decisions to purchase APS and does not directly affect the farmers' welfare levels.

In the second stage of the endogenous switching regression model, the equation for determining the farmers' family economic welfare is established, while full information maximum likelihood (FIML) estimation is applied to reduce the error due to potential selection bias and further capture the change in welfare level due to the farmers' purchase of APS. The binary outcome (the economic welfare level) conditional on the purchase of APS is expressed as the following transformation regime:

$$\text{Regime 1 (Purchase Services)}: \ Y_{im} = X\beta_{im} + \varepsilon_{im} \text{ if } D_i = 1 \tag{2}$$

$$\text{Regime 2 (No service purchased)}: \ Y_{in} = X\beta_{in} + \varepsilon_{in} \text{ if } D_i = 0 \tag{3}$$

where Y_{im} and Y_{in} are outcome variables for the farmers who purchased APS and those who did not, respectively, and X is a set of factors that influence the farmers' decision-making, including individual characteristics, family characteristics, and other aspects. The vectors β in Equations (2) and (3) are the correlation coefficients to be determined.

Since the purchase of APS or not depends on the farmers themselves, there may be a non-zero variance between the error term of the decision to purchase the service and the outcome equation. Assume that the error term in the response function and the threshold equation $(\varepsilon_{im}, \varepsilon_{in}, \mu_i)'$ is in the form of a normal distribution with zero mean. Its covariance matrix is assumed to be Σ, which takes the form of:

$$\Sigma = \begin{bmatrix} \sigma_n^2 & \sigma_{nm} & \sigma_{n\mu} \\ \sigma_{nm} & \sigma_m^2 & \sigma_{m\mu} \\ \sigma_{n\mu} & \sigma_{m\mu} & \sigma_\mu^2 \end{bmatrix} \tag{4}$$

This study focuses on the estimation of the average treatment effect, i.e., the change in the level of the farmers' family economic welfare triggered by the farmers' purchase of APS, which is reflected as the difference between purchased and unpurchased services. The average treatment effect is expressed as ATT (average treatment effect on treated), as shown in Equations (5)–(8). The equations for the expected conditions and the average treatment effect for the farmers who purchased APS and those who did not purchase APS are:

$$E[Y_{im}|D_i = 1] = \beta_m X_{im} + \sigma_{\mu m}\lambda_{im} \tag{5}$$

$$E[Y_{in}|D_i = 0] = \beta_{in} X_{in} + \sigma_{\mu n}\lambda_{in} \tag{6}$$

$$E[Y_{in}|D_i = 1] = \beta_{in} X_{in} + \sigma_{\mu n}\lambda_{in} \tag{7}$$

$$E[Y_{im}|D_i = 0] = \beta_m X_{im} + \sigma_{\mu m}\lambda_{im} \tag{8}$$

Then, the average treatment effect of the farmers' family economic welfare of the farmers who actually choose APS, i.e., the average treatment effect ATT of the treatment group, can be expressed as the difference between Equations (5) and (7):

$$ATT_i = E[Y_{im}|D_i = 1] - E[Y_{in}|D_i = 1] = (\beta_m - \beta_n)X_{im} + (\sigma_{um} - \sigma_{un})\lambda_{im} \tag{9}$$

Correspondingly, the average treatment effect on the farmers' family economic welfare status of the farmers who did not choose APS, i.e., the average treatment effect on untreated (ATU) for the control group, can be expressed as the difference between Equations (6) and (8):

$$ATU_i = E[Y_{in}|A_i = 0] - E[Y_{im}|A_i = 0] = (\beta_n - \beta_m)X_{in} + (\sigma_{un} - \sigma_{\mu\mathrm{m}})\lambda_{in} \tag{10}$$

In Equations (9) and (10), σ and λ are the covariance of the error term ε_i and the inverse Mills ratio, respectively. The interpretation of the results of the treatment effect is to observe the farmers' family economic welfare. By analyzing the mean of ATT and ATU, it is possible to examine both the effect of APS on the mean of welfare and to observe the differential effect of heterogeneity of APS and farmer groups on welfare.

3.3.2. Variable Selection

First, according to the model setting and theoretical analysis, the explanatory variable of this paper is farmers' family economic welfare level. Regarding farmers' welfare level indicators, most scholars in the existing research field have used indicators such as farmers' annual living consumption expenditure, annual net family income, year-end financial asset balance, net family income per capita, and poverty incidence as a proxy [66–68]. By drawing on previous methods of quantifying indicators and considering that farmers' living consumption expenditure and leisure status of family members are inseparable from the overall net income of farmers' families, and also based on the reliability and availability of data, this study chose the annual net income per capita of farmers' families as an indicator to measure the level of welfare. To further analyze the mechanisms underlying the impact of APS embedding on FFEW, it is worth noting that this study focuses on APS in a single crop scenario and, therefore, only corn-farming income is analyzed in this study. Income not related to agricultural activities is treated as labor income. By introducing annual net income per capita as an explanatory variable, the intrinsic mechanism of the impact of APS intervention on farmers' welfare is then verified.

Second, the explanatory variables in this study include farmers' APS purchases (SP), types of services purchased (TSP), and farmers' family labor allocations, which include the outworking situation (OS). SP is a dichotomous variable that takes the value of 1 when the farmer purchases APS; conversely, SP takes the value of 0 when the farmer does not purchase APS. Farmers' family labor allocation status is a substitution variable to analyze the "crowding out" effect of service embedding on the labor force, which promotes farmers' participation in other employment and, thus, income diversification. Outworking status is also a binary variable that takes the value of 1 when the farmer chooses to work outside the home and 0 when the farmer has no other income behavior. This is used to better capture the distribution of family labor, so as to explore the magnitude of the effect of the way labor is allocated on the level of welfare.

Third, the control variables selected in this study include the aspects of individual farmers' characteristics, family production and operation characteristics, instrumental variables, and dummy variables. Among them, the factor endowment of farmers is the key variable to be examined, and this study selects the indicators from three perspectives: labor factor, capital factor, and land factor. Among the labor force elements, the indicators of dependency ratio (DR), professional skill acquisition (PS), learning ability (LA), and aging degree (DA) were selected; dependency ratio was used to determine the basic structure of the farmers' family size, professional skill acquisition and learning ability were used to determine the level of the farmers' own labor capital, and aging degree was used to determine the weakening of labor resources; the capital element includes the variables production cost expense (PC) and investment in productive assets (IPA); the land element was selected to be measured by the indicator of planting size (ALA). In addition to this, the basic characteristics of the farmers were selected as the main variables of gender (GENDER), education level (EL), health status (HS), years of farming (YF), risk preference (RP), and social network (SN). In addition, to ensure the identifiability of the model, the indicator of how easy it is for farmers to find APS in the region was selected as an instrumental variable. The reason for choosing this variable as an instrumental variable is that the degree of development of regional APS has an important role in influencing farmers' behavior in purchasing APS, but this variable does not directly affect the farmers' income level. Considering the differences among provinces, this section also introduces a province dummy variable to control for this factor.

The specific model variables descriptions and their statistical descriptions are shown in Table 3.

Table 3. Descriptive statistics of the variables.

Latent Variables	Observed Variables	Description	Mean	Var.	S.D.
Farmers' Family Economic Welfare	Per capita annual net income of farmers' families	Annual net income from maize cultivation/Number of family members	17.630	238.170	15.433
Service Purchase (SP)	Have you purchased APS	0 = No; 1 = Yes	0.828	0.143	0.377
Types of Services Purchased (TSP)	The type of service you have purchased	1 = Self-farming; 2 = Partial link service purchase; 3 = Full link service purchase	2.078	0.416	0.645
Outworking Situation (OS)	Whether to carry out out-of-home work	0 = No; 1 = Yes	0.336	0.223	0.473
Individual Characteristics (IC)	Gender (IC1)	1 = Male; 2 = Female	1.053	0.051	0.225
	Education Level (IC2)	Years	7.097	7.836	2.799
	Health Status (IC3)	1 = Very Poor; 2 = Poor; 3 = General; 4= Good; 5 = Very Good	3.909	0.872	0.934
	Years of Farming (IC4)	Years	32.195	140.073	11.835
	Professional Skill (IC5)	0 = No; 1 = Yes	0.203	0.162	0.403
	Learning Ability (IC6)	1 = Does not attend training; 2 = Occasionally attends training; 3 = Attends training on time	1.480	0.317	0.563
	Risk Preference (IC7)	The range of values is 0–1, 0 indicates extreme risk appetite, 1 indicates extreme risk aversion	0.875	2.248	1.499
Family Characteristics (FC)	Dependency Ratio (FC1)	Number of elderly and young people/Total family size	0.483	0.117	0.342
	Production Cost Expense (FC2)	CNY	362.063	7013.950	83.749
	Investment in Productive Assets (FC3)	0 = No farm machinery; 1 = Farm machinery and self-use; 2 = Farm machinery half-leased and half-used; 3 = Farm machinery idle	0.629	0.475	0.689
	Planting Size (FC4)	Acres	44.612	2734.757	52.295
	Aging Degree (FC5)	Percentages	0.394	0.136	0.368
	Social Network (FC6)	Numbers	5.035	17.349	4.165
Social Characteristics (SC)	Farmland Damage (SC1)	Numbers	1.952	1.849	1.360
	Province Dummy Variables (SC2)	1 = Heilongjiang Province; 2 = Jilin Province; 3 = Liaoning Province	1.867	0.571	0.756

4. Results

4.1. Results of the Revenue Effect Level of "Agricultural Productive Services Embedding—Farmers' Family Economic Welfare Enhancement"

This study is based on statistical measurement software and the endogenous switching regression model was used to estimate the logical framework structure of this study. The model involves two phases of analysis. The first phase (service purchase phase) is an application of a probabilistic model in which the dependent variable is the farmer's purchase of APS. This variable is binary and has a value of 1 if the farmer purchases an APS and 0 otherwise. Table 4 shows the results of the estimation of the association between the choice of APS and farmers' welfare model in the service purchase stage. Column 2 of the table shows the results of the estimation of the factors influencing the decision to purchase APS, and columns 3 and 4 show the results of the estimation of the factors influencing the level of welfare between farmers who choose APS and farmers who do not choose APS, respectively. In the table, ρ1 and ρ0 are the correlation coefficients between the decision model and the error terms of the welfare model of the service purchase group and the welfare model of the service non-purchase group, respectively. The estimated value of the correlation coefficient ρ1 is statistically significant at 5%, which indicates that there is a self-selection problem in the sample, and the groups choosing APS and non-selected services are not randomly generated, but "self-selected" by farmers according to their own utility changes before and after outsourcing. Without correction, the estimated results obtained would be biased. This shows that it is appropriate to do econometric analysis using the endogenous switching regression model for the sample farmers' data.

Table 4. Endogenous switching regressions for the predicted service purchase phase.

Variables	APS Purchase Decision Model		Adoption of APS Farmer Group		Rejection of APS Farmer Group	
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
IC1	−0.100	0.3228887	46.375 ***	8.320205	0.779	1.948836
IC2	−0.002	0.027073	0.662	0.5421309	0.637 ***	0.164298
IC3	0.099	0.0818857	1.842	1.798169	1.264 ***	0.483621
IC4	0.009	0.0071062	−0.020	0.146222	0.083 *	0.045230
IC5	−0.376 **	0.1644666	1.290	3.172099	2.158 *	1.200138
IC6	−0.191	0.1180318	−4.782 **	2.390423	−0.963	0.864648
IC7	−0.006	0.0448746	0.713	0.8429274	1.513 ***	0.323386
FC1	1.156 **	0.5658243	−27.982 ***	10.47626	−15.928 ***	3.793280
FC2	0.006 ***	0.0011506	−0.022	0.0262424	−0.002	0.007426
FC3	−0.278 ***	0.1016466	15.940 ***	3.712962	1.718 **	0.682348
FC4	−0.003 **	0.0013317	0.063 ***	0.0229542	0.040 ***	0.012932
FC5	−0.875	0.5581334	29.992 ***	10.3300000	9.734 ***	3.653016
FC6	−0.010	0.0151928	0.862 ***	0.2981032	0.385 ***	0.110998
SC1	−0.200 ***	0.0529929	1.617	1.004809	−0.264	0.357025
SC2	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
IV	0.639 ***	0.0616735				
Constant	−3.457 ***	0.7323270	−80.110 ***	14.55561	1.287	4.550966
ln σ_1	2.521 ***	0.0256578				
ρ_1	−0.236 **	0.1117379				
ln σ_0	2.841 ***	0.0565749				
ρ_0	−0.254	0.1549515				
Wald Test	161.75 *** (0.0000)					
Observations	954	954	954	954	954	954

Note: Standard errors are in parentheses; *** significant at $p < 0.01$, ** significant at $p < 0.05$, and * significant at $p < 0.1$.

Aspects of individual characteristic variables. First, gender (IC1) and learning ability (IC6) had significant effects on the group of farmers who purchased APS, with gender being positively significant at the 1% level and learning ability showing a negative effect at

the 5% level. Meanwhile, gender and learning ability had no significant effect on farmers who did not purchase the services, indicating that both had a greater effect on the welfare level of farmers who purchased the services compared to those who did not choose the services. The effect of gender on welfare is confirmed to exist in the existing studies [69,70]. In this study, we found that men bring higher levels of economic well-being than women when they purchase APS. This is due to the fact that men gaining leisure time can choose to participate in other jobs to earn off-farm income as a way to boost the family economic level. The degree of welfare enhancement is weaker for farmers with higher learning ability in the group who purchased services, which indicates that, after the purchase of services, farmers have more time to participate in paid or unpaid skills training, which also results in some cost discounting. Thus, there is still some negative effect on the level of welfare, but to a lesser extent. Second, education (IC2), health status (IC3), years of farming experience (IC4), professional skills acquisition (IC5), and risk appetite (IC7) all have positive effects on the welfare level of the non-purchased farmers' group. This is due to the fact that farmers with higher education, better health status, longer farming experience, and certain agricultural production skills are capable of running their farmland intact without the use of outsourcing services. Compared to the risk of outsourcing in the case of information asymmetry, self-management is a direct way to improve the welfare of their families.

Aspects of family and social characteristics. First, family size dependency ratio (FC1), investment in productive assets (FC3), arable land area (FC4), degree of aging (FC5), and social network (FC6) all have important effects on farmers' family economic welfare, with dependency ratio being a negative inhibitory effect and all other variables pulling positively on farmers' welfare level. This is due to the fact that the larger the dependency ratio, the larger the consumption expenditure required by the family. Under the initial conditions of such a state, the value-added range of APS brought to the production of agricultural products is very limited, while at the same time paying for the purchase of APS, which is undoubtedly a great test of the welfare level. The four variables FC3–6 bring significantly higher welfare gains for farmers in the group that purchase APS than for the group that do not, but have a positive effect for both groups. This indicates that farmers with more agricultural machinery holdings, larger acreage, greater aging, and larger networks of relationships are better suited to purchasing APS and significantly bring about an increase in overall income levels after purchase. Second, at the level of social characteristics, the number of exposures to natural disasters does not have a significant effect on farmers' welfare level, but it has an impact on farmers' decision-making behavior. The more natural disasters farmers suffer from, the weaker the family's ability to take risks, and purchasing services is a risky behavior, thus creating a dampening effect on farmers' willingness to purchase services.

The treatment effects of the impact of the intervention of APS on the annual per capita net income of farmers' families can be further measured in this study using the above Equations (5)–(8), and the results are presented in Table 5 where (a) represents the sample farmers' expected income when they have in reality chosen APS, (b) represents their expected income when they have not participated in APS in real life, (c) and (d) represent counterfactual scenarios, (c) represents the expected income when farmers have not chosen APS, and (d) represents the expected income when farmers have chosen APS. Similarly, (e)–(l) measure the treatment effects on their family's economic welfare situation when they accept and reject services, using two major groups of farmers who purchase only some of the production link services and farmers who purchase all of the production link services, respectively.

Table 5. Analysis of the treatment effect of service embedding on welfare.

	Farmer Category	Accept APS (Income)	Reject APS (Income)	ATT	ATU
Level of farmers' family economic welfare	Farmers purchase APS	(a) 17.3281	(b) 9.6979	7.6303 *** (0.7209)	
	Farmers did not purchase APS	(c) 22.7141	(d) 19.0583		3.6558 *** (1.2332)
	Purchase part of the link service farmers	(e) 16.3255	(f) 7.3100	9.0155 *** (0.8067)	
	Farmers did not purchase part of the link service	(g) 21.4288	(h) 19.0553		2.3735 ** (1.2087)
	Purchase of all links of services for farmers	(i) 17.9634	(j) 11.6643	6.2991 *** (1.0214)	
	Farmers did not purchase the full range of link services	(k) 26.8995	(l) 20.5952		6.3042 *** (1.4799)

Note: *** indicates significant at the 1% level, ** indicates significant at the 5% level, ATT and ATU indicate the average treatment effects corresponding to farmers who chose different types of APS and those who did not choose APS, respectively.

Overall, there was a positive treatment effect of an APS purchase on farmers' family economic welfare, and it was significant at the 1% statistical level. Among them, the ATT estimates show that for farmers who have actually opted for APS, their annual net family income would have decreased by 44.03%, or from 2419 dollars to 1354 dollars per year on average, if they had not opted for APS. In addition, the ATU's estimates show that, if farmers who did not choose APS were able to participate in APS, their annual net family income per capita would increase from 2660 dollars to 3170 dollars, an increase of 19.18%. This suggests that APS can indeed improve farmers' welfare status. In terms of subgroups, farmers who outsourced part of their production processes had higher levels of welfare than those who outsourced all of their production processes, because partial outsourcing is more flexible and allows farmers to analyze the "shortcomings" of their production processes and create higher value by combining advantages and disadvantages through outsourcing. In contrast, farmers who entrust the entire production chain to the service provider not only pay a more expensive service fee, but also pay a certain degree of supervision costs during the service process, so that the full chain service has a smaller effect on farmers' welfare enhancement. In summary, Hypothesis 1 can be tested, and the purchase of APS has a significant positive effect on farmers' welfare level.

4.2. Results of the Substitution Effect Level of "Agricultural Productive Services Embedding—Farmers' Family Economic Welfare Enhancement"

This study analyzes the theoretical framework of "APS embedding—farmers' family economic welfare enhancement" based on the endogenous conversion regression model. The analysis of the substitution effect focuses on an in-depth discussion of the differential impact of the APS purchase with or without the APS purchase by dividing the farmers into those who have purchased the service and those who have not, according to the difference in APS purchase status, and labor allocation status is measured according to the farmers' outworking behavior. In this case, the purchase of services (SP) is a dichotomous variable, and the labor allocation situation (OS) is likewise a binary variable. According to the introduction of the research method and research model in the previous part of the article, the substitution effects model will generally group the farmers according to their working outside the home, even if the sample is divided into two subsamples: working outside the home and still working at home for farming or leisure. To what extent does the embedding of APS bring about an increase in farmers' welfare in the absence of intervention, i.e., when farmers are not working outside the home and do not have the effect of wage income? What changes exist in farmers' welfare levels when there is an intervening effect on labor

distribution? To what extent do these two effects differ? These doubts are the questions that need to be addressed in this study. Table 6 shows the estimation results of the endogenous switching regression model, where column 3 represents the sample farmers who have opted for APS in reality and column 4 represents their expected income level when they did not participate in APS in real life, while the counterfactual scenarios corresponding to each column are also included in the table.

Table 6. Results of the test for substitution effects of labor allocation.

	Farmer Category	Accept APS (Income)	Reject APS (Income)	ATT	ATU
Level of economic welfare of farmers' families	Farmers working outside	(m) 15.1838	(n) 11.1441	4.0396 *** (0.9770)	
	Farmers not working outside	(o) 18.4393	(p) 17.2079		1.2314 (1.6930)
	Farmers at home	(q) 21.5819	(r) 20.2784	1.3035 * (0.7419)	
	Farmers not at home	(s) 28.3130	(t) 22.6752		5.6378 *** (1.5500)

Note: * and *** represent significant at the 10% and 1% statistical levels, respectively; robust standard errors of the coefficient estimates are in parentheses.

As shown in Table 6, APS embedding had a significant positive treatment effect on farmers' family economic welfare under the substitution effect of labor allocation. In this case, the outcome of the family welfare enhancement for farmers who actually purchased APS outside of work is scenario (m); the outcome of the family welfare enhancement for those who actually did not purchase APS is scenario (p). Based on the counterfactual hypothesis, the outcome of the family welfare enhancement for farmers who purchase APS who work outside the home without purchasing the corresponding APS is scenario (n); the outcome of the family welfare enhancement for farmers who do not purchase APS with the corresponding APS is scenario (o). The same is true for the context (q)–(t). The last two columns in Table 6, ATT and ATU, indicate the average treatment effect of the welfare enhancement of the APS purchase behavior for farmers who went out to work and farmers who did not work, respectively, and the average treatment effect of the water welfare enhancement for farmers who went out to work and purchased the service are both significant at the 1% level. This allows for testing of Hypothesis 2; that labor allocation has a significant indirect positive effect on farmers' family economic welfare levels.

It can be clearly seen that, in comparison to the group of home-based samples, farmers who work outside have a more pronounced improvement in their family welfare situation and a more significant increase in income after purchasing APS. This is because the intervention of APS brings employment opportunities to the surplus labor within farmers' families. By going out to work, farmers can expand their income sources and increase their wage income, which leads to an increase in the overall welfare level. On the other hand, among farmers who work outside the home, those who purchase APS have a greater welfare-enhancing effect than those who do not. This is due to the fact that without the intervention of APS, farmers going out to work would have presented a shortage of labor needed in agricultural production, and the embedding of APS has allowed machinery to replace labor inputs, enhancing production efficiency and improving livelihoods. This study grouped the substitution effects to further illustrate that APS in the presence of the substitution effects did have a higher impact on welfare improvement.

5. Discussion

5.1. Integration with Previous Studies

In light of the existing academic research results in the field of farmers' welfare economy, most of the current research on how to improve farmers' welfare focuses on farmers'

land use behavior, environmental issues, agricultural marketing behavior, agricultural production and management organization, and agricultural land leasing and transfer [71–74]. For example, Lakhan et al. conducted a study on the mechanism of the impact of credit constraints on farmers' welfare in the agricultural production and operation process, and scientifically verified the suppressive effect of credit constraints on farmers' income levels, using wheat farmers in Pakistan [75]. Similar to their study, Ali et al. argue that soybean farmers in Togo are similarly constrained by credit capacity, which limits the increase in farmers' take-home incomes, again emphasizing the important role of solving the financing problem for the improvement of farmers' welfare levels [76]. Teka relates the farm package to farmers' welfare levels, develops an analysis using three rounds of panel data, and uses farmers' consumption expenditure levels to measure farmers' welfare, concluding that the program has a positive impact on enhancing farmers' welfare [77]. Guan examines the role of agricultural land titling in promoting farmers' welfare in rural China, emphasizing the important role of agricultural property rights stability in boosting farmers' income [78]. Regarding the form of embedding of APS in the modern agricultural sector, existing studies lack a better delineation of the logic between them and farmers' welfare. Compared to the existing academic literature, this study may have the following marginal contributions. First, in terms of perspective setting, this study focuses on the group of farmers in northeastern China in the selection of the research area, where APS have been initially developed under the advantages of natural conditions and long-term agricultural development accumulation. The participation rate of farmers in this region in APS is high and shows an upward trend year by year, and they are the main audience group of the services. Most of the existing studies focus on the macro impact of the development of APS or the factors that bring influence on their development, ignoring the process of changes in farmers' economic welfare under the new stage. In addition, raising farmers' income level, improving agricultural production efficiency, and maintaining sustainable and healthy agricultural development are the goals and motivations for the birth and development of APS. Second, in terms of research content, this study more systematically analyzes the important role of farmers' economic welfare enhancement after receiving APS based on the two paths of income effect and substitution effect and reveals the influence mechanisms between variables at different levels. Third, in terms of research methodology, this study constructs a theoretical framework of "APS embedding—farmers' family economic welfare enhancement" from two levels of the income effect and substitution effect based on the theory of biased technological progress, draws a logical framework diagram, and proposes a research path hypothesis. The theoretical framework and research hypotheses are then validated using one-on-one family research data. This study can provide new research ideas and methodological references for other studies on farmers' welfare.

5.2. Practical Implications

This study is centered on the main line of how the involvement of productive services in agriculture affects the economic welfare of farmers, a topic that is inextricably linked to the overall development of the national society and is an ongoing and much-needed discussion. The current situation of China is still "big country, small farmers". Small-scale farmers are the main force of agricultural production, and how to fully mobilize the agricultural production force, improve the efficiency of agricultural production, and enhance the happiness and sense of belonging of all people is the pursuit the country is committed to in terms of the development of agricultural modernization. With the development of urbanization, APS have emerged as a "substitute" for primary labor, and their development can effectively improve the level of agricultural production and promote scientific, standardized, and large-scale production. APS can drive small-scale farmers to higher returns by freeing up agricultural labor and updating agricultural technology tools. The research team of this paper found that the development of APS is plagued by information asymmetry, "free-rider" phenomenon, unclear legal delineation, and unstable linkage of interests. This is related to the development of agriculture, rural areas, farmers, and the

stable development of the APS industry. Our findings show that the embedding of APS raises farmers' family economic welfare levels, stimulates farmers to shift to non-farm jobs, and enhances welfare levels by expanding income channels. These findings imply that the government should enhance farmers' economic income from two perspectives: supporting agricultural service organizations and optimizing the labor market and preventing the return to poverty in a timely manner.

5.3. Inadequacies of This Study and Future Perspectives

This study also has the following deficiencies. First, there are still limitations in the selection of the research region. The research data used in this study are from three major grain-producing provinces within the Northeast China Plain region and, although this region is an important agricultural production base, the focus is still limited by focusing only on this area. The middle and lower reaches of the Yangtze River region, as well as the North China Plain region, in China are important grain-producing regions, and the maturation system differs from the high latitudes in the north, and the development of the APS industry is somewhat heterogeneous. Although some existing studies focusing on farmers' welfare similarly focus on the northeastern region, the reliability of the findings is not compromised [79]. Second, the time factor is difficult to control; the impact of APS embedding on farmers' welfare still needs to be explored in depth because economic improvement is not a time-sensitive issue but tends to be a slow but steady and continuous process. How does the impact of service embeddedness on welfare levels differ in the long run from the short run? Does this effect weaken or strengthen over time? Such questions require further discussion. Third, the focus of service links is weak. Due to the wide range, types and links involved in current APS, the heterogeneity of APS can have different effects on farmers' economic levels and labor allocation behavior. For example, types of services within the three stages of prenatal, intranatal and postnatal will affect the improvement of farmers' economic conditions to different degrees, and services with more labor-intensive characteristics will bring more obvious effects on labor allocation, etc.

Improvements in future work. First, the research area should be expanded. In order to increase the comparability of the study, the selection of samples should be further enriched. Take the Jianghan Plain, Poyang Lake Plain, Jianghuai Region and Chengdu Plain along the Yangtze River Basin in China as examples, which are important commercial grain bases with crop types covering soybean, wheat, maize, rice, and other varieties. In future research, the team will move the research area from north to south. The southern region has more crop maturity periods in a year, with more stringent requirements for farming time and higher requirements for APS. The impact on farmers' welfare is also expected to be different with the service embedded. Therefore, the conclusions will be more rigorous when the southern and northern research regions are analyzed against each other. Second, ongoing follow-up research is conducted. The use of panel data will increase the consideration of time series factors, so that the issue of the time point can be better controlled, thus enhancing the depth and breadth of the research. In the choice of research methods, the form can be optimized, such as combining pictures, videos, text, and other forms, or using randomized trials to control the interference factors more rigorously and improve the accuracy of the research. Third, future research can be analyzed from the perspective of multiple categories. The APS industry has been developed in several agricultural production stages, mainly in the mid-production stage. In the next stage of research, the types of services, such as tilling, sowing, and fertilization, will be further divided in more detail, as a way to examine the welfare-enhancing effects of different degrees of service heterogeneity issues. In addition, the focus on farmer heterogeneity will be more specific, further considering the extent to which farmer groups of different sizes and income structures respond to APS embedding.

6. Conclusions

This study constructs an analytical framework of "APS embedding—farmers' family economic welfare enhancement" in the process of farmers' economic welfare growth based

on two main paths: income effect and substitution effect and explores the substitution role of labor allocation in this framework. Based on the sample data collected, the endogenous switching regression model is used to investigate the factors and pathways of service embeddedness on farmers' welfare from the income effect and the substitution effect.

Through scientific argumentation and analysis, the main conclusions of this study include the following aspects. First, in the study of farmers' welfare, the application of the theoretical framework of biased technological progress is reasonable, and different forms of APS are embedded in the agricultural production chain, bringing direct "pulling power" to farmers through the income effect. While at the same time, the substitution effect due to labor "crowding out" expands farmers' income sources and enhances their economic welfare. On the one hand, from the perspective of individual influences, gender (IC1) and learning ability (IC6) contribute to farmers' income enhancement after the purchase of services, while education level (IC2), health status (IC3), years of farming experience (IC4), professional skill acquisition (IC5), and risk appetite level (IC7) are the influences that produce a pull on the welfare level in the absence of farmers' purchase behavior. On the other hand, all the variables at the family characteristics level have a positive effect on the increase of farmers' welfare, but this pulling power increases significantly after the purchase of services. Second, among the factors affecting the growth of farmers' family economic welfare levels, labor allocation, which is affected by the substitution effects, has a significant indirect effect on farmers' income profiles. The substitution effect of the outworking situation (OS) is significant, as farmers who choose to work outside the home have a larger increase in family welfare after purchasing services than farmers who do not work outside the home in the same service situation. This further suggests that the substitution effect from services frees up farmers' labor to enhance the level of farmers' family economic welfare through internal free allocation. Third, against the backdrop of deepening division of labor in the agricultural sector and increasing the separability of agricultural production, APS has both productive and service-oriented qualities. Driven by the mechanism of "APS embedding—farmers' family economic welfare enhancement", the overall welfare level of farmers has been increasing in recent years. However, there are various types of APS development, which can choose between partial and full production services, and not all farmers with different initial endowments are suitable for APS.

Based on the above findings, this study may lead to the following policy recommendations. First, while the development of "agriculture, rural areas, and farmers" has received widespread attention from the government and academia, the economic welfare of farmers has been initially improved, but agriculture is an important industry in China, and it is an enduring topic to steadily improve the welfare of farmers and enhance their sense of access and happiness. How farmers' welfare can be enhanced through APS requires a comprehensive consideration of their own endowment characteristics. Farmers with disadvantaged labor factor endowments experience a significant increase in welfare when they purchase APS. In contrast, farmers with abundant labor endowment do not experience such an impact. Therefore, the government needs to refine the registration and filing of farmers' information starting from the village collective level, pinpoint the part of each farmer's family that is disadvantaged in terms of production factors, and manage them in a graded manner for precise measures. The government should actively promote and popularize APS to farmers who are disadvantaged in terms of labor factors due to gender, age, and health status, and improve their economic income level by favoring this group.

Second, the government should pay close attention to the problem of heterogeneity in the forms of the supply of APS. Under counterfactual analysis, farmers who purchase some of the links of the services are more efficient in terms of welfare enhancement than those who purchase all of the links of the services. The form of purchasing services for all segments is more suitable for small-scale farmers with high aging and severe labor shortage. The partial link service model is more flexible for the average farmer, who is free to match his existing strengths and outsource his weak links to service providers to achieve greater benefits through comparative advantage analysis. The government should actively urge

all types of APS organizations, including agricultural cooperatives, individual farmers, and agricultural enterprises, to scientifically manage and standardize their services, and promote the formation of more uniform evaluation indicators and performance indicators in the industry. Categorization promotes more scientific and efficient mutual selection between farmers and service providers, reduces difficult problems such as transaction difficulties, establishes credibility mechanisms and access thresholds, and guarantees that farmers' welfare levels can be improved.

Thirdly, from the perspective of "crowding out" of labor, the intervention of APS will largely promote the transfer of surplus labor to other sectors, and the substitution effect brought on by the services is significant. The government should provide some support to reduce the potential moral hazard caused by information asymmetry in the labor market. Based on the current national situation, although the comprehensive quality of farmers has been generally improved in recent years, it is still far from the standard, and there are still certain risks or ambiguities in making job choices, work distance arrangements, and other matters. From the government's point of view, it should properly carry out recruiting information columns and other ways to introduce better quality and more suitable job opportunities into the countryside, or it can rely on local special agricultural products to supply the advantage of information technology, rooted in the origins of agricultural e-commerce construction. Thus, more opportunities and platforms can be brought to farmers so that they can quickly adapt to new forms of production and operation during the transition period of the substitution effect, find suitable income channels faster and better, and improve the welfare level of their families.

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