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Original Research

The Dual – Driven Impact of "Internet + Agricultural Insurance" on the Agricultural Carbon Welfare Performance in China

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Abstract

This paper constructs an agricultural carbon welfare performance indicator based on the "Two Mountains Theory" and the concept of green agriculture, which takes into account people's welfare and the environment, trying to answer the driving effects of "Internet + Agricultural Insurance" on welfare levels and environmental protection in different rural areas of China. Using Chinese provincial dynamic panel data from 2007-2017, a time-individual double fixed-effects model and a systematic GMM model were constructed to empirically find that at the national level, agricultural insurance contributes to agricultural carbon emissions, thereby weakening agricultural carbon welfare performance. The Internet contributes to agricultural carbon welfare performance. The joint effect of the Internet and agricultural insurance on agricultural carbon welfare performance is characterised by an Internet-led facilitation effect in the form of lower agricultural carbon emissions and higher rural welfare. This finding confirms the synergistic governance effect of " Internet + Agricultural Insurance" on high quality green development in agriculture and provides strong evidence for the implementation of this model.

Keywords: agricultural carbon welfare performance, internet, agricultural insurance

Introduction

The United Nations Sustainable Development Goals (SDGs) set out requirements and expectations on issues such as sustainable agriculture and the well-being of people. After China completes its fight against poverty in 2021, it begins to focus its governance on the rural revitalization, making every effort to build modern villages to promote national development and enhance the well-being of its citizens. In fact, as a traditionally agricultural country, rural development has always been a priority for China and has made remarkable achievements, not only supporting 22% of the world's population with only 7% of the world's arable land, but also representing an increase in the gross domestic product of the primary sector, which is mainly agricultural, from 102.75 billion yuan in 1978 to 101.6 billion yuan in 2020. However, China's rural economic development is still characterized by a crude development that relies on fossil energy,

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and the transformation of agriculture is imminent [1]. On how to promote the harmonious development of the economy and the environment, President Xi Jinping has put forward the guiding ideology of the “Two Mountains Theory”, which states that “Green mountains and clear water are equal to mountains of gold and silver”, and the guiding principle of “striving to reach the peak of carbon emissions by 2030 and achieving carbon neutrality by 2060”. The national goal is to achieve carbon neutrality by 2060. In response, Eric Solheim, former United Nations Under-Secretary-General and Executive Director of United Nations Environment Programme (UNEP), believes that the important idea of “Two Mountains Theory” shows that green industries offer opportunities and can create jobs and prosperity. China can share its green development experience with the world, and the world will be listening.

According to the environmental report of the United Nations Intergovernmental Panel on Climate Change (IPCC), agricultural production ranks second in total carbon emissions among global carbon emitting industries, after the electricity and thermal power industries. In response, as early as 2019 the National Strategic Plan for the Promotion of Quality Agriculture (2018-2022) promulgated by China has made accelerating the green development of agriculture one of the key tasks, and the green transformation of agriculture is to strike a balance among reducing energy consumption, promoting economic growth and safeguarding social welfare. However, the long agricultural production cycle, which is highly susceptible to changes in natural climatic conditions such as droughts and floods, as well as the impact of the market economy such as price fluctuations and capital shortages, make it even more difficult for China’s agricultural production, which is already not of high modern quality, to move away from rough development in order to implement green agriculture without distractions. In response, the importance of agricultural insurance has been emphasized in successive years of China’s Central Document No. 1 as well as in the 2019 Guidance on Accelerating the High-Quality Development of Agricultural Insurance, which is a reflection of the nature of agricultural insurance to address agricultural risks. However, the rapid development of agricultural insurance has been accompanied by the apparently “crude” characteristics of the emerging market, which has easily given rise to moral hazard and adverse selection, and has frequently led to problems such as false underwriting and false claims, seriously affecting the reputation and sustainable development of agricultural insurance. As a result, the public is beginning to think about whether “Internet+” technology can be applied to solve the many problems in the development of agricultural insurance. On the one hand, it can help to optimize the allocation of resources, promote agricultural technology and improve the efficiency of agricultural production and farmers’ sense of well-being. On the other hand, it can help to make agricultural insurance more “intelligent”, realize refined management and services, and promote the transformation, upgrading and high-quality development of agricultural insurance.

According to the Media Richness Theory, the right match of mediums will make the behaviour more effective and produce “twice the result with half the effort”. So, can the combination of “Internet + Agricultural Insurance” contribute to the high quality development of Chinese agriculture as expected, i.e. the concept of high quality agricultural development with the dual objectives of reducing agricultural carbon emissions and improving farmers’ well-being, in order to drive the realization of the economics and the environment in agriculture? Based on the above considerations, this paper introduces the dual concepts of agricultural carbon emissions and farmers’ welfare, constructs Agricultural Carbon Welfare Performance (ACWP) indicator, and explores the impact mechanisms of agricultural insurance and the Internet, alone or in combination, on ACWP. The findings and conclusions of this paper are intended to clarify a way to achieve the dual development of rural welfare and low carbon through “Internet + Agricultural Insurance” in China, as well as to provide a reference experience for other developing countries to promote the green transformation of agriculture.

Literature Review and Innovative Description

Literature Review

Most of the current scholarly research on agricultural insurance focuses on the “output effects” of agricultural insurance, such as the benefits of agricultural insurance for farmers to expand the scale of cultivation, thus increasing agricultural economic output (Zhang et al., 2019) [2]; financial compensation for affected crops to quickly resume agricultural production that help increase agricultural production efficiency (Peter and Panos, 2020) [3]; and increased consumption use of pesticides, fertilizers, and diesel fuel (Möhring et al., 2020) [4], resulting in increased carbon emissions in the atmosphere (Ren et al., 2020) [5] . In traditional agricultural insurance transactions, there is a serious information asymmetry between both subjects, insurance companies and farmers, and moral hazard and adverse selection problems bring great uncertainty to the operation of insurance companies, which may even lead to the failure of insurance companies (Alma and Peter, 2010) [6]. Nelson and Loehman (2007) [7] argue that in addition to the development of insurance through government legislation, policy formulation and financial subsidies, the innovative construction of various agricultural insurance-related information platforms can also play a positive role.

At the same time, China has been vigorously promoting the development of rural inclusive finance and believes that the development of rural Internet finance has become an important focus (Luo et al., 2018) [8], to the extent that it is actively trying to develop Internet insurance (Leemore et al., 2017) [9]. However, Tiago and Veríssimo (2014) [10] argue that e-commerce can reduce the transaction costs of agricultural insurance and improve the competitiveness of insurance products, but the technical standards and security and privacy issues that exist on the Internet itself limit the penetration of Internet agricultural insurance to a certain extent. Li (2020) [11] through the empirical examination of provincial panel data in China, concludes that Internet development can significantly promote the development of agricultural insurance, but with the increase in the level of Internet development, the regulatory cost then rises and tends to be presented as inhibiting the development of agricultural insurance, making the Internet agricultural insurance in China has not yet played its proper role. Li and Luo (2019) [12] argue that Internet agricultural insurance is efficient and low-priced, and can meet customers' needs for new types of insurance. However, China's Internet agricultural insurance started late, and there is a lack of professionals with Internet thinking, and the transformation of traditional agricultural insurance faces more difficulties.

Rural welfare is an important part of the social welfare system and is directly related to the well-being of farmers, rural development and the process of national modernization. However, it is difficult to avoid the contribution of the previous brash agricultural development model, which sacrifices the environment for economic welfare, being reflected in the rapid increase in the level of rural welfare in developing countries and most regions, represented by China. For example, there is a significant positive relationship between agricultural economic growth and agricultural carbon emissions (Hazell and Varabgis, 2020) [13], and a clear upward trend in agricultural carbon emissions directly or indirectly from agricultural activities (Xiong et al., 2016) [14], which include increased water use for agricultural irrigation, heavy use of fertilizers and pesticides (Sabiha et al., 2016) [15].

However, the relationship between agricultural economics and agricultural carbon emissions is gradually changing with the advancement of energy conservation and technology. Wu et al. (2018) [16] calculates the marginal cost of agricultural carbon emissions through a shadow price approach and suggests that carbon reduction responsibilities should be allocated according to the growing conditions in different regions, weighing carbon reduction against crop yield increase. Shortall and Barnes (2013) [17] measured the technical and environmental efficiency of Scottish farms using a DEA approach and found that the higher the technical efficiency, the lower the greenhouse gas emissions and the more competitive they were. Some scholars have found an "inverted U-shaped" curve relationship between agricultural economic growth and agricultural carbon emissions based on the Environmental Kuznets Curve (EKC) (Yan et al., 2019) [18], and there are even differences in the strength of decoupling between economic growth and environmental pressure in agricultural areas such as Beijing and Shanghai (Wang et al. 2019) [19].

In fact, as a multidimensional concept, rural welfare includes not only the income and consumption of rural residents, but also the health, education, social interaction, psychological condition and other important elements of individual development of the farmers themselves (Shi and Wen, 2009) [20]. Rural development should not be focused on improving welfare to the detriment of the ecological environment, nor should it be focused on reducing emissions to the detriment of improving rural welfare, and therefore the 'new drivers' of both are gaining attention. Not only are financial instruments central to economic growth and carbon emissions reduction (Zaidi et al., 2019) [21], but also technological instruments such as the Internet are important drivers of rural welfare and carbon emissions reduction (Nie et al., 2020) [22], and are important ways to tackle the growing problem of agricultural pollution (Zhang et al., 2020) [23].

Innovative Description

By collating the relevant literature, we found that: (1) Existing studies tend to analyse the welfare of rural areas or the rural environment from a single perspective and independently. This not only ignores the plurality of welfare in rural development and contradicts the "Two Mountains Theory" of balancing development and the environment, but also results in a fragmented and unsystematic focus on policies that contribute to comprehensive rural development. (2) The literature on the Internet and agricultural insurance development focuses mainly on the impact of the popularity of the Internet on agricultural insurance development. However, as an information and technology medium, the Internet can also be a key factor in the governance effectiveness of modern agricultural insurance. In particular, when it comes to the effects on rural welfare or agricultural carbon emissions, the synergistic or substitution effects of the Internet and agricultural insurance are not fully considered, making it difficult to accurately judge and grasp the combined effects and mechanisms of the relationship between the Internet and agricultural insurance.

Based on the above shortcomings, this paper constructs ACWP from the perspective of rural livelihood welfare and low carbon agriculture based on a sample of Chinese rural data from 2007 to 2017, and examines the single and combined impact of the Internet and agricultural insurance on ACWP. It is expected that the findings of the study will provide a policy mix for the supply of "Internet + Agricultural Insurance" in China, taking into account rural development and people's welfare. The main innovations include: first, based on theories of livelihoods and low carbon, the study constructs ACWP based on the idea of green agriculture. It provides an entry point for the “synergistic growth” of rural welfare and environmental optimization by systematically examining rural development in terms of both rural welfare growth and agricultural carbon emissions. Secondly, a theoretical analysis framework is constructed from the perspective of the dual drive of “Internet + Agricultural Insurance” on ACWP (as shown in Fig. 1). At the same time, we empirically analyse the unidimensional and overall mechanisms of the driving effects of the Internet and agricultural insurance, both singly and jointly, on ACWP, and thus clarify the rational path for “Internet + Agricultural Insurance” to contribute to sustainable agricultural development.

Material and Methods

This study integrates the Internet, agricultural insurance and high-quality agricultural development into a unified analytical framework to examine the mechanisms of the impact of the Internet and agricultural insurance on agricultural carbon welfare performance. Considering that agricultural insurance in China only entered its formal development period after the implementation of the agricultural insurance premium subsidy policy in 2007, this paper uses provincial-level panel data on rural areas in 30 Chinese provinces, municipalities and autonomous regions (excluding Hong Kong, Macau, Taiwan and Tibet) from 2007 to 2017. The data are obtained from the EPS Global Statistics Platform, the China Stock Market & Accounting Research database (CSMAR), as well as the China Statistical Yearbook, the China Rural Statistical Yearbook, the China Financial Yearbook, the China Insurance Yearbook, the China Education Statistical Yearbook, the Human Development Report published by the United Nations Development Programme (UNDP), the Statistical Compilation of 60 Years of New China, and the Historical Information on Population Census Data. Missing data are filled in by manually consulting the data of the statistical bureaus of the provinces, municipalities and autonomous regions, using the interpolation method.

Construction of ACWP

We measure agricultural carbon emissions by drawing on the more widely accepted method of evaluating agricultural carbon productivity in researches (Wu et al., 2020) [24], the main idea of which is the economic benefits generated per unit of agricultural carbon emissions. However, since this indicator cannot measure broad public welfare such as employment and education, this paper further expands on Wang et al. (2019) [25], i.e., incorporating the concept of green development, to construct an agricultural carbon welfare performance based on the ratio of Rural Human Development Index (RHDI) to Agricultural Carbon Emissions per Capita (ACEC). To ensure the comparability of agricultural carbon welfare performance across regions, the maximum and minimum values of agricultural carbon emissions per capita were chosen as the boundary quantities (i.e. 55,100 kg and 100 kg) when constructing the dimensionless indicator of agricultural carbon welfare performance.

The specific construction of ACWP is as follows.

$$\mathrm{ACWP} = \frac{\mathrm{RHDI}}{\mathrm{ACEC}}$$

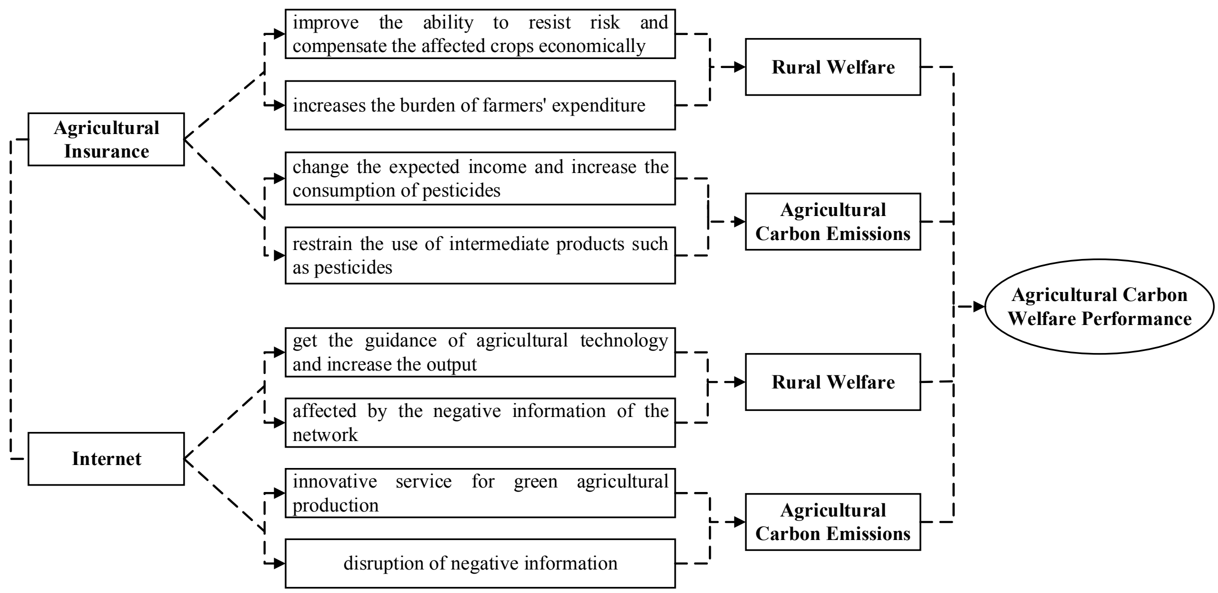

Fig. 1. Theoretical framework of the driving mechanism of the internet and agricultural insurance on ACWP in China.

$$ACEC = \frac{LN(Annual\ ACEC) - LN(100)}{LN(55100) - LN(100)}$$

Next, the RHDI and the ACEC are measured in turn.

Measurement of the RHDI

The United Nations Development Programme (UNDP) publishes the Human Development Index (HDI) to reflect the welfare level of a country or region. The index covers three dimensions: the income index, the education index and the health index, and it reflects economic welfare based on national income and non-economic welfare based on social choices. Since its release, the HDI has been revised and improved by the UNDP several times, so this paper adopts the technical indicators of the 2020 UNDP and refers to the calculation method of Ren et al. (2020) [26] to estimate the RHDI for each province, municipality and autonomous region in China. The specific calculation system is shown in Table 1.

The above calculation process gives three indices: I_{inc}, I_{edu} *and* I_{hea}. The RHDI for China can further be calculated as follows.

$$RHDI = (I_{inc} \times I_{edu} \times I_{hea})^{1/3}$$

Estimation of ACEC

Since there are no relevant statistics on agricultural carbon emissions by province in China, the following formula was used to estimate the total agricultural carbon emissions by province, drawing on the approach of Li et al [27], to collate 6 data on fertilizer, pesticide, agricultural film and agricultural diesel consumption as well as tillage (total crop sown area) and irrigation (effective irrigated area) for 30 provinces in China from 2007 to 2017.

The formula for estimating agricultural carbon emissions is: $E = \Sigma E_i = \Sigma T_i \cdot \delta_i$.

Where E is the total agricultural carbon emissions, E_i is the carbon emissions from each carbon source, T_i is the amount of each carbon emission source, and δ_i is the carbon emission factor for each carbon emission source. The agricultural carbon emission factors δ_i for each carbon source are shown in Table 2.

Variable Settings

Explanatory Variables

The development level of agricultural insurance (X_1), using agricultural insurance density, i.e. agricultural insurance premiums per farmer, as a measure of the development level of agricultural insurance. The higher the value of agricultural insurance density, the higher the level of agricultural insurance development. Taking into account the effect of price changes, the agricultural premium income data of each province is therefore deflated using 2007 as the base period.

Internet penetration (X_2), using the Internet penetration rate. Referring to the method of Cheng and Zhang (2019) [31], the number of Internet users in rural

Table 1. China Rural Human Development Index Indicator System.

Indicators	Calculation formula
Income index I_{inc}	$I_{inc} = \frac{LN(Rural\ disposable\ income\ per\ capita) - LN(200)}{LN(110000) - LN(200)}$
Education Index I_{edu}	$I_{edu} = \frac{Average\ education\ index + Expected\ Education\ Index}{2}$
Health Index I_{hea}	$I_{hea} = \frac{Average\ life\ expectancy - 20}{85 - 25}$

Table 2. Carbon sources, factors and reference sources for agricultural carbon emissions.

Source	Coefficient	Reference
Fertilizers	0.8956 kg · kg^{-1}	West (2002) [28], Oak Ridge National Laboratory, USA
Pesticides	4.9341 kg · kg^{-1}	Oak Ridge National Laboratory, USA [29]
Agricultural film	5.18 kg · kg^{-1}	Institute of Agricultural Resources and Ecological Environment, Nanjing Agricultural University
Diesel	0.5927 kg · kg^{-1}	United Nations Intergovernmental Panel on Climate Change
Tillage	312.6 kg · km^{2}	School of Biology and Technology, China Agricultural University
Agricultural irrigation	20.476 kg · hm^{2}	Dubey (2009) [30], Li (2011) [27]

areas as a percentage of the total population in rural areas was used as a measure. The higher the value of the variable, the higher the level of Internet development and coverage in rural areas.

Control Variables

Combining theoretical analysis, as well as existing studies (Shi, 2019; Zhou, 2015) [18, 32], this paper uses agricultural fixed investment (K_1), arable land per capita (K_2), mechanization level (K_3), road density (K_4), electricity consumption level (K_5), and urbanization level (K_6) as control variables.

Agricultural fixed investment (K_1). Capital investment is not only an effective driver of rural economic growth, but also plays an important role in increasing farmers' income and improving agricultural productivity. Therefore, this paper chooses to use the measure of farm household fixed asset investment per capita. Also taking into account the price factor, the amount of rural fixed asset investment is deflated using 2007 as the base period.

Arable land per capita (K_2). As land is an important element of agricultural production and the main asset of farmers, the rural arable land per capita measure was chosen.

Mechanization level (K_3). With the modernization of China's agriculture, the level of agricultural mechanization is increasing, and suitable agricultural machinery can effectively improve agricultural production efficiency, so the total mechanical power per capita is used for the measurement.

Road density (K_4). The economic links between urban, rural and provincial areas are becoming increasingly close, where the importance of roads, highways, national highways and provincial roads for the travel of residents and the transport of materials is self-evident. Therefore regional operational road density is used as a metric.

Electricity consumption level (K_5). The level of rural electricity consumption reflects the degree of development of the countryside, where rural electricity provides for the livelihoods of rural residents and agricultural production, and is therefore measured using per capita electricity consumption.

Urbanization level (K_6). As China's economy grows, the pace of urbanization is accelerating, with agriculture shifting to non-agriculture and farmers to urban residents. Moreover, urbanization can lead to better infrastructure, increase farmers' wage income while reducing rural labour and increasing per capita arable land. Therefore, this paper uses the ratio of the number of regional urban households to the total regional population as a measure.

Econometric Model Setting

This paper constructs a dual fixed effects econometric model of time points and individuals based on provincial panel data for China. The inclusion of year and province fixed effects in the model not only avoids bias due to omitted variables in the model, but also addresses the endogeneity issue. Equation (1), Equation (2) and Equation (3) represent the test models of agricultural insurance and the internet on ACWP, rural welfare levels and agricultural carbon emissions respectively. In the formula, the subscript i denotes province and t denotes year; T represents time fixed effect, U represents province fixed effect; ε is the random disturbance term. The model is set up as follows.

$$Y\underset{i,t}{1} = \beta_0 + \beta_1 X\underset{i,t}{1} + \beta_2 X\underset{i,t}{2} + \beta_3 X\underset{i,t}{1} \cdot X\underset{i,t}{2} + \gamma_1 K\underset{i,t}{1} + \gamma_2 K\underset{i,t}{2} + \gamma_3 K\underset{i,t}{3} + \gamma_4 K\underset{i,t}{4} + \gamma_5 K\underset{i,t}{5} + T_t + U_i + \varepsilon_{i,t} \quad (1)$$

$$Y\underset{i,t}{2} = \beta_0 + \beta_1 X\underset{i,t}{1} + \beta_2 X\underset{i,t}{2} + \beta_3 X\underset{i,t}{1} \cdot X\underset{i,t}{2} + \gamma_1 K\underset{i,t}{1} + \gamma_2 K\underset{i,t}{2} + \gamma_3 K\underset{i,t}{3} + \gamma_4 K\underset{i,t}{4} + \gamma_5 K\underset{i,t}{5} + T_t + U_i + \varepsilon_{i,t} \quad (2)$$

$$Y\underset{i,t}{3} = \beta_0 + \beta_1 X\underset{i,t}{1} + \beta_2 X\underset{i,t}{2} + \beta_3 X\underset{i,t}{1} \cdot X\underset{i,t}{2} + \gamma_1 K\underset{i,t}{1} + \gamma_2 K\underset{i,t}{2} + \gamma_3 K\underset{i,t}{3} + \gamma_4 K\underset{i,t}{4} + \gamma_5 K\underset{i,t}{5} + T_t + U_i + \varepsilon_{i,t} \quad (3)$$

Considering that agricultural carbon emissions and rural welfare growth are a continuous dynamic process, i.e. agricultural carbon emissions and welfare growth in the current period will not only be influenced by factors such as policy, economic environment and geography in the current period, but also by the behaviour of previous periods on the current period. We therefore used a systematic GMM dynamic model and added a one-period lag of ACWP as an explanatory variable in the model. The effect of the Internet development and agricultural insurance on ACWP was examined through a systematic GMM. The econometric model was set up as follows.

$$Y\underset{i,t}{1} = \beta_0 + \alpha_1 Y\underset{i,t-1}{1} + \beta_1 X\underset{i,t-1}{1} + \beta_2 X\underset{i,t-1}{2} + \beta_3 X\underset{i,t-1}{1} \cdot X\underset{i,t-1}{2} + \gamma_1 K\underset{i,t-1}{1} + \gamma_2 K\underset{i,t-1}{2} + \gamma_3 K\underset{i,t-1}{3} + \gamma_4 K\underset{i,t-1}{4} + \gamma_5 K\underset{i,t-1}{5} + T_{t-1} + U_i + \varepsilon_{i,t-1} \quad (4)$$

Results and Discussion

Descriptive Statistics of Variables

Overview

From the descriptive statistics of the variables in Table 3, it is found that: the mean value of ACWP is 0.0153, with a standard deviation of 0.0034. Since ACWP is a ratio concept and the value is small, it

Table 3. Descriptive statistical analysis.

Variables	Sample size	Mean	Standard deviation	Minimum	Maximum
Y_1	330	0.0153	0.0034	0.0776	0.2573
Y_2	330	0.725	0.186	0.576	0.894
Y_3	330	142.88	61.00	39.31	354.98
X_1	330	55.32	67.045	0.4	338.729
X_2	330	0.299	0.193	0.021	0.778
K_1	330	7.10	0.63	4.11	8.25
K_2	330	0.232	0.187	0.041	1.03
K_3	330	1.491	0.717	0.391	3.817
K_4	330	0.878	0.482	0.073	2.115
K_5	330	6.56	1.15	4.65	10.47
K_6	330	0.541	0.135	0.282	0.896

indicates that the provincial differences in China's ACWP are not obvious and there may be regional contiguity. The mean value of rural welfare is 0.725 with a standard deviation of 0.186. However, the UN's Human Development Index for China is 0.752, indicating that there is still a development gap between China's urban and rural areas, making the rural welfare level slightly lower than the urban one. This has become an important practical need for China to vigorously promote its "rural revitalization strategy". The mean value of agricultural carbon emissions per capita is 142.88 with a standard deviation of 61. Comparing this to Carbon Brief's published carbon emissions per capita of approximately 7.16 tonnes in China in 2018, it shows that China's rural carbon emissions are still high and show a wide disparity across provinces. The mean value of agricultural insurance is 55.32, which is still far from the standard of RMB 500 per capita set by the China Banking and Insurance Regulatory Commission, while the standard deviation of 67.045 also indicates a large degree of dispersion in agricultural insurance, i.e. the implementation of agricultural insurance varies from province to province. The mean value of Internet development is 0.299, with a standard deviation of 0.193. According to the Statistical Report on the Development Status of the Internet in China, there were 211 million Internet users in rural China in 2018, accounting for 26.3% of all Internet users. This data further indicates that there is still more room for development of Internet penetration in rural China.

Correlation Test

Spearman and Pearson correlation coefficient matrices among the main variables are shown in Table 4. It can be seen that there is a negative correlation between the development level of agricultural insurance and the performance of agricultural carbon welfare, and there is a positive correlation between the popularity of the Internet and the performance of agricultural carbon welfare. In addition, the absolute value of

Table 4. Correlation coefficient matrix of main variables..

Variables	Y_1	X_1	X_2	K_1	K_2	K_3	K_4	K_5	K_6
Y_1	1	-0.083***	0.173***	0.195***	0.196***	0.049***	-0.023***	0.032***	-0.143***
X_1	-0.074***	1	0.131***	-0.151***	-0.148***	0.023**	0.071***	0.035***	-0.067***
X_2	0.165***	0.112***	1	-0.188***	-0.187***	0.021***	0.141***	0.132***	0.044***
K_1	0.193***	-0.122***	-0.187***	1	0.893***	-0.132***	-0.013**	0.042***	0.036***
K_2	0.201***	-0.152***	-0.201***	0.986***	1	-0.133***	-0.014**	0.038***	0.032***
K_3	0.048***	0.008	0.021***	-0.132***	-0.143***	1	0.036***	0.051***	-0.101***
K_4	0.002	0.079***	0.112***	-0.035***	-0.042***	0.062***	1	0.132***	-0.012***
K_5	0.035***	0.058***	0.087***	0.0237***	0.005	0.063***	0.100***	1	-0.051***
K_6	-0.152***	-0.069***	0.042***	0.041***	0.052***	-0.114***	-0.043***	-0.066***	1

correlation coefficient between control variables is lower than 0.5, which also shows that there is no serious multicollinearity between control variables, and the selection of control variables is effective. In addition, the variance inflation factors of the main variables are all less than 5, further avoiding the effect of multicollinearity.

Spatial and Temporal Trends

In order to clearly demonstrate and analyze the development characteristics of China's ACWP, this paper further explores the dynamic trends in time and space with respect to the three core variables of ACWP, rural welfare level and agricultural carbon emissions respectively.

Figs 2 and 3 show the annual change in ACWP and its spatial distribution, respectively. As ACWP is a comprehensive assessment of the development of rural areas in terms of both welfare levels and carbon emissions, larger values indicate a better assessment of the combined performance of agricultural carbon emissions and rural welfare levels in the area. In terms of time, the ACWP shows an increasing trend year by year. After ten years of continuous development, the value has increased by about 17% in 2017 compared to 2007, which shows that the combined performance of China's rural areas has been improving in terms of both "low carbon and welfare". In addition, the timeline also shows that China's ACWP grew fastest in the periods 2008-2010 and 2013-2014. This may be due to the fact that the period 2006-2010 was an important implementation period for China's 11th Five-Year Plan. On the other hand, the change of Chinese state institutions in 2013 and the new leadership's increased focus on controlling pollutant emissions and safeguarding social welfare have combined to boost ACWP.

The spatial trends in Fig. 3 show that, firstly, ACWP is generally distributed in a "high east and low west, high south and low north" pattern, which is in line with the current economic disparities between the east and west of China. This may be due to the advanced economy in the eastern coastal region of China and the high level of rural modernization in the south, which makes farmers with a good economic base more environmentally conscious. Secondly, the regional development of ACWP over the decade has generally expanded from the eastern coastal provinces to the inland provinces, as reflected in the expanding darker areas in the graph, which is an indication of the overall upward trend in China's ACWP. Thirdly, the regional

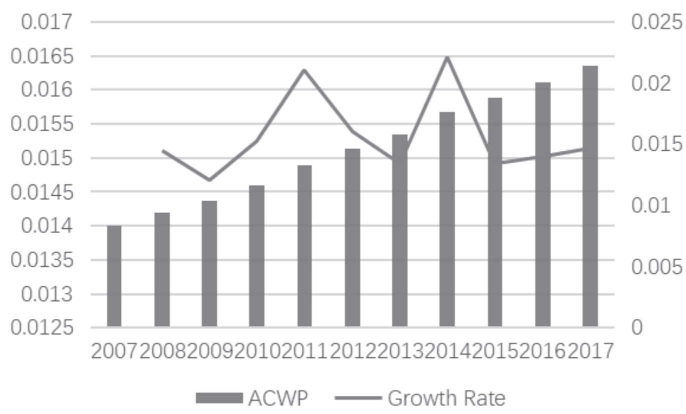

Fig. 2. Annual trends in ACWP.

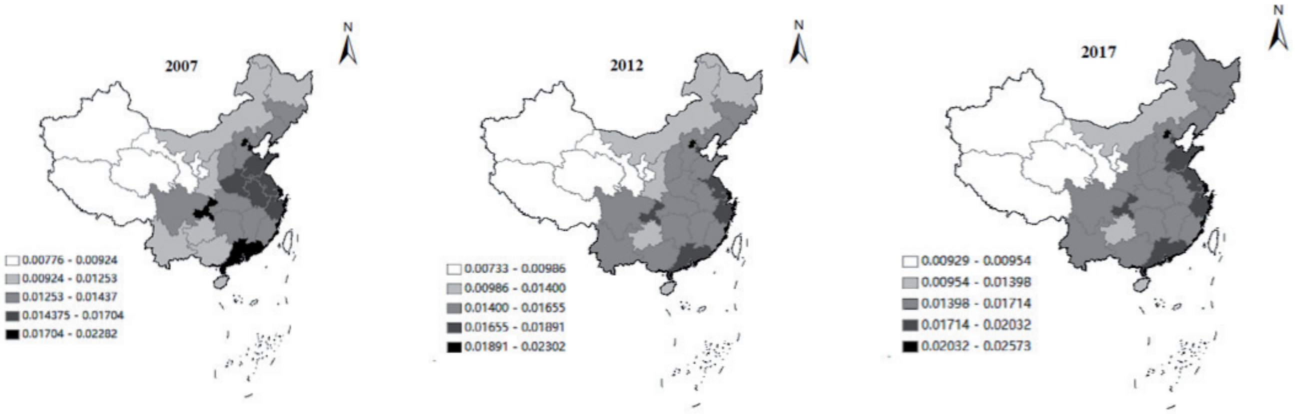

Fig. 3. Spatial distribution of ACWP.

contiguity of ACWP is evident, and the trend is towards contiguity and improvement, a result that further reflects the explanation of the small standard deviation (0.0034) in the descriptive analysis in Table 3.

Figs 4 and 5 represent the mapping of annual changes in the RHDI and its spatial distribution, respectively. In terms of time, the trend is largely similar to that of ACWP. On the one hand, the RHDI shows a year-on-year upward trend, which is inextricably linked to the continued promotion of China's national strategy for poverty eradication and the long-term focus on the three issue of "agriculture, rural areas and farmers". This reflects the fact that in the last decade, China's rural infrastructure has been improving, medical and educational standards have been rising, farmers' incomes have improved and their quality of life is getting better. On the other hand, the growth rate of the RHDI has slowed down since roughly 2014, but, combined with the mean value of 0.725 in Table 3, the RHDI from this year onwards has largely reached a reasonably high level compared to a full score of 1.

Looking at the spatial distribution in Fig. 5: firstly, there is a degree of variability in the RHDI across Chinese provinces and this variability has increased year on year from 2007 to 2017. This characteristic is matched by the standard deviation result of 0.186 in Table 3. Through the variation, we can see that the regions with high RHDI in China are mainly located in the economically developed coastal areas in the east (Jiangsu, Zhejiang, Guangdong and Liaoning provinces). This may be due to the fact that these regions have well-developed rivers, vast plains, and good economic transport facilities, numerous seaports and frequent foreign trade, which are good support for the development of both farmers and agriculture. Secondly, China's provinces have a good foundation for the development of the RHDI and show a dynamic trend of "east to west", which is clearly related to China's economic development strategy of "East leading West". Specifically, not only had the RHDI reached a high level of 0.625-0.671 in most provinces in 2007, but after a decade of development, it has also increased from 0.671 to 0.671. Moreover, after ten years of development, it has gradually evolved from the same level in 2007 for the eastern, central and western provinces to a stepped level in 2017 for the eastern, central and western provinces, which is closer to the economic situation of each province. This also suggests that there may still be a degree of dependence on economic development in China's RHDI.

Figs 6 and 7 show the year-by-year mapping of agricultural carbon emissions and their spatial

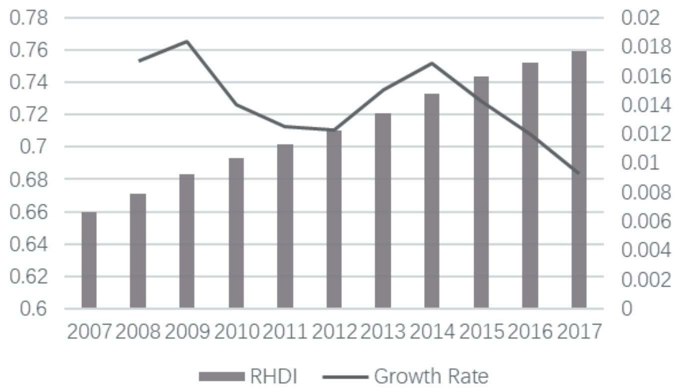

Fig. 4. Annual trends of the RHDI.

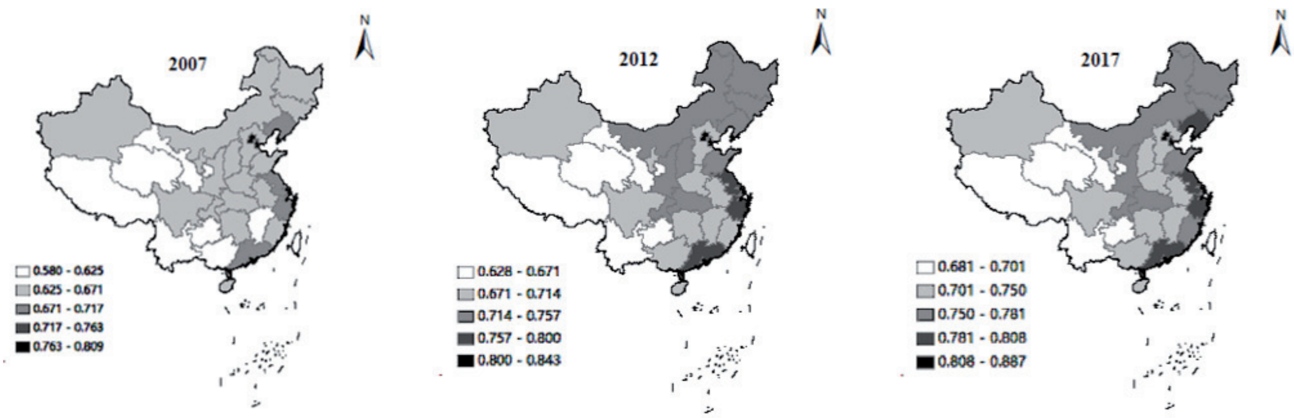

Fig. 5. Spatial distribution of RHDI.

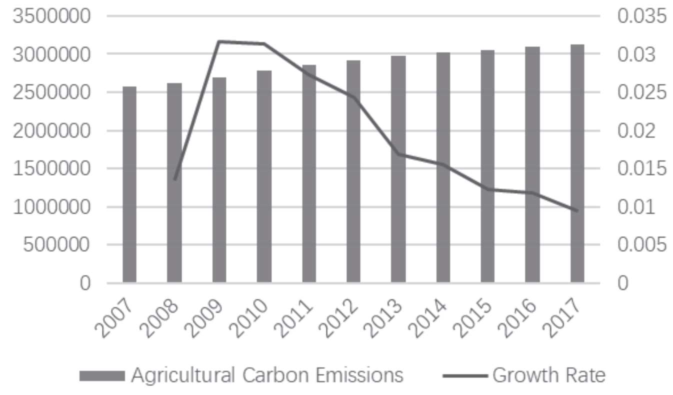

Fig. 6. Annual trends in agricultural carbon emissions.

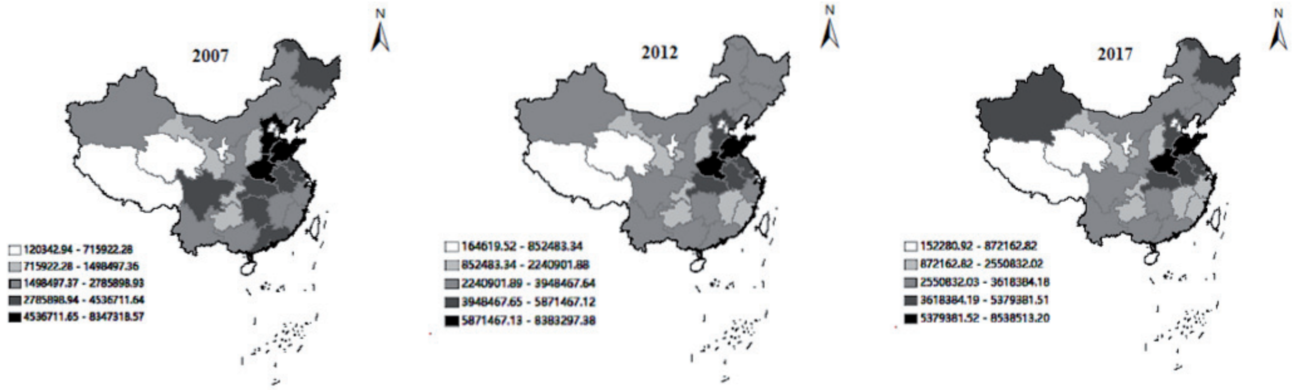

Fig. 7. Spatial distribution of agricultural carbon emissions.

distribution. In terms of time, China's agricultural carbon emissions have remained at a high level over the decade, averaging roughly 2.7 million tonnes per year, indicating that China's agricultural economy is still characterised by high carbon dependency, which provides a realistic need for reform of China's agricultural carbon emissions. Despite this, the decade-long growth rate of agricultural carbon emissions began to decelerate significantly from about 2010, and the total amount of carbon emissions began to show a year-on-year stabilisation trend. This was probably due to the fact that in 2010 China's Ministry of Agriculture explicitly put forward the requirement to strengthen the prevention and control of agricultural surface source pollution, indicating a gradual improvement in the control of agricultural carbon emissions led by policy.

Looking at the spatial trends in Fig. 7: first, the differences in China's agricultural carbon emissions across provinces are more pronounced, as shown by the differences in the colours of the neighbouring provinces in the figure. This result coincides with the results of the larger standard deviation (61) in Table 3, indicating that there are still some gaps in the quality of control of agricultural carbon emissions across provinces. Second, after a decade of development, the regions with high amounts of agricultural carbon emissions in China have gradually clustered from the national prevalence in 2007 to the traditional agricultural provinces of Xinjiang, the Beijing-Tianjin-Hebei region (Beijing, Tianjin, Shandong, Hebei and Henan) and Heilongjiang in 2017, indicating that China's green reform of agriculture is effective and reasonable.

Regression Results

The regression results in Table 5 show that the lagged term of ACWP has a significant effect on the current period's ACWP, indicating the need for a dynamic panel regression model. Specifically, there is a significant positive relationship between the one-period lagged variables and ACWP, indicating that factors such as policy and economic environment in the current period will not only affect the current period's ACWP, but will also continue to affect the next period.

Agricultural insurance has a significant negative relationship with ACWP, with an impact coefficient of -0.056, indicating that for every 1% increase in agricultural insurance intensity, ACWP decreases by 5.6%. This can be interpreted to mean that the introduction of agricultural insurance does not lead to

Table 5. Testing the impact of the Internet and agricultural insurance on ACWP.

Variables	ACWP				ACEC		RHDI	
	FE OLS		SYS-GMM		FE OLS			
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
$Y_{1i,t-1}$			0.964*** (13.68)	0.973*** (14.21)				
X_1	-0.056* (-1.69)	-0.043** (-2.32)	-0.035** (-2.40)	-0.042* (-1.93)	0.18*** (6.08)	0.24*** (7.10)	0.31* (1.67)	0.45*** (2.89)
X_2	0.082** (2.11)	0.081* (1.80)	0.033* (1.69)	0.046** (1.96)	-0.078** (-2.16)	-0.086* (-1.68)	0.52 (1.1)	0.53* (1.65)
$X_1 \cdot X_2$		0.036** (2.22)		0.045 (0.78)		-0.087*** (-3.80)		0.338*** (3.99)
R_SQ	0.8032	0.8321			0.8346	0.8236	0.8763	0.8976
F_TEST	65.32***	65.33**			83.78***	83.46***	123.65***	125.36***
AR(2)			0.446	0.486				
Sargan			1.00	1.00				

an increase in ACWP, but rather a decrease in ACWP. Disaggregating each indicator, agricultural insurance shows a significant positive change in relation to agricultural carbon emissions and a significant positive relationship with growth in rural welfare levels. This suggests that in the current environment of declining primary sector share and significant agricultural population outflow, provinces (municipalities) still exist to improve agricultural output levels at the expense of the environment by increasing agricultural production efficiency, thereby gaining infrastructure investment in rural areas and improving welfare performance. Further, the marginal agricultural carbon emissions were found to be 24%, suggesting that agricultural insurance increases agricultural carbon emissions and that the insurance sector is a "puddle" of moral hazard. Farmers who take out agricultural insurance are more willing to take on the risks associated with pesticides, mulch, fertilisers and other agricultural intermediates than uninsured farmers who expand their crops, making the insured farming practices more polluting to the environment. Each unit of agricultural insurance development increases the level of rural welfare by 0.45 units, indicating that agricultural insurance spreads the risks faced by agricultural production and promotes agricultural economic growth, allowing more funds to be invested in public welfare products such as basic education, public health and transport in rural areas. This confirms the role of agricultural insurance as a "stabilizer" and "enabler", and provides strong evidence for the introduction of agricultural insurance across the country. However, as the increase in rural welfare levels is relatively small compared to the increase in agricultural carbon emissions, the combined effect of the two makes the development of agricultural insurance a negative driver of ACWP, further suggesting that there is still much room for improvement in the "Two Mountains Theory" of relying on agricultural insurance alone to achieve high quality green agricultural development.

Internet development and ACWP show a significant positive variation with an impact coefficient of 0.081, indicating that for every 1% increase in the level of Internet development, ACWP increases by 8.1%. This means that the increase in the level of Internet penetration and application in rural areas has an important role to play in digitally aiding agricultural output, improving the rural public service system, such as the education system and healthcare system, and improving environmental quality monitoring and technical governance. Dissecting the two indicators separately shows that there is a significant negative variation between the Internet and agricultural carbon emissions, with a marginal agricultural carbon emission of -8.6%, the popularization of the Internet has effectively reduced agricultural carbon emissions. The reasons for this may be: on the one hand, Internet informatization has realized the integration and information sharing of agricultural environmental resources, improved the government's agricultural carbon emission supervision level and governance efficiency, and the public's awareness and enthusiasm to participate in environmental protection. On the other hand, compared with the traditional agricultural production mode, the development of agriculture through the Internet has improved the agricultural production efficiency and the quality of agricultural products, reduced agricultural carbon emissions and alleviated the agricultural ecological pressure. A significant positive relationship between the Internet and the level of rural welfare, with each unit increase of Internet penetration in rural areas increasing the level of rural welfare by 0.53 units, further indicating that the development of the Internet has effectively reduced agricultural carbon emissions and promoted the growth of rural welfare. It can be argued that the

Internet, as a technological and information medium, influences agricultural production and the digital use of farm household labour, thus affecting agricultural economic growth and improving rural social welfare. Compared to traditional agricultural production methods, the use of the Internet to develop agriculture improves the efficiency and quality of agricultural production and reduces the burden on farmers. On the one hand, the Internet provides a medium way for farmers to learn new technologies, for example, modern farming techniques and crop pest control techniques. On the other hand, the Internet provides new channels for the sale of agricultural products, for example, "Tik Tok" and "Moments", etc., to promote and sell the agricultural products they produce online.

The interaction term between the Internet and agricultural insurance has a significant positive impact on ACWP, indicating that "Internet + Agricultural Insurance" can significantly contribute to the improvement of ACWP, i.e. the "digitalization" of the Internet is a good complement to agricultural insurance. This can be explained by the fact that "Internet + Agricultural Insurance" provides an effective solution to the problems of over-reliance on government subsidies and inadequate regulatory measures in the development of agricultural insurance, and alleviates the problem of information asymmetry between the government, insurance institutions and farmers. Moreover, through the screening and determination of big data on the Internet, the problem of adverse selection by farmers in taking out agricultural insurance has been avoided to a certain extent. The Internet data and related media exposure also play a good role in regulating farmers' farming behaviour and eliminating moral risks. Overall, the use of the Internet has complemented and improved China's agricultural insurance service system.

Robustness Tests

Dynamic Panel Estimation

Considering that factors such as policy and economic environment in the previous period will have a continuous dynamic impact on agricultural carbon emissions and rural welfare, thus a lagged first-order term of ACWP is added to the model to construct a dynamic panel model, and a systematic GMM analysis is used, all of which pass the corresponding tests. Although the coefficients of the explanatory variables change, the sign and significance of the coefficients are consistent with the benchmark analysis and can demonstrate that the baseline regression results are robust.

Considering Lagged Effects

Since there may be time lag effects on the development of Internet and agricultural insurance and other control variables on ACWP, this paper replaces agricultural insurance, Internet, both interaction terms and other control variables with their respective lagged one-period terms and continues to test them using time-individual two-way fixed effects. The regression results are shown in Table 6. The lagged one-period coefficients of agricultural insurance, Internet, and the two interaction terms do not change significantly in sign when compared with the baseline regression, which can indicate that the results of this paper's regression analysis are robust.

Replace Dependent Variable

In order to test the significant impact of "Internet + agricultural insurance" on the ACWP, this study replaced the measure of the dependent variable. We chose the DEA-Malmquist method to calculate agricultural carbon productivity as an alternative variable of ACWP. Agricultural carbon productivity is defined as the ratio between output and required input in agricultural production. Among them, the output index is the GDP of primary industry of each province in China from 2006 to 2017, which represents the agricultural output index of each region. The input index is agricultural carbon emission, agricultural capital stock, agricultural labor force and land capital, which is calculated by Deap 2.1. The results of specific

Table 6. Robustness tests considering the effect of lagged effects.

Variables	ACWP		ACEC		RHDI	
	FE OLS		FE OLS			
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
X_1	-0.012* (-1.83)	-0.031*** (-2.62)	0.236*** (5.83)	0.253*** (6.79)	0.45 (0.65)	0.65 (1.38)
X_2	0.061* (1.61)	0.076 (0.93)	-0.138*** (-3.46)	-0.157** (-2.50)	0.86 (0.01)	0.98 (0.52)
$X_1 \cdot X_2$		0.152** (2.39)		-0.25*** (-3.39)		0.43** (-2.01)
R_SQ	0.7632	0.7765	0.8473	0.8375	0.8525	0.8897
F_TEST	56.42***	54.38***	63.75***	62.39***	81.56***	77.67***

Table 7. Robustness tests of substituted dependent variable.

Variables	FE OLS	
	Modle 15	Modle 16
X_1	-0.038** (-2.37)	-0.074*** (-2.61)
X_2	0.059* (1.84)	0.032 (0.64)
$X_1 \cdot X_2$		0.231** (2.48)
R_SQ	0.8102	0.7953
F_TEST	48.72***	55.63***

regression are shown in Table 7. Compared with the baseline regression, the coefficient sign has not changed significantly, which proves that the regression analysis results of this paper are robust.

Conclusions and Recommendations

This paper constructs ACWP based on the concept of green agriculture development, and combines President Xi Jinping's "Two Mountains Theory" with individual and time-point dual fixed effects models and systematic GMM estimation models to empirically analyze the impact of "Internet + Agriculture Insurance" on ACWP using China's provincial panel data from 2007-2017. The following main conclusions were drawn: the development of agricultural insurance has a significant negative relationship with ACWP, while the popularity of the Internet significantly drives the improvement of ACWP. The Internet's role in promoting the process of improving ACWP is greater than the inhibiting effect of agricultural insurance, so the interaction between the two significantly promotes regional ACWP, indicating that there is a synergistic effect on the joint impact effect of the Internet and agricultural insurance on ACWP. There is a positive relationship between the development of agricultural insurance and agricultural carbon emissions, and a significant negative relationship between the popularity of the Internet and agricultural carbon emissions, while the interaction between agricultural insurance and the Internet plays a role in reducing carbon emissions. The increase in the development of agricultural insurance significantly contributes to the improvement of rural welfare, and the popularity of the Internet also significantly modulates the level of rural welfare, while the interaction of agricultural insurance and the Internet significantly increases the level of rural welfare.

Promote the deeper integration of the "Internet + Agricultural Insurance" strategy to comprehensively improve the ACWP. Firstly, the policy regulations on agricultural insurance should be improved and amended to guide the agricultural insurance market to become more standardized and rational in order to effectively match the combined needs of the rural economy and the environment. Secondly, accelerating the penetration of Internet technology in rural areas, especially the penetration and application of Internet technology in backward rural areas, promoting the deep integration of Internet technology with the development of agricultural insurance and reducing systemic risks such as moral hazard and adverse selection in the process of agricultural insurance development. For example, strengthen cross-border linkage and information sharing in environmental management; establish an information communication platform between the government and the public, and encourage the public to report agricultural pollution violations and monitor the results of law enforcement. Thirdly, make full use of the accurate classification function of big data to carry out effective advertising and promotion, and then tap potential insurance customers, and constantly improve the marketing mode of online sales of insurance on the Internet to further improve the coverage of agricultural insurance. Fourthly, establish a fair and equitable agricultural insurance market environment, and give full play to the technical advantages of the Internet to improve agricultural insurance innovation, making agricultural insurance products more rational and simple to serve the insured farmers well.

For other developing countries or regions, agricultural insurance and Internet technologies need to be developed in a focused manner according to regional realities in order to effectively promote rural welfare and economic growth. On the one hand, agricultural insurance should be promoted and subsidized in areas where there is an urgent need to develop the agricultural economy, in order to ensure that agricultural insurance is risk-proof and economically driven. However, this process requires the selection and control of the appropriate level of agricultural insurance in accordance with the regional environmental carbon carrying capacity in real time. On the other hand, in rural areas where the regional economic welfare level is already good, the Internet can be further increased to build a framework for the development of a virtuous cycle of ACWP and the 'environmental governance' role of the Internet. At the same time, the region can take advantage of the intelligence of the "Internet+" to accelerate the transformation and upgrading of agriculture and create resource-saving and environmentally friendly ecological agriculture.

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Conflict of Interest

The authors declare no conflict of interest.

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