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Research on the influence of Internet technology popularization on the green development of agriculture in the Yangtze River Economic Belt

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ABSTRACT

Based on the panel data from 2000 to 2018, the super efficiency SBM-DEA model is used to calculate the agricultural green development efficiency of 11 provinces and cities in the Yangtze River economic belt, and then the Tobit econometric model is used to empirically test the impact of Internet technology popularization on the agricultural green development of the Yangtze River economic belt. The results show that: (1) on the whole, the efficiency of agricultural green development in the Yangtze River Economic Belt showed a downward trend in fluctuations from 2000 to 2018; in terms of regions, the efficiency of agricultural green development in various regions of the Yangtze River Economic Belt varies greatly, showing a spatial pattern of "downstream > upstream > midstream". (2) The popularization of Internet technology has significantly promoted the green development of agriculture in the Yangtze River Economic Belt; at the same time, there is a significant positive correlation between rural human capital and the green development of agriculture in the Yangtze River Economic Belt, while the level of agricultural mechanization, the degree of capital deepening, the level of urbanization, and agricultural economic growth inhibit the improvement of the green development of agriculture in the Yangtze River Economic Belt to a certain extent. Therefore, the local governments of the Yangtze River Economic Belt should actively promote the popularization of Internet technology, enhance the Internet awareness of farmers, and give better play to the enabling role of Internet technology in the green development of agriculture in the Yangtze River Economic Belt.

Keywords: Yangtze River Economic Belt; popularization of Internet technology; green development of agriculture; super efficiency SBM-DEA model

1. Introduction and literature review

As an important inland river economic belt in China, the Yangtze River Economic Belt covers 9 provinces and 2 cities. According to the data from the National Bureau of Statistics, its area accounts for 21.4% of the country's total land area, and its GDP and population account for more than 40% of the country. It is the most important agricultural production area and rural agglomeration area in China. However, with the development of the agricultural economy in the Yangtze River Economic Belt, the contradiction between agricultural development and ecological environment protection has become increasingly prominent. Many agricultural

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areas along the Yangtze River have shown such ecological environment problems as the decline of groundwater level, the decline of soil fertility, the aggravation of agricultural non-point source pollution, the weakening of agricultural ecological service functions, and the increasingly severe quality and safety of agricultural products. On 11 September 2018, the Ministry of Agriculture and Rural Areas issued implementation opinions on supporting the green development of agriculture and rural areas in the Yangtze River Economic Belt, which proposed that in order to further promote the green development of agriculture in the Yangtze River Economic Belt, the use of chemical fertilizers and pesticides should be reduced, the diversity of aquatic organisms should be protected, the reuse of agricultural wastes should be promoted, and the preferential support for rural construction should be strengthened to beautify the rural living environment and promote the revitalization of rural industries. Therefore, how to better change the mode of agricultural development and drive high-quality agricultural development with green development has become an urgent choice for the sustainable development of agriculture in the Yangtze River Economic Belt.

In the face of complex agricultural resources and environmental problems, it is difficult to deal with them by using traditional governance means, management methods, or financial and material resources[1]. With the continuous promotion of China's green development and ecological civilization construction, the public's awareness of environmental protection has been continuously enhanced. At the same time, the application of a new generation of information technology, big data technology, which originates from the Internet and its extension, is also developing. At present, it is entering an intelligent development stage characterized by deep data mining and integrated applications. The informatization and modernization of ecological environment governance are facing unprecedented development opportunities. The report of the 19th National Congress of the Communist Party of China proposed that we should promote the deep integration of the Internet and the real economy, cultivate new growth points for China's economic development, accelerate scientific and technological innovation, and build a network power, digital China, and smart society. With the promotion of the construction of digital China, we have entered a new stage of information development marked by big data. The data resource collection and application capabilities of various industries have been continuously improved, and the data accumulation has become increasingly rich. According to the 48th statistical report on China's Internet development issued by the China Internet Network Information Center (CNNIC), China's Internet penetration rate had exceeded 71.6% by June 2021. The popularity of the Internet has profoundly changed people's economic behavior and way of life. Under the development pattern of domestic circulation as the main body and domestic and international double circulation, the Internet will further play an important role in promoting economic recovery, ensuring social operation, improving social governance, and improving government services and regulatory capacity.

While the popularization of Internet technology has an important impact on China's economic development, there are several issues worthy of in-depth consideration and research: What impact does the popularization of Internet technology have on the green development of agriculture? From the perspective of Internet technology, what strategies should be taken to achieve green agricultural development and sustainable utilization of resources? In recent years, scholars' attention to agricultural green development has been mainly reflected in the connotation definition, efficiency measurement, and influencing factors of agricultural green development. Yu believes that green development in agriculture is a new model of modern agricultural development, and it is necessary to realize green transformation in agriculture in key areas such as development concept, water and soil resource protection, production behavior norms, and ecological risk assessment of production technology[2]. Sun et al.[3] pointed out that, as a development concept, agricultural green development is the concrete manifestation of the scientific judgment that "green mountains and green waters are golden mountains and silver mountains" in agricultural development, focusing on the coordinated development of the agricultural economy, social development, and ecological environment. Tu and Gan[4] and Jin[5] found that the status of agricultural green development in most parts of China is worrying, the level is low, and the development is unbalanced, the driving force is insufficient, and the response is not strong[4,5]; however, Wei et al.[6], Zhao and Yu[7], Gong and Li[8] used the comprehensive index method to measure the main grain producing areas around the country and found that the level of agricultural green development has significantly improved, and there are large differences in the level of agricultural green development among regions; Qi et al.[9] used entropy weight method, Theil index method and convergence analysis to find that China's agricultural green development level is the best in the East and the worst in the West. The gap in green agricultural production level across the country and the three major regions has an expanding trend, which is mainly caused by the difference in production level between regions. In terms of the factors affecting the green development of agriculture, some scholars have found that the level of machinery, production level, human capital[4], confirmation of agricultural land rights, financial support for agriculture, industrialization level, urbanization level[10], credit support[11], and agricultural industry agglomeration[12] have different degrees of impact on the green development of agriculture. Only a few scholars have made a descriptive analysis of the impact of information technology on agricultural sustainable development in the literature on the impact of the Internet, a new variable, on agricultural green development. Wang[13] believes that the Internet can not only affect traditional ideas and production methods but also promote the circulation of agricultural and sideline products and the promotion of agricultural technology. Liu[14] proposed that digital agriculture is conducive to promoting the transition from traditional agriculture to modern agriculture and the transformation and upgrading of agricultural industrial structures, so as to promote the green and sustainable development of agriculture. Zhang and Mao[15] believe that the Internet affects all production links in agriculture, can continuously expand the scale of agricultural production, innovate the profit growth point of agriculture, and reduce the marketing risk caused by the expansion of agricultural production scale[15].

In general, the current research rarely carries out in-depth and systematic discussion on the impact of the popularization of Internet technology on the green development of agriculture, and the literature on river basins is even less. Therefore, based on the panel data from 2000 to 2018, this paper will take the Yangtze River Economic Belt as an example, evaluate the efficiency of agricultural green development by using the unexpected output super efficiency SBM-DEA model, and then empirically test the impact of Internet technology popularization on the agricultural green development of the Yangtze River Economic Belt in order to practice the concept of "ecological priority, green development" from the perspective of Internet technology. It provides decision-making reference for promoting the Yangtze River Economic Belt to become a leading demonstration zone for the high-quality development of agriculture in the basin.

2. Efficiency evaluation of agricultural green development in the Yangtze River Economic Belt

2.1. Index system construction

As a strategic tool and management means to assess the intensive and economical utilization of resources and the improvement of environmental quality in agricultural development and to ensure that agricultural products are green and pollution-free, the efficiency assessment of agricultural green development focuses on obtaining more expected outputs and less unexpected outputs with as little input as possible in agricultural development. The higher the efficiency of agricultural green development, the higher the level of agricultural sustainable development, and vice versa. Therefore, based on the evaluation indexes of Huang et al.[16] and Tu et al.[17], an evaluation index system for the efficiency of agricultural green development in the Yangtze River

Economic Belt is established from the two aspects of input and output to measure the quality of its agricultural green development (see **Table 1**).

Table 1. Evaluation index system of agricultural green development efficiency in the Yangtze River Economic Belt.

Index system	Primary index	Secondary index (unit)
Investment index	Labor input	Number of employees in the primary industry (10,000)
	Capital investment	expenditure on agriculture, forestry and water affairs (100 million yuan)
	Agricultural machinery input	Total power of agricultural machinery (10,000 KW)
	Land input	Sown area of crops (1000 HA)
	Water input	Effective irrigation area (1000 HA)
	Pesticide input	Pesticide application amount (10,000 tons)
	Fertilizer input	Net application amount of agricultural chemical fertilizer (10,000 tons)
	Agricultural film input	Agricultural film consumption (10,000 tons)
	Energy input	Agricultural diesel consumption (10,000 tons)
Output indicators	Expected output	Total agricultural output value (100 million yuan)
	Unexpected output (environmental pollution index)	Comprehensive index of agricultural non-point source pollution
		Agricultural carbon emission (10,000 tons)

In **Table 1**, the unexpected output is mainly measured by the "environmental pollution index", constructed by the two secondary indicators of the agricultural non-point source pollution comprehensive index and agricultural carbon emissions. In order to better reflect the situation of agricultural non-point source pollution, referring to the data processing method of Fang and Zeng[18], the comprehensive index of agricultural non-point source pollution is constructed by using the entropy method to fit the four indicators of nitrogen loss, phosphorus loss, pesticide residue and agricultural film residue. The loss amount of nitrogen (phosphorus) fertilizer is equal to the sum of the use amount of nitrogen (phosphorus) fertilizer and the nitrogen (phosphorus) content of compound fertilizer (assuming that the ratio of nitrogen, phosphorus and potassium in compound fertilizer is 1:1:1) multiplied by the fertilizer loss coefficient of 0.65, the pesticide residue amount is equal to the pesticide application amount multiplied by the pesticide residue coefficient of 0.5, and the agricultural film residue amount is equal to the use amount of agricultural film multiplied by the agricultural film residue coefficient of 0.1. Referring to the research results of Wang and Zhang[19], the agricultural carbon emission is equal to the consumption or area of the six carbon emission sources of chemical fertilizer, pesticide, agricultural film, agricultural diesel, agricultural irrigation and agricultural seeding multiplied by the corresponding emission coefficient, which is 0.896 (kg/kg), 4.934 (kg/kg), 5.180 (kg/kg), 0.593 (kg/kg), 25 (kg/HA) and 312.600 (kg/HA).

2.2. Calculation of agricultural green development efficiency

The SBM-DEA model is used to calculate the efficiency of agricultural green development. Because the DEA model requires a positive correlation (radial) between input and output, in the process of agricultural production, the input of some agricultural resources will lead to unexpected output; that is, there will be a negative correlation (non-radial) between input and output. Tone (2002)[20] proposed a non-radial super efficiency SBM-DEA model for unexpected output, which effectively avoided the non-radial problem of classical DEA model in the process of unexpected output index processing and realized the effective evaluation of multiple decision-making effective units. Therefore, this paper will use the unexpected output super efficiency SBM-DEA model to measure the agricultural green development efficiency of 11 provinces and cities in the Yangtze River Economic Belt, and, on this basis, draw the change trend chart of agricultural green development efficiency in the Yangtze River Economic Belt (see **Figure 1**) and the regional comparison chart of agricultural green development efficiency (see **Figure 2**).

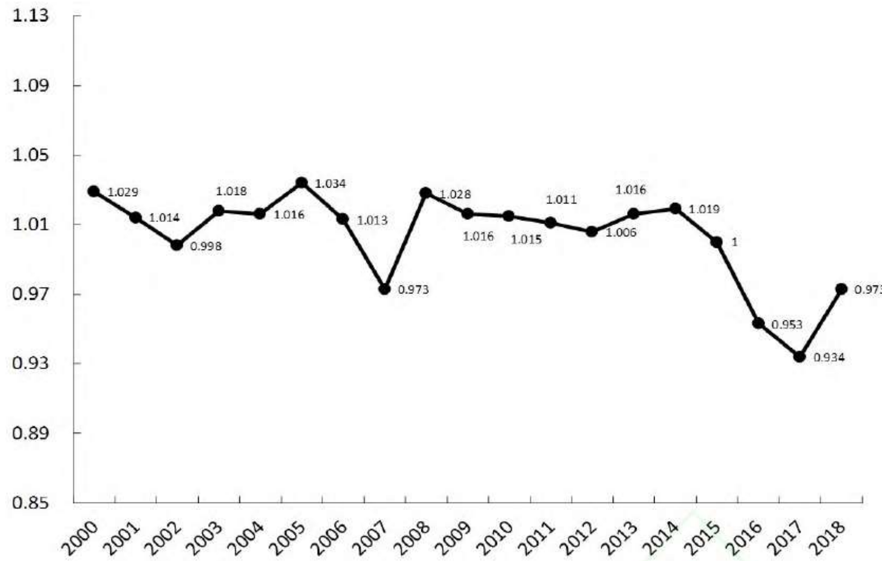

Figure 1. Change trend of agricultural green development efficiency in the Yangtze River Economic Belt from 2000 to 2018.

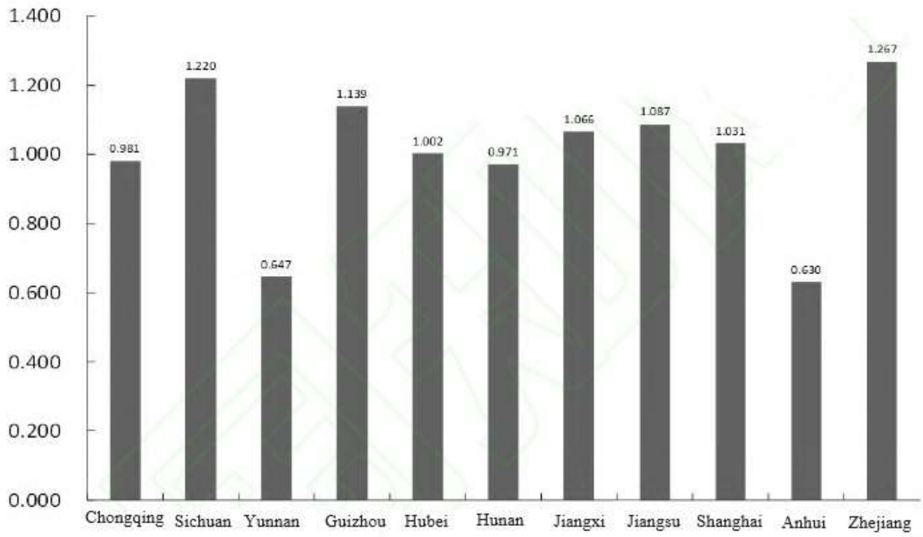

Figure 2. Regional comparison of agricultural green development efficiency in the Yangtze River Economic Belt from 2000 to 2018.

According to the availability of data, the time interval for measuring the efficiency of agricultural green development in the Yangtze River Economic Belt is 2000–2018. The original data are mainly from the statistical database of China Economic Network, EPS database, China Statistical Yearbook (2001–2019), and the statistical yearbooks of various regions in 2001–2019.

According to **Figure 1**, from 2000 to 2018, the efficiency of agricultural green development in the Yangtze River Economic Belt declined in fluctuation; there have been two big troughs in the efficiency of agricultural green development in the Yangtze River Economic Belt, namely, 2007 and 2017. From 2000 to 2014, the efficiency of agricultural green development in 2007 was less than 1, and it was relatively stable and greater than 1 in other years; from 2014 to 2017, the efficiency of agricultural green development showed a downward trend year by year, from 1.019 to 0.934, and rebounded and improved in 2018. Since 2004, the state has increased its support for agriculture, implemented agricultural tax reduction and exemption, agricultural direct subsidies, and strengthened its investment in agricultural finance. The central government's support for agriculture has reached the highest level in previous years. In 2006, the policy of completely abolishing agricultural tax was officially promulgated, which greatly improved farmers' enthusiasm for production. However, the extensive characteristics of agricultural production are still significant. In addition, from 2007 to 2008, agricultural production was affected by the southern snow disaster, the Wenchuan earthquake, international financial crisis, and other adverse factors, resulting in the first trough (0.973) of agricultural green development efficiency during the study period in 2007; then the economy entered the new normal. The efficiency of agricultural green development in the whole basin was relatively stable from 2008 to 2014. However, since the agricultural supply side structural reform in 2015, farmers have a tendency to strengthen the input of consumption resources such as pesticides and agricultural film in order to improve agricultural production efficiency, which may lead to an increase in unexpected output. The overall efficiency of agricultural green development shows a gradual downward trend, and the average value is less than 1. In 2017, the 19th National Congress of the Communist Party of China put forward the strategy of rural revitalization, which requires taking the road of rural green development. The efficiency of agricultural green development will be eased and improved by 2018.

According to **Figure 2**, the efficiency of agricultural green development in various regions of the Yangtze River Economic Belt varies greatly. From 2000 to 2018, Zhejiang (1.267) had the largest average efficiency of agricultural green development and Anhui (0.630) had the smallest. There are 6 regions where the average agricultural green development efficiency of the Yangtze River Economic Belt exceeds the average agricultural green development efficiency of the Yangtze River Economic Belt (1.003), including Sichuan (1.220), Guizhou (1.139), Jiangxi (1.066), Jiangsu (1.087), Shanghai (1.031) and Zhejiang (1.267). Among them, the higher efficiency of agricultural green development in Guizhou is due to the lower application of pesticides, chemical fertilizers, agricultural films and other elements that pollute the environment, and the higher technical efficiency; the high efficiency of agricultural green development in Jiangsu, Shanghai and Zhejiang is mainly due to the high level of industrialization and more talents in the Yangtze River Delta, which makes the level of agricultural technology and agricultural production higher. Chongqing, Yunnan, Hubei, Hunan and Anhui are the top five regions with the average value of agricultural green development efficiency. Among them, Yunnan, Hubei, Hunan and Anhui are the main grain producing areas in China, indicating that the agricultural green development efficiency of the main grain producing areas in China is low, mainly due to excessive investment in resources and low resource utilization efficiency. There are two regions with high efficiency of agricultural green development in the upper reaches of the Yangtze River, one region with high efficiency of agricultural green development in the middle reaches of the Yangtze River, and three regions with high efficiency of agricultural green development in the lower reaches of the Yangtze River; that is, the distribution of regions with high efficiency of agricultural green development in the space presents a pattern of "downstream > upstream > midstream".

3. The impact of the popularization of Internet technology on the green development of agriculture in the Yangtze River Economic Belt

3.1. Model setting

Since the efficiency of agricultural green development in the Yangtze River Economic Belt is between 0 and 1.4, based on previous research experience, this paper selects Tobit panel data regression model to study the impact of Internet technology popularization on agricultural green development in the Yangtze River Economic Belt. The model is constructed as Equation (1):

$$AEE_{it} = \alpha_0 + \alpha_1 INTER_{it} + \sum_{j=1}^{n} \beta_j X_{jt} + \varepsilon_{it} \quad (1)$$

where, α_0 is the intercept term, ε_{it} is the random error term, AEE_{it} represents the efficiency of agricultural green development, $INTER_{it}$ is the core explanatory variable of this paper, Internet technology penetration, X_{jt} represents the control variable, and β_j represents the coefficient to be estimated of the control variable.

3.2. Index description and data source

The explained variable is the efficiency of agricultural green development, using the results of the previous measurement. The core explanatory variable is the Internet technology penetration rate, which is measured by the proportion of Internet users in the total population (%). In addition, agricultural green development efficiency is also affected by many factors. This paper mainly introduces five control variables, namely, agricultural mechanization level (MECHA), capital deepening degree (CAP), rural human capital (HUM), urbanization level (CITY) and agricultural economic growth (AGRI). Among them, (1) agricultural mechanization level (MECHA) is expressed by the ratio of total power of agricultural machinery to total sown area of crops (kw/HA). Improving the level of agricultural mechanization is conducive to promoting the increase of agricultural output. Producers have the incentive to increase factor input and expand the scale of output, resulting in an increase in pollution levels. However, it may also improve the ability of agricultural pollution control and the agricultural environment. (2) Capital deepening degree (CAP) is measured by the ratio of agricultural financial expenditure to agricultural employees (10,000 yuan/person). The degree of capital deepening will affect the mode of agricultural production and the input allocation of agricultural production factors, thus affecting the green development of agriculture. (3) Rural human capital (HUM) is expressed by the proportion (%) of the population with high school and above per 100 rural labor force population. The more educated the agricultural practitioners are, the more willing they are to learn the relevant knowledge of agricultural production, which is conducive to improving the efficiency of agricultural production and promoting the green development of agriculture. (4) The urbanization level (CITY) is expressed by the proportion (%) of the urban resident population in the total population. Urbanization will increase farmers' non-agricultural employment, increase farmers' income, and promote farmers' investment in pesticides, fertilizers, agricultural films and other resources. To some extent, it is not conducive to the green development of agriculture. (5) Agricultural economic growth (AGRI) is expressed as the proportion (%) of agricultural GDP to total GDP. Agricultural economic growth is easy to form a "driving" growth mode of factors. The increase in the input of polluting factors reduces its utilization rate, increases agricultural environmental pollution, and is not conducive to the green development of agriculture.

The empirical research range is still 2000–2018, and the research objects are 11 provinces and cities in the Yangtze River Economic Belt. The original data are from China Statistical Yearbook (2001–2019), China Rural Statistical Yearbook (2001–2019) and regional statistical yearbooks from 2001 to 2019. Some missing data is supplemented by exponential smoothing coefficient method. **Table 2** shows the descriptive statistics of each index of data after sorting. It can be seen from **Table 2** that the variation range of each variable is large, which reflects that there are certain differences in the efficiency of agricultural green development in various regions of the Yangtze River Economic Belt, indicating that the basic data on the relationship between Internet technology penetration and agricultural green development efficiency is good.

Table 2. Descriptive statistics of variables (2000–2018).

Variable	Symbol	Average value	Standard deviation	Maximum	Minimum value
Agricultural green development efficiency	AEE	1.0036	0.2208	1.5660	0.5100
Internet technology penetration	INTER	26.2243	21.0443	75.3781	0.1461
Agricultural mechanization level	MECH	3.7197	1.7226	8.2184	0.5599
Capital deepening degree	CAP	0.5694	1.4009	11.5082	0.0029
Rural human capital	HUM	14.3814	6.6167	37.0000	4.8500
Urbanization level	CITY	47.7210	16.9216	89.6000	19.0047
Agricultural economic growth	AGRI	12.2941	6.2517	26.3118	0 .2910

3.3. Empirical observation of variable relationship

In order to further understand the relationship between Internet technology penetration and agricultural green development efficiency, a scatter diagram between Internet technology penetration and agricultural green development efficiency is made, as shown in **Figure 3**. It can be seen from **Figure 3** that there seems to be a positive correlation between the Internet technology penetration rate and the efficiency of agricultural green development, that is, the improvement (or decrease) of Internet technology penetration will improve (or decrease) the efficiency of agricultural green development to a certain extent, but the relationship between the two cannot be fully explained by observation. The empirical observation will be empirically tested by establishing a model below.

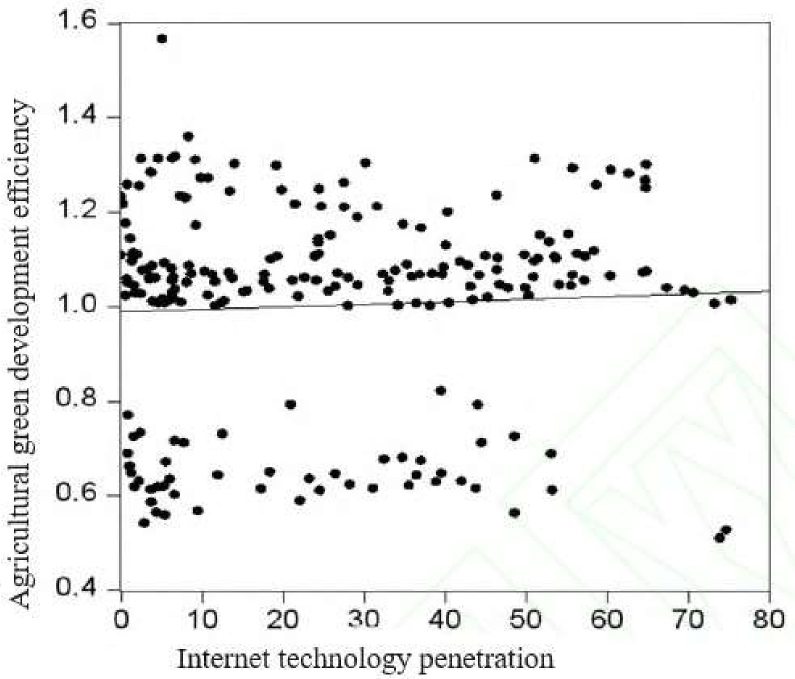

Figure 3. Relationship between Internet technology penetration and agricultural green development efficiency.

3.4. Empirical test and result analysis

In order to ensure the credibility of the empirical research results, firstly, LLC and IPS methods are used to test the stationarity of each index. The results are shown in **Table 3**. It can be seen from **Table 3** that the explained variable AEE obeys order 1 single integer; among the explanatory variables, the variable AGRI is subject to order 0 single integer, and the variables INTER, MECH, CAP, HUM and CITY are subject to order

1 single integer. According to the principle of comprehensive judgment, it can be judged that the data for all indicators are stable.

Table 3. Unit root test results of variable data.

Variable	Symbol	Average value	Standard deviation	Maximum	Minimum value
Agricultural green development efficiency	AEE	1.0036	0.2208	1.5660	0.5100
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Note: ***, ** and * respectively indicate that the statistical value is significant at the level of 1%, 5% and 10%, the same as the following table.

Then, corresponding to the regression models (1)–(5) in **Table 4**, the cointegration test is carried out for the variable system in each model by using Kao test and Pedroni test. The results are shown in **Table 5**. According to **Table 5**, all variable systems in models (1)–(5) reject the original hypothesis at the significance level of 1%, that is, the panel data of models (1)–(5) have a cointegration relationship, and all variable systems have a long-term equilibrium relationship, so regression analysis can be carried out.

Table 4. Impact of Internet technology penetration on agricultural green development efficiency.

Variable	Symbol	LLC	IPS
Agricultural green development efficiency	AEE	–0.8785	–1.1866
	AAEE	–10.0319***	–8.3032***
Internet technology penetration	INTER	7.2655	10.1159
	AINTER	–2.7230***	–1.6568**
Agricultural mechanization level	MECH	–0.4555	3.0011
	AMECH	–7.6605***	–5.9233***
Capital deepening degree	CAP	10.1535	13.5090
	ACAP	–4.8553***	–3.8232
Rural human capital	HUM	–2.9238***	–1.0134
	AHUM	–14.6706***	–12.5392***
Urbanization level	CITY	–1.7859**	4.2281
	ACITY	–9.8853***	–7.4236***
Agricultural economic growth	AGRI	–6.6631***	–1.3942*

Note: the values in brackets are robust standard errors.

Table 5. Panel cointegration test.

Inspection method	Statistic name	(1)	(2)	(3)	(4)	(5)
Kao test	ADF-Satistic	16.5474***	16.2411***	16.3546***	16.2108***	14.9526***
Pedroni test	Penel PP-Satistic	–3.4855***	–3.5333***	–3.0603***	–2.7751***	–4.2692***
	Penel ADF-Satistic	–4.6822***	–4.5918***	–3.6967***	–3.2613***	–2.8127***

Note: the original assumptions of Kao test and Pedroni test are that there is no cointegration relationship between variables; (1) ~ (5) in the table corresponds to the model (1)–(5) in **Table 4**.

In the model regression, it is found through the Hausman test that it is more scientific to use the fixed effect model for estimation, and the final results are shown in **Table 4**. The model in **Table 4** (1) is the result of regression estimation by taking the efficiency of agricultural green development as the explained variable and then adding the core explanatory variable and the level of agricultural mechanization; (2)–(5) is the regression result of gradually adding the degree of capital deepening, rural human capital, urbanization level, and rural economic growth on the basis of model (1).

It can be seen from **Table 4** that in models (1)–(5), with the introduction of various control variables, the regression coefficients of Internet technology penetration rate Inter are significant at the level of 1% or 5% and are positive, indicating that, under the control of other explanatory variables, Internet technology penetration has a significant role in promoting the green development of agriculture in the Yangtze River Economic Belt. In recent years, digital agriculture in the Yangtze River Economic Belt has developed rapidly. New generation Internet information technologies and equipment, such as the Internet of Things, big data, artificial intelligence, precision agriculture, and aviation, have been widely used in the fields of facility planting, facility breeding, the circulation of agricultural products, and quality and safety traceability. Profound changes are taking place in the mode and format of agricultural production and operation. Internet technology has broad market prospects for the green development of agriculture. Taking Yunnan Province in the upper reaches of the Yangtze River as an example, with the help of information technologies such as big data, cloud computing, and the Internet of Things, Yunnan Province has built a comprehensive industry platform called the "Yunnan green agriculture platform," integrating agricultural information and online services. By using Internet thinking and integrating industry resources, Yunnan Province has given full play to the origin and location advantages of Yunnan's agricultural development by providing investment attraction, agricultural material supply, and agricultural machinery. Comprehensive information services, such as the distribution process, help the green development of agriculture. Hubei Province in the middle reaches of the Yangtze River has been making a comprehensive understanding of the number of agricultural pollution sources in the remediation of agricultural non-point source pollution. Less application of chemicals and more application of organic fertilizers have continuously become the production choices of most new agricultural business entities in Hubei. By 2019, the application of chemical fertilizers and pesticides in Hubei had achieved negative growth for six consecutive years. The ultimate pursuit of green, ecological, and organic is not only reflected in food production but also in aquaculture and animal husbandry. By June 2019, the resource utilization rate of livestock and poultry breeding wastes in Hubei had reached 71.68%. A total of 1,276,000 mu of fences, fences, cages, and cages have been removed for breeding, and 274,000 mu of fertilized breeding has been banned, effectively curbing external pollution factors and alleviating agricultural non-point source pollution[21]. In the lower reaches of the Yangtze River, Zhejiang Province, as the National Agricultural Sustainable Development Experimental Demonstration Area and the first batch of pilot areas for agricultural green development promoted by the whole province, has actively promoted agricultural "machine replacement" in recent years, vigorously developed "smart agriculture", and made traditional agriculture plug in the wings of the Internet in production, circulation, sales, and other links. In 2014, Zhejiang focused on establishing and improving the quality and safety traceability system of agricultural products, conducted real-time supervision over the whole process of agricultural production, and analyzed and utilized its supervision data to better serve the quality and safety supervision of agricultural products. At the same time, build the Zhejiang smart agriculture cloud platform and form a "big agriculture" data center through agricultural business applications and data at all levels to scientifically guide agricultural production and operation management, government decision-making supervision, and social public services[22].

From the control variables: (1) the level of agricultural mechanization significantly inhibited the promotion of agricultural green development in the Yangtze River Economic Belt. Generally speaking, agricultural mechanization, as the main embodiment of agricultural technology progress, can improve the utilization rate of resources, directly reduce the carbon emission intensity of unit agricultural disposable energy, and control and reduce agricultural ecological damage and environmental pollution. The negative impact here may be due to the fact that the interests of agricultural producers drive the increase of factor input and the expansion of output scale, coupled with the system mismatch or the distortion of technology application values[23], thus forming the paradox of agricultural technology progress and environmental degradation. (2) The degree of capital deepening has significantly inhibited the promotion of agricultural green development. Capital deepening can guide the benign development of agricultural production and improve the enthusiasm for rural labor production. However, the negative impact on the agricultural environment may be that the direct or indirect government subsidies to farmers will distort the market price of products and factors while promoting agricultural development and then affect the production behavior of farmers, the mode of natural resource utilization, the choice of agricultural production structure, the structure and quantity of agricultural chemical factors, It leads to the unreasonable use of natural resources and environmental damage[24], which makes the capital deepening not make much contribution to the improvement of agricultural green development in the long term. (3) Rural human capital has a significant positive impact on the green development of agriculture in the Yangtze River Economic Belt. With the continuous advancement of agricultural modernization in the areas along the Yangtze River, agricultural production cooperatives, large-scale planting, and family farms have become a trend. The green development of agriculture in the Yangtze River Economic Belt requires agricultural producers to have higher quality to participate in production and management. (4) The level of urbanization has a significant negative impact on the green development of agriculture in the Yangtze River Economic Belt. The reason may be that with the promotion of urbanization in various regions of the Yangtze River Economic Belt and the improvement of farmers' income levels, the opportunity cost of engaging in agriculture continues to increase, the labor force is transferred from agriculture to non-agricultural industries, and agricultural production is gradually changing from the traditional labor-intensive production mode to the capital-intensive mode[25]. The excessive and improper use of agricultural means of production such as chemical fertilizers, pesticides, and agricultural film has caused serious pollution of the agricultural ecological environment in the basin. (5) Agricultural economic growth has a significant negative impact on agricultural green development. Agricultural economic growth depends more on the consumption of natural resources and the increased input of production factors. The rapid development of cauliflower (vegetables, fruits, and flowers) farmland relying on high chemical input and a large-scale livestock and poultry breeding industry with high pollution risk may lead to the intensification of agricultural non-point source pollution due to the increase in production in the whole basin. Moreover, the treatment of agricultural non-point source pollution is complex and arduous. There are many problems in the treatment, such as the weak sense of responsibility of the treatment subjects, the lax treatment, and the lack of long-term operation mechanisms. The situation of agricultural non-point source pollution caused by the growth along the river is still severe, which inhibits the green development of agriculture.

4. Conclusions and policy implications

Based on the panel data from 2000 to 2018, taking the Yangtze River Economic Belt as an example, this paper calculates the efficiency of agricultural green development in 11 provinces and cities and then empirically tests the impact of Internet technology popularization on agricultural green development in the Yangtze River Economic Belt. The study found that: (1) on the whole, the efficiency of agricultural green development in the Yangtze River Economic Belt showed a downward trend in fluctuations in 2000 and 2018;

and (2) geographically, the efficiency of agricultural green development in various regions of the Yangtze River Economic Belt varies greatly, showing a spatial pattern of "downstream > upstream > midstream". (2) The popularization of Internet technology has significantly promoted the green development of agriculture in the Yangtze River Economic Belt; at the same time, there is a significant positive correlation between rural human capital and the green development of agriculture in the Yangtze River Economic Belt, while the level of agricultural mechanization, the degree of capital deepening, the level of urbanization, and agricultural economic growth inhibit the improvement of the green development of agriculture in the Yangtze River Economic Belt to a certain extent. Therefore, local governments at all levels in the Yangtze River Economic Belt should actively promote the popularization of Internet technology, enhance farmers' Internet awareness, and give better play to the enabling role of Internet technology in the green development of agriculture in the Yangtze River Economic Belt.

In order to better promote the enabling role of Internet technology in the green development of agriculture in the Yangtze River Economic Belt, we should focus on four aspects. First, we should make good use of cutting-edge Internet technologies such as artificial intelligence, blockchain, and data mining to grasp the changes in agricultural development from a higher level and all dimensions, establish and improve the supervision system for the agricultural production process in the Yangtze River Economic Belt, monitor and collect information about the production, circulation, and transaction of agricultural products, and build an agricultural big data platform to release relevant information to provide more accurate information services. Second, integrate industry resources, give full play to the characteristics and advantages of various regions of the Yangtze River Economic Belt, sell characteristic agricultural products through the Internet, promote rural tourism, and improve the information service level of agricultural products from the aspects of investment attraction, famous and high-quality enterprises, agricultural materials supply, agricultural machinery, agroforestry and gardening, distribution process, etc. Third, accelerate the construction of rural Internet infrastructure, build a multi-level service platform, improve the logistics network system, increase the overall planning of logistics resources at the county level, encourage postal services, supply, and marketing cooperatives to cooperate with platform e-commerce and modern logistics enterprises, and improve the circulation capacity and commercialization of green agricultural products. Fourth, strengthen the guidance of local governments at all levels, strengthen the training, promotion, and application of Internet technology for farmers, increase publicity through radio, television, and other forms, and improve farmers' Internet awareness to meet the needs of green agricultural development.

Conflict of interest

The authors declare no conflict of interest.

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