Re-examining the Effect of Social Embeddedness on Technology Diffusion from the Perspective of Scale Differentiation— A Case Study from China

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Abstract

Social embeddedness has always been regarded as an important channel for agricultural technology diffusion. However, dramatic changes have taken place in social embeddedness of rural households in the Green Revolution, its role should be re-examined in new era. Using survey data of 583 rural households from Zhejiang Province, China, we analyzed the differences in social embeddedness between large-scale famers and small-scale farmers, and its role in promoting chemical fertilizer-reducing technologies. The results showed that there are significant differences in social embeddedness, scale of social networks of large-scale households is larger, the heterogeneity is stronger, and the degree of cognitive, cultural, and political embeddedness is also higher. Social embeddedness is still important to technology diffusion, higher degree of structural, cultural, and political embeddedness will promote farmers' adoption. The impact of social embeddedness on two types of farmers' adoption behavior is different: size of social networks, access to green production, recognition to green production and public information have higher total influence for large-scale households than small-scale households; while heterogeneity of social network and subsidies can only impact larger-scale farmers. Therefore, using social embeddedness to accelerate the diffusion of environment-friendly technologies, we must pay attention to the differences in social embeddedness of farmers.

Keywords: Social Embeddedness; Scale Differentiation; Integrated adoption of chemical fertilizer reducing technologies (IACFRTs); Technology Diffusion; the Second Green Revolution

JEL Classification Code: Q12

Introduction

Although successful in increasing food production and Total Factor Productivity (Evenson and Gollin, 2003; Avila and Evenson, 2010), the Green Revolution also had adverse effects on sustainability of the food system in some developing countries (Singh, 2000; Gómez *et al.*, 2013). Such as, overuse of chemical fertilizers caused soil degradation, groundwater depletion, non-point source pollution, increased greenhouse gas emissions and other environmental problems (Shiva, 1991; Conway, 1999; Zeng *et al.*, 2014). Mismanagement of synthetic pesticides led to loss of biodiversity and food quality problems (Pimentel, 1996; Boxstael *et al.*, 2013; Zhang *et al.*, 2015). The Second Green Revolution is urgently needed to address the declining ecosystem quality and continuing climate change (Clay and Zimmerer, 2020).

Since played an important role in the diffusion of agricultural technologies during the Green Revolution, the potential of social embeddedness has naturally attracted widespread attention in the Second Green Revolution (Magnan et al., 2015; Ward and Pede, 2015; Li et al., 2018). As early as the 1940s, Polanyi (1944) put forward the concept of embeddedness, which describes the phenomenon that economic behavior is embedded in social situations. He attributed the reason why economic behavior deviates from the theoretical hypothesis to the ignorance of the interference of social activities on economic behavior. Granovetter (1985) combined the concept of embeddedness and social network, indicating that economic behavior is embedded and regulated by social network. The role of social embeddedness in enhancing the adoption of new agricultural technology are trifold (Bandiera et al., 2005; Anderson and Feder, 2007): First, interactions and connections enable individuals to obtain information about the new technology (Valente, 1996; Uzzi, 1997; Granovetter, 2005; Conley and Udry, 2010; Genius et al., 2014), especially for those who have no access to obtain information from government; Second, social networks facilitate exchange of tacit knowledges related to new technologies through social learning (Rogers, 1962; Banerjee, 1992; Munshi, 2004; Matuschke, et al., 2007; Dessie et al., 2012); Third, social embeddedness can relax labor and financial constraints of farmers through mutual assistance (Krishnan and Patnam, 2014).

However, the Green Revolution also reshaped the social structure in some developing countries (Cleaver, 1972; Freebairn, 1995; Foster and Rosenzweig, 1996; Hazell, 2010; Kerr, 2012; Dawson et al., 2015). One of the most typical changes is the differentiation of farmers. Owing to differences in family endowments, capability to adopt new technologies varies significantly, which widens the gap among farmers and causes household stratification, changing farmers' social networks and social embeddedness (Munshi and Rosenzweig, 2005).

Insofar as farmers' social embeddedness changes can it still be important channel for agricultural technology diffusion in the Second Green Revolution?

China provides an applicable field for testing it. For one reason, to accelerate the transformation toward sustainable and environmentally friendly agriculture, China is promoting fertilizer-reducing technologies comprehensively. Integrating fertilizer-reducing technologies and capitalizing on the synergistic effect between these techniques can improve the efficiency of technology diffusion, which is also common in other developing countries in the Second Green Revolution. However, integrated adoption of chemical fertilizer-reducing techniques (IACFRTs) means more uncertainties and have higher requirements for technology diffusion channels. For another reason, rural land-use rights transfers in recent years have intensified the differentiation of farmers in China, dividing farmers into large-scale ones and small ones, reconstructing the rural stratum structure and stratum relationship, changing farmers' social embeddedness (Li and Gao, 2013; Tian and Chen, 2013; Zhou, 2017; Han, 2019).

Therefore, from the perspective of land scale differentiation of farmers, this article uses samples from China to re-examine the role of social embeddedness in agricultural technology diffusion in the Second Green Revolution. This study mainly answers the following questions: (1) What are the differences in social embeddedness between large-scale households and small-scale households? (2) Will social embeddedness still have positive impact on farmers' IACFRTs? (3) Are there differences in the impact of social embeddedness on IACFRTs between large-scale households and small-scale households?

The main contribution of this paper is to re-examine the role of social embeddedness in the Second Green Revolution and further explore the heterogeneity of social embeddedness in environment-friendly technology diffusion. Some researchers have tried to explain the heterogeneity of social embeddedness through structural lens (Hu, 2016; Chen et al, 2020), but they ignore the fact that social embeddedness is determined both by personal preferences and social structural factors (Liang, 2010). Using endogenous switching model (ESM), we can more systematically understand the mechanism and heterogeneity of the social embeddedness in technology diffusion in this new era.

Theoretical Analysis

According to social embeddedness theory, economic behavior (even general human behavior) is embedded in social system and influenced by pressure, restriction or guidance from the social structure. Therefore, perhaps the most promise as a means to understand how social embeddedness function is to define and explain it by full aspect. The classification of Zukin and DiMaggio (1990), namely structural embeddedness, cognitive embeddedness, cultural embeddedness and political embeddedness, enlightens our research.

Structural embeddedness

Structural embeddedness emphasizes that individuals are influenced by the function and structure of the social network. Differences in structural embeddedness are manifested in the size, centrality and heterogeneity of social networks. The larger the social network size, the more information and resources it can provide. Centrality focuses on the position of an individual in his social network. Individuals at the center of social networks usually take precedence in obtaining resources and information, maintaining cooperative relationships with other farmers (Andersson *et al*., 2001; Coleman, 2015). In addition, the heterogeneity of social relations is also an important feature (Hansen, 1999), which measure the differences in social and economic characteristics of network members. Social networks with high heterogeneity can bring more diverse information and complementary resources. However, high heterogeneity also increases the searching cost and the uncertainty of technology adoption.

In Chinese traditional acquaintance society, farmers can obtain technical information through long-term continuous communications and interactions in social network to reduce technical uncertainty (Fei, 1998). With the aggravation of productivity differentiation, farmers are gradually divided into large-scale households and small households. The two kinds of farmers are dissimilar in production mode and operating purpose, inducing differences in the demand for natural resources, social services and government support. However, the scarcity of natural resources and social resources in a certain region will inevitably lead to competition between large-scale farmers and small farmers in the same social network (Han, 2019). The reshaping of stratum relationships leads to the gradual separation of their social network, the social networks of the two types of farmers will differ, showing differences in structural embeddedness and its functions on diffusion of new technology.

Cognitive embeddedness

Cognitive embeddedness refers to the influence of educational background, cognitive structure and inherent thoughts on individual economic behavior (Zukin and Dimaggio, 1990). According to theories of cognition, cognition is the mediation of behavior and emotion, and the interpretation of cognition directly affects individual behavior. The differences in resources and production mode between large-scale households and small households lead to significant differences in their attitudes toward new technology. Constrained by limited resources, or scattered land, small farmers lack the ability to accept modern agricultural production modes (Ruan, 2019; Chen, 2019), and they also enthusiasm to understand modern agricultural technologies. This implies that in the face of new technology, small farmers may be more likely to be bound by inherent perceptions and ideas, thus creating differences in the cognitive embedding and its roles.

Cultural embeddedness

Cultural embeddedness indicates that economic decisions are influenced and restricted by cultural factors such as cultural traditions, value norms and the consciousness shared by local people (Zukin and Dimaggio, 1990). China has a long history of ecological agriculture. However, unlike traditional ecological agriculture, modern green agriculture is new mode that aggregates modern factors. Therefore, although the traditional green farming culture and ecological concept contribute to the extension of chemical fertilizer-reducing technologies, demonstration project created by the government may play a guiding role in improving farmers' consciousness and initiative of green production. As local demonstration zones and demonstration projects are usually set up in scale farmland and conducted by large-scale households, which makes differences in the access to new technology between large-scale farmers and smallholder farmers. At the same time, the differences in production methods and operating goals may lead to differences in the recognition to green production.

Political embeddedness

Political embeddedness refers to how various political factors and their characteristics influence economic behavior (Zukin and Dimaggio, 1990), which is reflected in the fact that government will bring pressure on or provide guidance for individual behavior (Liu, 2010; Jiang and Yan, 2018). Due to the threshold of scale economy of agricultural machinery and other factors (Guo, 2018; Zhang and Luo, 2020), government policies tend to be "scale-oriented", which makes great differences in political embeddedness between scale and small households.

In summary, with the continuing differentiation of farmers and the reconstruction of rural class structures, the social embeddedness of farmers with different land scale has also changed substantially. This may be an important reason why previous studies have found that different types of social networks, such as strong and weak relationships, functional and constructive social networks, kinship and friendship networks, and kinship and business relationships, play different roles in promoting technology diffusion (Ma *et al*., 2018). Therefore, to fully implement the positive role of social embeddedness in accelerating technology diffusion, we need to deconstruct the differences between large-scale farmers and small farmers' embeddedness from the aspects of structure, cognition, culture, politics, etc., and clarify the differences in the impact of various embeddedness on farmers' technology adoption.

Data and Methodology

Data

We employed a random sample of 583 households from a survey on IACFRTs in Zhejiang Province in 2017-2018. Zhejiang Province, demonstration area on ecologically friendly development in China, has taken the lead in the extension of fertilizer -reducing technologies. More importantly, Zhejiang Province is one of the earliest regions in Economic Reform and open up, leading in urbanization and farmer stratification. According to the third national agricultural census data, the proportion of large-scale households in Zhejiang Province is 10.12%, while the nationwide proportion is only 1.73%.

Households were randomly selected based on a multi-stage cluster approach. First, 2-3 counties were randomly selected in Hangzhou, Jinhua and Huzhou, all these cities are important grain producing areas. Then, 1-2 villages were randomly selected from each county, and approximately 15-20 households were randomly selected from each village. The survey was conducted one-on-one with a total of 655 questionnaires of which 583 were valid, with a response rate of 89.01%.

Variable Selection

The core issue to be tested in this paper is the differences in social embeddedness and its roles in IACFRTs between large-scale households and small households. According to the theoretical analysis, social embedded ness may affect farmer's operational land scale as well as the farmer's choice of IA CFRTs.

Precise definition of large-scale households and small households is a prerequisite for the research. According to the national production subsidy classification standard and related research (Luo *et al*., 2017), this article regards the farmers who with more than 3.33(three point three three) ha operational land as large-scale households, other farmers are regarded as small-scale households.

The dependent variable is farmers' integrated adoption of chemical fertilizer-reducing techniques (IACFRTs). Chemical fertilizer-reducing techniques in this study refer to the integrated agricultural production model developed by the Chinese Academy of Agriculture (Miao *et al*., 2017). This model takes into full consideration the rice cultivation methods in the Yangtze River Basin and patterns in different seasons. Therefore, the model is highly repeatable. Of the 11 core rice cultivation techniques, we select 5 chemical fertilizer-reducing techniques: soil testing and formula fertilizer, organic fertilizer, straw returning, slow-release fertilizer and deep fertilizing. These techniques reduce chemical fertilizer through different paths. Soil testing and formula fertilizer aims to adjust the structure and quantity of fertilizers precisely to suit the need for specific nutrients. The application of organic fertilizer and straw returning can both increase the organic contents and microorganisms in the soil. The application of slow-release fertilizer and deep fertilizing reduce fertilizer by controlling the rate at which fertilizer nutrients are converted and extending their effect. The above techniques involve multiple production steps, such as tilling, sowing, fertilizer application, field management, and straw processing, integrating these techniques will enable better utilization of the synergistic effect.

The core variables are four kinds of social embeddedness. Difference in structural embeddedness is reflected in the scale, centrality, and heterogeneity of social networks. In this study, the number of villagers with whom the interviewed farmer keep frequent contact is used to measure the size of social networks. The social networks usually based on geographic relations and kinship, so face-to-face interactions in these networks are still the main sources from which farmers obtain information (Zhang and Cao, 2017). Whether the interviewed farmers have management roles in their villages is used to measure the centrality of social networks. This approach is based on the fact that currently, village managers play an elite role in rural China — they are both “agents” of the state’s interests and representatives of the interests of local communities (Sun, 2009). As such, they are located at the most important nodes in social networks of villages. This centrality can bring comparative advantages in getting information and resource to individuals. The proportion of non-farm households and farm households who have different operational scales among the total number of acquaintances of interviewed farmers is used to measure the heterogeneity of social networks. Currently, farmer differentiation is mainly driven by productivity differentiation; therefore, non-farm households and farmers with different operational land scales may provide heterogeneous information regarding production and technology to the farmers studied. Cognitive embeddedness is measured using evaluation of current rice field pollution and the negative impact of fertilizer overuse. With regard to cultural embeddedness, the distance between each household interviewed and the demonstration zone is used to measure the difference in the access to these environment-friendly technologies, and the recognition to IACFRTs by households is used to measure their acceptance of the value of green production and normalization. Two variables are adopted to measure political embeddedness: whether the farmers interviewed have received public information distributed by governments, and whether they have received subsidies for straw returning, or for purchasing organic fertilizers and slow-release fertilizers.

The identification variable is the number of register population under a household. Since there is certain endogeneity between farmers' operational land scale and IACFRTs, ESM is adopted to address potential endogeneity issues. According to the ESM, we need to find an identification variable which affect whether a farmer can reach the large operational scale but does not directly affect the IACFRTs. This study uses the number of register population under a farm household as the identification variable. The allocation of land among households in rural China is based on the number of register population in each household. Generally, the more people in a household, the larger is the acreage the household obtains. In Zhejiang Province, however, as the per capita arable land is only 0.037 ha, therefore almost no household can directly reach the threshold of scale operation (3.33 ha). Additionally, a large number of register population under a household does not mean more farming workers are available in the household; it follows that such households do not necessarily prefer labor-intensive fertilizer reducing techniques and show differences in IACFRTs.

Based on existing research (Mase *et al*., 2017; Gao *et al*., 2019), the following variables are used as control variables: education, age of the head of household, and proportion of non-farm income to total household income.

The descriptive statistics (Table 1 and Table 2) indicate that farmers who adopt all 5 techniques discussed above only account for 38.42% in this sample. Furthermore, 25.71% of small-scale farmers have adopted all the techniques, while 58.08% of large-scale households have adopted all the techniques. The difference between the two groups of households is significant (Table 2). Additionally, the results indicate that the farmers generally have a low education level, they are older, non-farming income has become an important income source for most of the sample households.

Methodology

This study adopts the ESM to rectify the "self-selection" issue between operational land scale of households and their IACFRTs. The ESM redresses the sample selection bias caused by observable and unobservable variables; it can also address the unreasonable assumption that the two groups in sample — large-scale households and small-scale households — have homogeneous effects. As such, the transformation will improve the results of the estimation (Maddala, 1983).

The ESM consists of a selection equation and an outcome equation. The selection equation is used to examine the impact of social embeddedness on the operational land scale of farmers, which, in turn, demonstrates the indirect impact of social embeddedness on IACFRTs. The outcome equation is applied to examine the impact of the social embeddedness and land scale of households on IACFRTs, thus revealing the direct impact of social embeddedness on IACFRTs. Specifically, the equations are as follows:

$$L_i^* = a + \gamma_1 S_i + \beta_1 X_i + u_i \quad L_i = 1 \; if \; L_i^* > 0, L_i = 0 \; otherwise \tag{1}$$

$$T_i^* = b + \gamma_2 S_i + \varphi L_i^* + \beta_2 Y_i + v_i \quad T_i = 1 \; if \; T_i^* > 0, \quad T_i = 0 \; otherwise \tag{2}$$

In the equation, L_i^* denotes the land scale of household i; φ is the estimation coefficient of land scale in the outcome equation; $L=1$ denotes a large-scale household; $L=0$ denotes a small-scale household; T_i^* is the observed value of the adoption; $T=1$ denotes IACFRTs; $T=0$ denotes no adoption; S_i denotes the social embeddedness of household i; γ_1 and γ_2 denote the estimation coefficients of social embeddedness in the selection equation and outcome equation, respectively; X_i and Y_i denote the control variables that influence the production scale of and technology adoption by household i, respectively; a and b are constants in the selection equation and outcome equation, respectively; and u_i and v_i are the random disturbances in the selection equation and outcome equation, respectively.

Combining the selection equation and the outcome equation, we can get the total impact of social embeddedness on IACFRTs (including both direct impact and indirect impact) as the following equation:

$$T^* = h + (\gamma_2 + \gamma_1 \varphi) S + \beta_3 I + \beta_4 D + \varepsilon \tag{3}$$

In equation (3), I is the control variable; D is the identification variable; β_3 and β_4 are their estimation coefficients, respectively; h is a constant; ε is the random disturbance; γ_2 denotes the direct impact of social embeddedness IACFRTs; $\gamma_1 \varphi$ denotes the indirect impact; and $(\gamma_2+\gamma_1\varphi)$ is the overall impact. $\gamma_1\varphi$ is positive, indicating that social embeddedness enhances the positive effect of land scale on IACFRTs.

Differences in social embeddedness between large-scale households and small-scale households

Social embeddedness of large-scale households differed significantly from small-scale farmers (Table 2). In terms of structural embeddedness, the number of villagers who maintain contact was approximately twice as large as that of small-scale farmers, and their social networks were more heterogeneous (the proportion of non-agricultural farmers or nonequal-scale farmers among acquaintances in the social network was as high as 60%), while the social networks of small farmers were smaller and more homogeneous, showing the typical characteristics of strong ties. As to cognitive embeddedness, large-scale households' evaluation of environmental pollution and negative effects of fertilizer application were more serious than small farmers, but t-test results showed that only evaluation of pollution was a significant difference at the 10% level. In terms of cultural embeddedness, the recognition to Green Production of large-scale households was stronger than that of small farmers (significant at the 1% level). The average distance between large-scale households and demonstration area is slightly larger, but the difference is not significant. Because the selection of demonstration area needs to take the applicant's operating capacity and the demonstration scope into account. Therefore, the distribution of demonstration area in the county is relatively scattered. In order to avoid competition between resources and subsidy, the distance between large-scale households is often larger than that of small households, which leads the average distance between scale households and the demonstration area is slightly larger. The political embeddedness of large-scale households was significantly higher because they accepted more information and subsidies from government.

Difference in the impact of social embeddedness between large-scale households and small-scale households

Endogeneity test for land scale

To assess the necessity of the ESM, it is necessary to test whether land scale is an endogenous variable in the outcome equation. Based on the shared random effect, this study develops the relationship between random disturbances u_i and v_i as follows:

$$\begin{cases} u_i = \omega\theta_i + \zeta_i \\ v_i = \theta_i + \xi_i \end{cases} \tag{4}$$

In the equation, it is assumed that θ_i, ζ_i, and ξ_i are independent and identically distributed variables that have an expected variable of 0 and variance of 1; θ_i denotes the shared random effect, and ω is its estimation coefficient and a factor loading item; and ζ_i and ξ_i denote the errors in equations u_i and v_i, respectively. The covariance matrix between random disturbances u_i and v_i is derived as the follow:

$$Cov(u_i, v_i) = \Sigma = \begin{pmatrix} \omega^2+1 & \omega \\ \omega & 2 \end{pmatrix} \tag{5}$$

Further, the relationship between disturbances u_i and v_i can be expressed as follows:

$$\rho = \frac{\omega}{\sqrt{2(\omega^2+1)}} \tag{6}$$

In the equation, ρ is the correlation coefficient between random disturbances u_i and v_i. If $\rho = 0$, then the land scale of the farm household is an exogenous variable; the selection equation and outcome equation are estimated separately, and the unbiased estimator of the coefficient is then derived. Otherwise, land scale is an endogenous variable, and it is necessary to construct the ESM to estimate the coefficient.

The results (Table 3) show that correlation coefficient ρ between the random disturbances in the selection equation and outcome equation does not equal to 0 at the 1% level, indicating that land scale is an endogenous variable. As such, the selection equation and outcome equation cannot be estimated separately, and there is a need to construct an ESM.

Validity test of the identification variables

The number of register population under a household has a significant negative impact on the operational scale of farm households (significant at the 10% level). As discussed earlier, the per capita operational land in Zhejiang Province is 0.037 ha. A household with 10 registered family members would only have 0.37 ha of land, which is significantly less than 3.33 ha, the threshold for a farm to be considered large-scale. Additionally, Zhejiang is among the regions in China where the reform and opening up and economic development in the private sector had a head start. Larger number of register population in a household faces higher survival pressure, and accordingly, these households are more likely to take on other non-farming jobs and leave the agricultural sector.

The direct impact of social embeddedness on IACFRTs

The results of the outcome equation (Table 3) indicate that structural embeddedness, cultural embeddedness, and political embeddedness have significant direct impacts on IACFRTs. Regarding structural embeddedness, the impact of social network scale is significant at the 1% level. The IACFRTs require more costs. Larger social networks not only provide more information regarding production techniques, thereby reducing the uncertainty of technology (Wang *et al.*, 2020; Gessesse *et al.*, 2018), it can also bring about more abundant resources, thereby promoting the adoption. The centrality and heterogeneity of social networks do not have significant impact. The former may be because village managers work “full time” in their positions and no longer do farming work; as such, their identities as village managers do not bring about sufficient resources to farming and agricultural technology adoption. The latter occurs because, although social network heterogeneity means more abundant information, it also increases information redundancy, which requires more costs to identify useful information; as a result, if the farmer lacks sufficient discriminating ability, the heterogeneity reduces the impact of social networks.

With regard to cognitive embeddedness, evaluation of environmental pollution and fertilizers’ negative impact do not have significant impacts. Zhejiang is a leader in transitioning to green development. In 2014, the province implemented an initiative to “treat polluted water, prevent floods, address waterlogging, secure water supply, and conserve water”. In 2016, the province implemented the Plan for Preventing and Treating Soil Pollution in Zhejiang Province. This policy requires strengthening the prevention and treatment of rural non-point source pollution as well as soil reclamation pollution. As a result, farmers generally do not perceive farmland pollution as a serious issue and are not well aware of the negative impact of fertilizers.

In terms of cultural embeddedness, both the access to green production and the recognition to green production have positive impacts on IACFRTs. This indicates that recognition to green production is an important precondition for their adoption. Farmers with a stronger awareness of the importance of green production are more likely to adopt these techniques. The distance to demonstrations, has a negative impact, indicating that demonstrations do have positive effect.

For political embeddedness, public information from government has a significant positive impact on IACFRTs. Green subsidies have a positive yet nonsignificant impact. This is mainly because green subsidies have certain “scale thresholds” that prevent small-scale households from accessing these subsidies. As a result, the motivation effect of green subsidies is not significant.

The indirect impact of social embeddedness on IACFRTs

Since social embeddedness can indirectly reinforces IACFRTs by promoting larger-scale farming operations, the difference in the impact of social embeddedness between large-scale households and small-scale households is mainly embodied by the indirect impact of social embeddedness (the results of the selection equation in table 3) on IACFRTs.

As shown in Table 3, the results of the selection equation and the computation of the indirect impact in equation (3) indicate that structural embeddedness(scale and heterogeneity of social networks), cultural embeddedness(the access to green production and recognition of green production), political embeddedness(public information and subsidies) all have a significant positive impact on large-scale farmers, thereby indirectly reinforcing IACFRTs and creating the difference in the effect of social embeddedness between large-scale households and small-scale households. Of the variables discussed above, social network scale, access to IACFRTs, recognition to IACFRTs, and public information have both significant indirect impacts and direct impacts (Table 4). Given that the mechanisms through which the above variables impact farmers’ adoption have been discussed, for brevity, here only discusses the indirect impacts of heterogeneity and subsidies.

Currently, rural land transfer usually occurs between people who know each other; as such, a higher degree of social network heterogeneity means that more farmers in the social network are working in non-farming businesses, farmers have more opportunities to acquire land through land transfers. Additionally, households have more opportunities to obtain heterogenous information and resources, further helping farmers increase their farming capacity and operational scale. However, heterogeneity has certain “threshold effects”. Only when heterogeneity brings about sufficiently diversified information and resources and farmers have the ability to distinguish relevant from useless information will heterogeneity have a positive effect; otherwise, heterogeneity will reduce the efficiency of households in utilising the information and hamper the adoption of new techniques. Compared with small-scale farmers, large-scale farmers undoubtedly have stronger land management capabilities and ability to distinguish. As a result, heterogeneity has a significant indirect impact, but the direct impact is not significant.

Whether subsidies for inputs or subsidies for agricultural production, subsidies can effectively reduce the operating costs of households and increase their operating efficiency, thereby motivating farmers to increase their operational scale to maximise their interests. With the land area of households' approaching the threshold of "large scale", farmers have a stronger demand for IACFRTs that have a scale effect, such as irrigation and fertilizer application; this, in turn, promotes the adoption of IACFRTs.

Impact of control variables on IACFRTs. The selection equation (Table 3) indicates that the education, age, and proportion of non-farm income have significant impacts on the operational scale of households. Farmers who are older, have a lower education level, and spend little time on non-farming work are more likely to have large-scale farms. This is because older farmers with less education usually do not have the ability and opportunities to work in non-farming sectors, and therefore, their family business focuses on farming. Additionally, small-scale farming operations have low returns; only when they increase in operational scale will farm households obtain more policy support so as to improve operational returns. As such, they are more motivated to attain a large operational scale through land transfers. The outcome equation indicates that only the age of the head of household has a significant positive impact on IACFRTs. This is because older farmers tend to have worked longer in farming operations and have a better understanding of the economic and environmental costs caused by fertilizer overuse; as such, they have stronger motivation to adoption, i.e., to "save costs and improve efficiency" and to achieve sustainable farming.

Conclusion and Discussion

Main aim of this paper is to explore the differences in social embeddedness and its roles in environment-friendly technology diffusion between large-scale households and small households in the Second Green Revolution. The results of our empirical analysis showed that with differentiation of farmers, there are obvious differences in social embeddedness and its roles.

Firstly, there are obvious differences in social embeddedness between large-scale households and small households. Compared with small households, large-scale households have a larger social network scale with stronger heterogeneity, and a higher degree of cognitive, cultural and political embeddedness. This means that large-scale households are better embedded in the progress of agricultural green production transformation. While small households lack the ability to transform green production into production behavior and lack government support for technology adoption, which is related to a series of agricultural industrial-supporting policies aimed at “achieving scale production” in the early stage.

Secondly, social embeddedness is still an important for the diffusion of environment-friendly technology diffusion in the Second Green Revolution. Structural embeddedness, cultural embeddedness and political embeddedness all have all significant direct impact on farmers’ IACFRTs. Specifically, larger scale of social network, higher degree of recognition to green production and government information will facilitate farmers’ adoption, no matter larger-scale households or small-scale households.

Thirdly, the difference in social embeddedness between large-scale households and small-scale households has heterogeneous effects on their adoption behavior. Size of social networks, access to green technology, recognition to green production and public information all have significant indirect impact and direct impact on IACFRTs, meaning that these kinds of embeddedness have higher total influence for large-scale households. However, heterogeneity of social network, subsidies only significant direct impact, which means these kinds of embeddedness can only promote large-scale famers’ adoption.

According to the conclusion, the using of social embeddedness in promoting the extension of environment-friendly technologies should be cautious. For large-scale households, we can cultivate their cognition of green production, or carry out multi-agent and multi-mode technical training to strengthen their ability to get more information. However, for small-scale farmers, merely providing more technical information is not enough, it is necessary to provide technical training, technology demonstration and public service projects to directly reduce the difficulty of technology adoption. What’ s more, government should expand the coverage of government subsidies, especially to formulate publicity and subsidy policies for small-scale farmers.

Acknowledgements

This paper was supported by The National Social Science Fund of China (19CGL035)

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Tables and figures

Table 1. Variable selection and descriptive statistics

Variable Name		Definition	Mean	Standard Deviation
Dependent variable	IACFRTs	Whether adopt all five fertilizer reducing technologies: 0=No; 1=Yes	0.38	0.49
Scale variable	Land scale	Whether large-scale farm households: 0=No; 1=Yes	0.39	0.49
Structural embeddedness	Size	the number of villagers with whom the interviewed farm households keep frequent contact with;	8.98	5.64
	Centrality	Whether the interviewed farm households have management roles in their villages: 0=No; 1=Yes	0.10	0.30
	Heterogeneity	The proportion of non-farm households and farm households that have different operational scales among the total number of acquaintances（%）	35.49	26.71
Cognitive embeddedness	Evaluation of Pollution	1 = No pollution at all; 2 = Slight pollution; 3 = Moderate pollution; 4 = Serious pollution	2.16	1.11
	Evaluation of Fertilizer's Negative Impact	1 = No impact at all; 2 = Slight impact; 3 = Moderate impact; 4 = Serious impact	1.84	0.96
Cultural embeddedness	Access to IACFRTs	The distance between farmers and the nearest technology demonstration area (meters)	2022.45	3670.66
	Recognition to IACFRTs	1 = totally disagree; 2 = disagree; 3 = Moderate; 4 = agree;5= totally agree;	2.53	1.61
Political embeddedness	Public information dissemination	Whether the government has publicized the reduction of fertilizer and pesticides by posting posters and distributing materials: 0=No; 1=Yes	0.75	0.43
	Government Subsidies	Whether local farmers receive subsidies of straw back to the field technology, the purchase of slow-release fertilizer and organic fertilizer projects: 0=No; 1=Yes	0.51	0.50
Control variable	Education	1 = Primary school; 2 = Middle school; 3 = High school; 4 = Beyond high school	2.04	0.78
	Age	Age of head of household	53.40	11.05
	Proportion of non-farm income	Proportion of non-farm income to total income (%)	43.78	29.22
Identification variable	the number of people registered	the number of people registered under a household	4.95	4.42

Table 2. IACFRTs and social embeddedness for large-scale households and small-scale households

	Variable	Large-scale Households		Small-scale Households		T-test
		Mean	SD	Mean	SD	Sig
Dependent variable	IACFRTs	0.58	0.5	0.26	0.44	0.000***
Structural embeddedness	Size	12.35	6.37	6.8	3.75	0.000***
	Centrality	0.12	0.32	0.09	0.28	0.018**
	Heterogeneity	60.95	19.7	19.02	15.29	0.002***
Cognitive embeddedness	Evaluation of Pollution	2.46	1.05	1.97	1.11	0.096*
	Evaluation of Fertilizer's Negative Impact	1.94	0.98	1.77	0.95	0.464
Cultural embeddedness	Access to IACFRTs	2287.64	5491.75	1850.9	1630.88	0.249
	Recognition to IACFRTs	3.16	1.78	2.12	1.36	0.000***
Political embeddedness	Public information dissemination	0.83	0.38	0.7	0.46	0.000***
	Government Subsidies	0.92	0.27	0.25	0.43	0.000***

Table 3. Estimation results of ESM

	Selection Equation (Land Scale)			Outcome Equation (IACFRTs)		
Variable	Coefficient	SD	Z-value	Coefficient	SD	Z-value
Land scale				0.7625***	0.2360	3.2300
Size	0.1501***	0.0249	6.0200	0.0316**	0.0139	2.2800
Centrality	-0.3879	0.3997	-0.9700	0.0538	0.2083	0.2600
Heterogeneity	0.0669***	0.0082	8.1300	0.0002	0.0035	0.0600
Evaluation of Pollution	0.0814	0.1142	0.7100	0.0480	0.0594	0.8100
Evaluation of Fertilizer's Negative Impact	-0.0724	0.1317	-0.5500	0.0959	0.0647	1.4800
Access to IACFRTs	0.0003***	0.0001	3.2500	-0.0004***	0.0001	-7.4500
Recognition to IACFRTs	0.2233***	0.0836	2.6700	0.2347***	0.0450	5.2200
Public information dissemination	0.4837*	0.2650	1.8300	0.4516***	0.1497	3.0200
Government Subsidies	1.7315***	0.2619	6.6100	0.1141	0.1589	0.7200
Education	-0.0277**	0.0114	-2.4200	0.0095	0.0059	1.6200
Age	0.4599***	0.1585	2.9000	0.2251***	0.0831	2.7100
Proportion of non-farm income	-0.0122***	0.0043	-2.8200	0.0026	0.0021	1.2300
Number of people registered	-0.1489*	0.0876	-1.7000			
Constant	-4.3580	0.9733	-4.4800	-3.4130	0.4737	-7.2100
ρ				-0.5818***	0.0699	-8.3200

Table 4. Decomposition of the impact social embeddedness on IACFRTs

Variable		Impact	Calculation	Result
Structural embeddedness	Size	direct impact	γ_3	0.0316
		indirect impact	$\gamma_{12}\varphi'$	0.1145
		total impact	$\gamma_3 + \gamma_{12}\varphi'$	0.1461
	Heterogeneity	direct impact	γ_5	0.0002
		indirect impact	$\gamma_{14}\varphi'$	0.0510
		total impact	$\gamma_5 + \gamma_{14}\varphi'$	0.0512
Cultural embeddedness	Access to IACFRTs	direct impact	γ_8	-0.0004
		indirect impact	$\gamma_{17}\varphi'$	0.0002
		total impact	$\gamma_8 + \gamma_{17}\varphi'$	-0.0002
	Recognition to IACFRTs	direct impact	γ_9	0.2347
		indirect impact	$\gamma_{18}\varphi'$	0.1703
		total impact	$\gamma_9 + \gamma_{18}\varphi'$	0.4050
Political embeddedness	Public information dissemination	direct impact	γ_{10}	0.4516
		indirect impact	$\gamma_{19}\varphi'$	0.3688
		total impact	$\gamma_{10} + \gamma_{19}\varphi'$	0.8204
	Government Subsidies	direct impact	γ_{11}	0.1141
		indirect impact	$\gamma_{20}\varphi'$	1.3203
		total impact	$\gamma_{11} + \gamma_{20}\varphi'$	1.4344

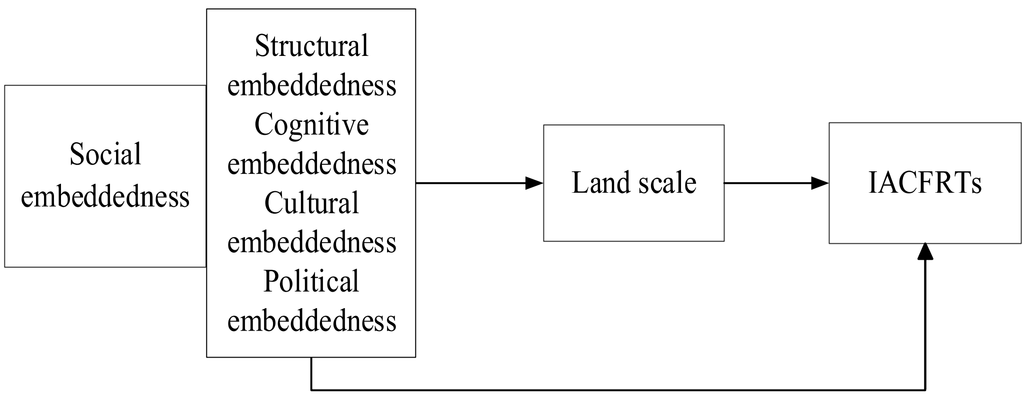

Figure 1 Mechanism through which social embeddedness influences the IACFRTs