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Social capital, land tenure and the adoption of green control techniques by family farms: Evidence from Shandong and Henan Provinces of China

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ABSTRACT

In China, land tenure security refers to the stability of land management rights in the context of the *Three Rights Separation Policy*, according to which rural land ownership rights, land contract rights, and land management rights can be separated and land management rights can be freely transferred. We apply endogenous switching probit models to a dataset of 443 family farms in Shandong and Henan Provinces to investigate the influence of social capital and land tenure security on family farms' adoption of green control techniques (GCTs). We develop simplified equations to verify whether social capital strengthens the positive effect of land tenure security on family farms' GCT adoption. Specifically, we focus on the different effects of embedded and disembedded social capital. Our findings show that both social capital and land tenure security have significant positive effects on family farms' adoption of GCTs. Furthermore, social capital strengthens the positive effect of land tenure security on GCT adoption, but the effects of embedded and disembedded social capital are different. Government policies should strengthen the stability of land management rights and cultivate the social capital of family farms, especially disembedded social capital.

1. Introduction

In the Chinese practice of integrated pest management (IPM), green control techniques (GCTs) are based on plant protection strategies that focus on prevention, comprehensive prevention and control, and green plant protection. The aim of GCTs is to reduce the use of chemical pesticides and encourage the adoption of resource-saving and environmentally friendly practices, such as ecological management, biological control, physical control, and moderate pesticide use. GCTs play an essential role in ensuring the quality of agricultural products, protecting the environment, and enhancing food security. They also contribute to reducing crop losses, increasing yields (Rahman, 2013), and improving farmers' net income and welfare (Muriithi et al., 2016; Gao et al., 2019). However, GCTs are infrequently used in China, which has restricted the sustainable development of Chinese agriculture.

Previous studies have examined factors that can encourage farmers to adopt GCTs, including householder characteristics (Kabir and Rainis, 2015; Korir et al., 2015), resource endowments (Allahyari et al., 2016; Kabir et al., 2017), human cognitive characteristics (Abadi, 2018; Zhang et al., 2018), technical characteristics (Himmelstein et al., 2016; Abdollahzadeh et al., 2017), and subjective norms (Timprasert et al., 2014; Rezaei et al., 2019). These factors are undoubtedly important.

However, China is undergoing a socioeconomic transformation (Liu et al., 2016a,b; Yang et al., 2018), which has had deep influences on China's vast rural areas (Li et al., 2014; Cheng et al., 2019a,b) and been accompanied by rapid changes in land policy (Liu et al., 2014a; Liu, 2018). Studies on farmers' behavior, including their decision to adopt GCTs, should acknowledge these changes by recognizing the distinctive characteristics of this great transformation. First, the construction and development of formal institutions in rural areas are lagging (Long et al., 2010; Liu and Li, 2017). Rural areas are best described as "relational" societies in which social capital is an important supplement to the formal system. Bourdieu (1986), a French sociologist, first proposed the concept of social capital. Developed by Coleman (1988); Putnam (1993), and others, the concept now includes networks, norms, and trust. Theoretically, social capital helps farmers gather information, exchange techniques, and raise funds. It can effectively cover shortages in government technology extensions, reduce farmers' technical

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learning and usage costs, and ease financial constraints, thus encouraging the adoption of new technologies. A large number of empirical studies have affirmed the role of social capital in encouraging farmers to adopt improved farmland management (Wossen et al., 2015), irrigation (Hunecke et al., 2017), and livestock feed technologies (Birhanu et al., 2017), but relatively few have considered the influence of social capital on farmers' adoption of GCTs.

Second, the reform of the rural household responsibility system, which began in the early 1980s, allocated farmland according to the number of family members and greatly mobilized farmers' enthusiasm for production; however, it also led to serious land fragmentation (Li et al., 2018). At present, land fragmentation is a key factor hindering the improvement in land use and agricultural production efficiency in China (Liu et al., 2016a, 2016b, 2018). The Chinese government has emphasized the development of moderate-scale agricultural operations in its annual *No. 1 Policy Document of the Central Government* since 2012. Land circulation is an important means for strengthening moderate-scale agricultural operations (Ye, 2015). China's land circulation policies have evolved from totally prohibiting to beginning to allow circulation and, finally, to advocating circulation through institutional innovation. Before 1984, land circulation was illegal. For example, the *Constitution of the People's Republic of China*, which was promulgated and implemented in 1982, clearly stipulated that "no organization or individual may appropriate, buy, sell or lease land, or unlawfully transfer land in any way." In 1984, the government began to acknowledge farmland transfers. The *Several Policy Measures on Current Agricultural and Rural Economic Development*, which were issued by the General Office of the CPC Central Committee and the State Council in November 1993, stated that "under the premise of insisting on the collective ownership and not changing the use of land, with the consent of the contractor, the land use rights shall be allowed to be transferred with compensation according to law." The *Law of the People's Republic of China on Land Contract in Rural Areas*, which was adopted in 2002, stipulated that "the contracted management rights can be circulated by subletting, leasing, swapping, transferring or other circulation means according to law," effectively promoting the development of the farmland transfer market. In 2014, the *No. 1 Policy Document of the Central Government* further divided land contract management rights into contract rights and management rights and proposed the flexibility of management rights for the first time. In the same year, the *Opinions on Guiding the Orderly Transfer of Rural Land Management Rights to Develop a Moderate Scale Operations of Agriculture* issued by the General Office of the CPC Central Committee and the State Council "contracted farmers are encouraged to circulate farmland by subletting, leasing, swapping, transferring, sharing or other means according to law"; however, in accordance with China's special dual land system, rural land was still owned by village committee collectives (Zhou et al., 2019a,b). Although the current land policies have accelerated the pace of land circulation, the rural land rental market in China remains small, with lagging laws and regulations, few institutional mechanisms, little incentive to circulate, short contract periods, the persistence of informal and oral contracts and high transfer risks. These factors lead to frequent disputes over land transfers (Xu et al., 2018; Wang et al., 2018).

Although in many countries, land tenure security is measured by the existence of "a formal land use certificate" (Muchomba, 2017), in China, land tenure security refers to the stability of land management rights in the context of the *Three Rights Separation Policy*, according to which rural land ownership rights, land contract rights, and land management rights can be separated and land management rights can be transferred freely. Land tenure security is an important prerequisite for the adoption of new farming technologies. Land tenure security strengthens farmers' awareness of tenure security and lowers their investment risks. Land tenure security also reduces financing difficulties and improves farmers' repayment ability, promoting the adoption of new farming techniques. Many empirical studies have affirmed that land tenure security has a significant impact on farmers' adoption of sustainable agricultural practices (Kassie et al., 2013), soil and water conservation (Teshome et al., 2016), and modern rice technologies (Paltasingh, 2018). In conclusion, in the context of rural China, which features a relational society with an immature land transfer market and imperfect laws and regulations, it is necessary to incorporate social capital and land tenure security into the analytical framework of farmers' GCT adoption. Empirical studies that do so are lacking; thus, our analysis fills this gap.

In particular, this study addresses three gaps in the literature. First, the literature does not consider how social capital strengthens the effect of land tenure security on farmers' green technology adoption. Social capital contributes to farmers' land tenure security (Katz, 2000), which in turn promotes the adoption of new technologies. Most previous studies have discussed the direct impact of social capital on the adoption of new technologies without examining whether social capital strengthens the effect of land tenure security on the adoption of new technologies. In this study, based on the influence of social capital and land tenure security on farmers' GCT adoption, we elucidate the mediating effect of land tenure security, enriching the literature on technology adoption.

Second, the literature has largely ignored the heterogeneity of social capital. Informatization, networking, and improvements in social mobility have gradually eliminated regional restrictions on Chinese farmers' social communication networks (Liu et al., 2014b; Bai et al., 2014). Both the methods and the scope of communication networks have become increasingly "disembedded" as social relations have been lifted out of the local contexts of interaction and restructured over time and in different spaces (Giddens, 1991). The disembedded nature of social relationships has weakened the traditional role of embedded social capital in rural areas, and disembedded social capital has become the main form of rural social capital. In this study, we refer to embedded social capital as a set of social resources characterized by homogeneity and closeness, which are defined by blood, kinship and geographical relationships. In contrast, disembedded social capital is a set of social resources that are characterized by heterogeneity and are based on new occupational relationships, broad communication spaces, and the primary use of indirect communication methods (Xie and Wang, 2016). These different forms of social capital may have different effects and mechanisms on farmers' adoption of new technologies (Sseguya et al., 2018). However, most studies on social capital overlook its heterogeneity. In particular, the new characteristics and trends in Chinese farmers' social capital have not attracted academic attention. Therefore, we distinguish between embedded and disembedded social capital. By analyzing the different influences of these two types of social capital on land tenure security and farmers' GCT adoption, we provide new insights for understanding GCT adoption.

Third, the literature does not pay attention to potential endogeneity. Studies such as Paltasingh (2018) and Rijn et al. (2012) ignore endogeneity when estimating the impact of social capital on land tenure security and farmers' technology adoption as well as the impact of land tenure security on farmers' technology adoption behavior. Therefore, we avoid simultaneity between social capital and land tenure security and between social capital and GCT adoption in our social capital measurement indicators and further use endogenous switching probit models to weaken endogeneity and obtain more robust estimation results.

Under the influence of the policy systems of the market economy and agricultural modernization, Chinese farmers are classified either as traditional peasants who are employed part-time and are decentralized or as family farms characterized by specialization, integration, organization, and socialization. The two types of agricultural systems can coexist for a long period. Family farms are a trend in China's agricultural development, and they play a leading role in the application of scientific and technological achievements and green development. Currently, 70.8% of the total operating area of family farms involves rights transferred from nonfamily farms.[1] We use data from 443 family farms in Shandong and Henan Provinces as our sample and apply endogenous switching probit models to reveal the influence of social capital on land tenure security and the combined influence of social capital and land tenure security on family farms' adoption of GCTs. We also establish simplified equations for the switching and outcome equations to verify whether social capital strengthens the effect of land tenure security on family farms' adoption of GCTs. Finally, we investigate the different influences of embedded and disembedded social capital.

Our identification strategy has two advantages. First, we decompose farmers' social capital into embedded and disembedded social capital. This step allows us to expand the research scope of social capital theory and more accurately understand the attributes and characteristics of farmers' social capital in the context of social change. Second, we reveal the mediating role played by land tenure security, which strengthens the positive effect of social capital on technology adoption and the different influences of embedded and disembedded social capital on technology adoption. In doing so, we provide new theories and empirical evidence to explain farmers' technology adoption behavior under the background of land contract and management rights reform and social changes in China.

2. Theory and hypotheses

2.1. Direct impact of social capital on GCT adoption by family farms

Previous studies of the impact of social capital on technology adoption show that social capital can influence family farms' GCT adoption through four pathways (Teklewold et al., 2013; Chen et al., 2014; Li et al., 2019): accessibility to information, technical exchange channels, accessibility to funds and the size of the labor force. First, information accessibility is a key factor in family farms' GCT adoption (Genius et al., 2014), and social capital helps family farms obtain GCT information (Micheels and Nolan, 2016). Using social capital, family farms can obtain relevant information promptly, reduce information asymmetries, and enhance the perceived ease of use and usefulness of GCT; thus, social capital can positively affect family farms' GCT adoption. Second, technical exchange channels are the most effective way for family farms to master the specifics of GCT operation (Paul et al., 2017). Increased social capital means that family farms can communicate techniques within and between groups (Zhou et al., 2018), which helps farmers not only gain timely and effective technical assistance but also accumulate technical knowledge. Third, accessibility funds significantly and positively influences GCT adoption by family farms (Paustian and Theuvsen, 2017), and social capital helps expand financing channels, raise credit availability, and improve funding (Teklewold et al., 2013), thereby easing financial constraints in the GCT adoption process. Finally, family farms' GCT adoption behavior is closely related to the size of the labor force (Boncinelli et al., 2017). With greater social capital, family farms can obtain more aid from workers and alleviate problems of insufficient labor input for GCT adoption and hence, promote GCT adoption. Therefore, our first and second hypotheses are as follows.

H1. Social capital has a positive impact on family farms' GCT adoption.

H2. Compared with embedded social capital, disembedded social capital allows family farms to better collect information, exchange technologies, and expand financing channels by providing broader social networks, verifying information more quickly and more accurately, and communicating technology with more skilled family farms. That is, different types of social capital have different impacts on family farms' GCT adoption.

2.2. Effect of social capital on the relationship between land tenure security and GCT adoption by family farms

Social capital influences GCT adoption directly and indirectly by strengthening the effect of land tenure security on adoption. Land tenure security helps farmers ensure returns on investment (Paltasingh, 2018), which promotes the adoption of GCTs. Moreover, family farms with higher levels of social capital may be more familiar with and have more trust in farmers who transfer land in the land transfer process, which can effectively reduce the costs of land transfer process and make farmers more willing to rent land for longer periods and to sign written contracts (Jiang et al., 2018a,b). In addition, family farms with social capital can obtain the information and legal and financial support they need to complete the land transfer process, thus improving their ability to guarantee land tenure security (Compton and Beeton, 2012). Therefore, we propose our third, fourth, and fifth hypotheses as follows.

H3. Land tenure security has a positive impact on family farms' GCT adoption.

H4. Social capital strengthens the effect of land tenure security on family farms' GCT adoption.

H5. Compared with embedded social capital, disembedded social capital enables family farms to become more familiar with and gives them more trust in land transfers by providing more information and legal and financial support. As a result, land tenure security can be strengthened and the adoption of GCTs can be higher when there is greater disembedded social capital. That is, different types of social capital strengthen the relationship between family farms' land tenure security and GCT adoption to different extents. Fig. 1 presents the theoretical framework used in this study.

3. Research design

3.1. Econometric model

The endogenous switching probit model is composed of a switching equation and an outcome equation. The switching equation is used to estimate the impact of a family farm's social capital on land tenure security. The outcome equation is used to estimate the impact of a family farm's social capital and land tenure security on its GCT adoption.

$$L_i^* = a + \gamma_{1m}S_{im} + \beta_1 X_i + u_i \qquad L_i = 1 \quad if \quad L_i^* > 0, \quad L_i = 0 \quad otherwise \quad <1>$$

$$T_i^* = b + \gamma_{2m}S_{im} + \varphi L_i^* + \beta_2 Y_i + v_i \qquad T_i = 1 \quad if \quad T_i^* > 0, \quad T_i = 0 \quad otherwise \quad <2> \qquad (3.1)$$

L_i^* represents the observed value of land tenure security of family farm i. φ is the estimated coefficient in the outcome equation. T_i^* represents the observed value of the GCT adoption behavior of family farm i. S_{im} represents the social capital of family farm i, m is the type of social capital, and $m \in \{1, 2, 3\}$; $m = 1$ represents composite social capital, and $m = 2$ and 3 represent embedded and disembedded social capital, respectively. γ_{1m} and γ_{2m} are the coefficients to be estimated in the switching and outcome equations, respectively. When examining the impact of social capital and land tenure security on family farms' GCT adoption behavior, m is 1; when further analyzing the different impacts of different types of social capital, m is 2 or 3. X_i and Y_i are control variables that affect family farm i' s land tenure security and GCT adoption behavior, respectively, and β_1, β_2 are their corresponding estimated coefficients. a and b are the constant terms in the switching and

[1] Source: "Ministry of Agriculture and Rural Affairs: Authoritative Data Report on Family Farms, Land Circulation and Collective Economy in 2016" http://www.yidianzixun.com/article/0J0Z43AJ.

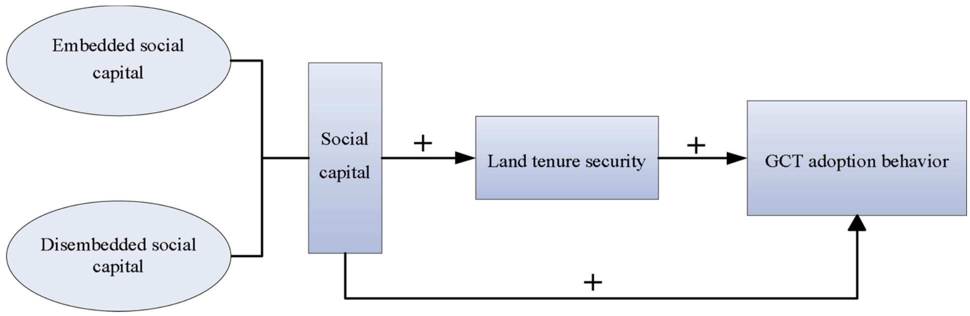

Fig. 1. Theoretical framework.

outcome equations, respectively. u_i and v_i are the residual terms in the switching and outcome equations, respectively.

To judge the necessity of establishing the endogenous switching probit model, it is necessary to test whether land tenure security is an endogenous variable in the outcome equation. Based on shared random effects, we establish the relationship of residual terms between u_i and v_i (Miranda and Rabe-Hesketh, 2006):

$$\begin{cases} u_i = \omega\theta_i + \zeta_i \\ v_i = \theta_i + \xi_i \end{cases} \tag{3.2}$$

θ_i, ζ_i, and ξ_i are hypothesized to be independent and identically distributed with a mean of 0 and a variance of 1. θ_i is the shared random effect, and ω is its estimated coefficient, which is a factor loading. ζ_i and ξ_i are the error terms. The covariance matrix of the residual terms u_i and v_i is

$$Cov(u_i, v_i) = \Sigma = \begin{pmatrix} \omega^2+1 & \omega \\ \omega & 2 \end{pmatrix}. \tag{3.3}$$

The relationship of residual terms between u_i and v_i can be expressed as

$$\rho = \frac{\omega}{\sqrt{2(\omega^2+1)}}, \tag{3.4}$$

Where ρ is the correlation coefficient of the residual terms u_i and v_i. If $\rho \neq 0$, land tenure security is an endogenous variable. It is necessary to establish the endogenous switching probit model to estimate the coefficients; if the results of the test indicate that land tenure security is an exogenous variable, the switching and outcome equations need to be independently estimated to obtain unbiased estimates of the coefficients.

To explore whether social capital strengthens the effect of land tenure security on family farms' adoption of GCTs, the effects of family farms' social capital on their GCT adoption behavior are estimated from the endogenous switching probit model, which is divided into direct and indirect effects. Starting with the simultaneous switching and outcome equations in the endogenous switching probit model, Equation < 1 > in (3.1) can be incorporated into < 2 > , and the resulting simplified equation is

$$T^* = h + (\gamma_{2m} + \gamma_{1m}\varphi)S_m + \beta_3 I + \beta_4 D + \varepsilon, \tag{3.5}$$

Where I and D are the control and identification variables, respectively, and β_3 and β_4 are their respective coefficients. h is a constant term, and ε is a random error term. γ_{2m}, $\gamma_{1m}\varphi$, and $\gamma_{2m} + \gamma_{1m}\varphi$ are the direct, indirect, and total impact of social capital on family farms' GCT adoption, respectively. If $\gamma_{1m}\varphi$ is positive, social capital strengthens the effect of land tenure security on family farms' adoption of GCTs. In addition, by comparing $\gamma_{12}\varphi$ and $\gamma_{13}\varphi$, one can test whether embedded and disembedded social capital have different effects on the relationship between land tenure security and GCT adoption.

3.2. Variable measurements

3.2.1. Family farm GCT adoption behavior

T represents a family farm's adoption of GCTs. If the family farm adopts GCTs, then T equals 1 and 0 otherwise.

3.2.2. Family farms' land tenure security

As described previously, in China, land tenure security refers to the stability of land management rights in the context of the *Three Rights Separation Policy*, where land management rights can be transferred freely from land ownership rights and land contract rights. Previous studies have measured the stability of land management rights by considering two variables: the terms and the contract type of rural land transfer (Wang et al., 2015; Zou et al., 2016; Qiu et al., 2017). Based on these studies, we define stable land management rights as the case where the family farms and the land transfer farmers sign a written contract with a transfer term of three years or more[2] . In our study, L is a variable indicating whether the land management rights are stable. When the family farm signs a written contract with a transfer term of three years or more, it equals 1, and otherwise 0.

3.2.3. Family farms' social capital

Due to the wide variety of social capital, there is no standard for selecting indicators for this variable. Scholars usually select measures based on their research questions. Our selection of social capital measurement indicators is informed by our intention to reduce the simultaneity between measures of social capital and land tenure security and between measures of social capital and GCT adoption variables. For embedded social capital, we consider three aspects of the connotation of social capital: networks, norms, and trust. For disembedded social capital, drawing on the definition and on the study of Xie and Wang (2016), we consider three aspects: spatial mobility, career transition, and occupational relations. Favor pattern is a way for family farms to maintain their social and interpersonal communication networks. Gift spending is a relatively stable index reflecting the level of favor exchanges engaged in by a family farm (Kansanga, 2017). Therefore, we measure networks by asking family farms to report the total amount of money spent annually on relatives, neighbors, and friends. The social atmosphere is a real reflection of a village's ethical norms, and a good social ethos can effectively promote collective action (Zissi et al., 2010). Therefore, we measure norms by asking householders what the social atmosphere is like in their villages. Money lending to nearby people effectively reflects family farms' trust in relatives, neighbors and friends (Wuepper et al., 2018). Therefore, we measure trust by asking householders whether they have lent money to relatives, neighbors, and friends. The purchase of houses in cities and towns can help family farms

[2] The useful life of GCTs, such as insect-killing lamps and insect-proof screens, is generally longer than three years. Family farms are expected to be more likely to adopt GCTs when they have written contracts for three years or more. Without this stability, they may view GCTs as a wasted investment.

expand their social network and improve the heterogeneity of their social network structure (Sørensen, 2016). Therefore, spatial mobility is measured by asking householders whether they have bought houses in a city or town. Experience in non-agricultural jobs helps family farms establish business credit consciousness and obey implicit market norms (Wu et al., 2018). Therefore, the career transition variable is measured by asking householders whether they have engaged in non-agricultural work. Major disasters, such as droughts and floods, have serious impacts on agricultural production and operation, and the decision to donate to disaster relief can reflect donors' trust in other agricultural producers and operators (Herzog and Yang, 2018). Therefore, the occupational relations variable is measured by asking householders whether they have contributed to disaster relief, such as after droughts and floods. The network variable is measured with an actual numerical value, the norm variable is measured using a 7-point Likert scale, and the remaining variables are coded as 1 for "yes" and 0 for "no."

We use a weighting method that combines the factor analytic and entropy methods[3] to obtain three indices: composite social capital, embedded social capital, and disembedded social capital.

3.2.4. Identification variable

To ensure the identifiability of the switching and outcome equations, at least one control variable in the switching equation must be excluded from the outcome equation (Wossen et al., 2017). Farmland transfer service centers provide legal consultations, examine farmers' qualifications, publish relevant information, provide contract services, and handle transfer disputes (Huang and Ding, 2016). Family farms located closer to a farmland transfer service center can obtain more information and legal support, have lower transaction costs and risks in farmland transfers and are more likely to sign long-term written contracts with other farmers. Therefore, we use the distance to the nearest farmland transfer service center as our identification variable, which is measured by the actual distance.

3.2.5. Control variables

Following previous studies, we select eight control variables: householder gender, age, degree of education, village cadre status, risk preferences, funding status, planting scale, and planting structure.

Householder characteristics. 1) Gender. Studies have shown that women are more conservative and cautious in their thinking than men. To ensure land tenure security, women tend to sign long-term written contracts. However, they are less likely than men to adopt IPM (Khataza et al., 2018). We code the gender variable such that "male" equals 1 and "female" equals 0. 2) Age. Older householders may be more likely to be influenced by habits. They often make verbal contracts with farmers and are more resistant to new technologies and knowledge (Jensen et al., 2014). We measure a householder's age as his/her actual age. 3) Degree of education. Family farms with more education are more aware of the importance of land tenure security and the potential advantages of IPM (Korir et al., 2015). We use a householder's number of years of education to measure the education variable. 4) Village cadre status. Village cadre members are usually rural elites who have more information about land transfer market conditions and new technologies and are likely to sign long-term written contracts and adopt new technologies in response to the government's call to lead by example (Jiang et al., 2018a,b; Zeng et al., 2019). We code this variable such that "yes" equals 1 and "no" equals 0. 5) Risk preferences. Family farms with higher risk tolerance are expected to be willing to try new things, including signing long-term written contracts, and to be more comfortable with the uncertainties of new technology (Gong et al., 2016). We use a 7-point Likert scale to measure risk preferences.

Production and operation characteristics. 1) Funding status. Family farms with sufficient funds may be able to better cope with land transfer and technology input costs and tend to sign long-term written contracts and adopt new technologies (Zhou et al., 2019a,b; Zhang et al., 2018). We measure funding status on a 7-point Likert scale. 2) Planting scale. Larger family farms have greater proportions of transferred farmland in their total farmland areas and thus a greater dependence on transfers of cultivated land. They are also expected to hope that land tenure security will lead to a stable income, so they choose to sign long-term written contracts (Cheng et al., 2019a,b). Furthermore, family farms with more cultivated land may benefit more from the GCT scale effect and may therefore be more motivated to adopt GCTs (Barnes et al., 2019). We measure the planting scale as the actual area of cultivated farmland. 3) Planting structure. Cash crops require more investment in specific assets than grain crops and require more land tenure security, which encourages family farms growing such crops to sign long-term written contracts (Panichvejsunti et al., 2018). In addition, cash crops have higher expected returns and stricter quality and safety requirements, prompting family farms growing such crops to adopt IPM (Jensen et al., 2014). We measure planting structure as the ratio between grain crop planting area and the total cultivated area; if it exceeds 50%, it is coded as 1, and 0 otherwise.

3.3. Data source

Shandong and Henan Provinces were selected for this field study for several reasons. First, Shandong and Henan Provinces respectively rank first and fourth among the 31 provinces in China in terms of the number of family farms; thus, they show promise for future development[4] . Second, Henan and Shandong are important agricultural production areas, with the second and third highest grain output, respectively, among the 31 provinces of China[5] . Third, Henan and Shandong have the second and sixth largest total land transfer area, respectively, indicating more active markets[6] . Fourth, both provinces face serious challenges in pest control.

The survey was conducted in two stages. The first stage was the preinvestigation stage. In October 2017, 20 family farms in Shandong Province were randomly selected for household interviews. The clarity of the questionnaire was improved after this stage. The second stage was the formal survey, which was conducted from January to March 2018. A stratified random sampling method was used to gather data. First, all the counties in each province were sorted according to regional GDP and divided into five categories: very high, relatively high, medium, relatively low, and very low. Four counties were randomly selected from each category (as shown in Fig. 2). Then, within each sampled county, all townships were sorted according to the number of family farms registered with the industry and business departments and divided into three groups: high, medium, and low. Two townships were randomly selected from each group. Finally, two family farms were randomly selected from each sampled township. Therefore, the sample for each province covered 20 counties, 120 townships, and 240 family farms. Overall, 480 questionnaires were distributed, and 443 valid questionnaires were returned. A validity rate of 92.3% was achieved after eliminating questionnaires that omitted key information or presented self-contradictory information (for instance, where age is less than the number of years of education).

[3] Due to space limitations, we do not discuss this process here. Interested readers can refer to Appendix A for details.

[4] Rural Economic System and Management Department of the Ministry of Agriculture, Rural Development Institute of Chinese Academy of Social Sciences: "China Family Farm Development Report. 2016", 1st edition, Beijing, China Social Sciences Press, 2016.

[5] Source: "Announcement of the National Bureau of Statistics on Grain Yield in 2017", http://www.stats.gov.cn/tjsj/zxfb/201712/t20171208_1561546.html.

[6] Rural Economic System and Management Department of the Ministry of Agriculture, Rural Cooperative Economy Management Station of the Ministry of Agriculture: "China Rural Management Statistics Annual Report (2015)", Beijing, China Agricultural Press, 2016.

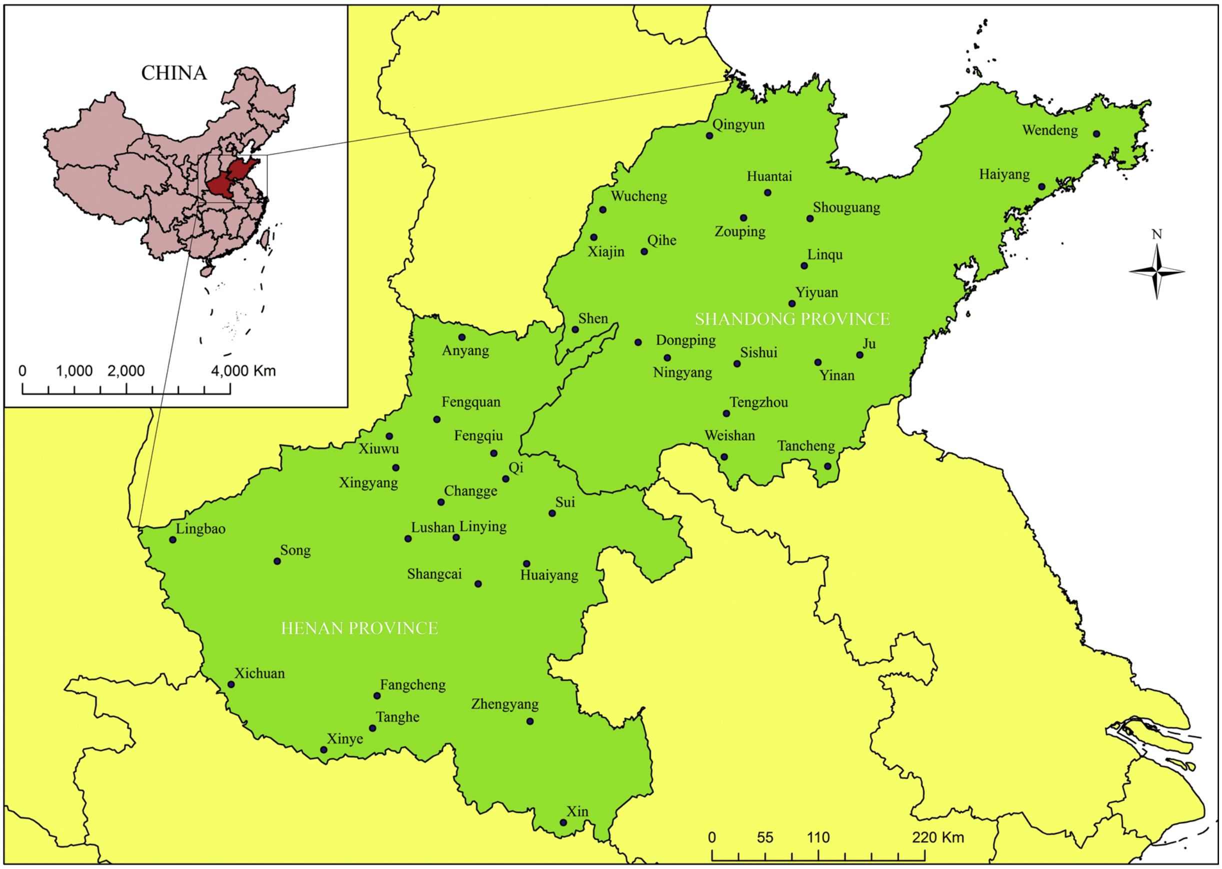

Fig. 2. Study area.

3.4. Sample description

As shown in Table 1, 174 of the 443 family farms surveyed in this study (39.28%) adopted GCTs, and 156 family farms (35.21%) had stable land management rights. The low GCT adoption rate and the unstable status of land management rights are consistent with the findings of other studies.

In terms of householder gender, 384 householders (86.7%) were male. In terms of householder age, 263 householders (59.4%) were middle-aged (between 40 and 50). In terms of the degree of education, the years of education ranged from 6 to 9 years, and the majority of householders (256, or 57.8% of the sample) had junior high school education. Sixty-three householders – or 14.2% of the sample – had village cadre status. In terms of risk preferences, “very low,” “low,” “relatively low,” “neutral,” “relatively high,” “high,” and “very high” family farms accounted for 14.38%, 15.58%, 22.12%, 12.19%, 13.29%, 11.51%, and 10.93% of the sample, respectively, showing a roughly uniform distribution of risk preferences. The average funding status value was 3.217, indicating low funding for family farms. In terms of planting scale, 44.70% of the family farms (198) had 100–300 mu, and 23.93% had 300–500 mu. A total of 315 family farms (71.11%) had planting structures based on grain crops. These statistics are consistent with the results reported in the *Family Farm Development Report, 2016*[7] . In addition, the average distance from a family farm to the nearest farmland transfer service center was 4.878 km, and the average social capital composite index value was 0.442.

[7] Rural Economic System and Management Department of the Ministry of Agriculture, Rural Development Institute of Chinese Academy of Social Sciences: “China Family Farm Development Report. 2016,” 1st edition, Beijing, China Social Sciences Press, 2016.

Table 2 displays the descriptive statistics for the social capital variables. The division of social capital into embedded and disembedded types results in an embedded social capital index value of 0.531, indicating that family farms have an average level of embedded social capital. The average amount of money spent annually on relatives, neighbors, and friends by family farms (in log form) was 7.8372. The villages had relatively good social atmospheres, and 61.85% of family farms lent money to relatives, neighbors, and friends. The disembedded social capital index has a value of 0.4165, indicating that family farms have low to middle levels of disembedded social capital. Overall, 148 family farms (33.41%) had houses in cities or towns, 213 householders (48.08%) engaged in non-agricultural work, and 364 householders (82.17%) made contributions to disaster relief after droughts and floods.

4. Estimation results

As shown in Table 3, the correlation coefficient ρ of the random disturbance terms in both the switching and the outcome equations is significant at the 1% level, indicating that the stability of land management rights is an endogenous variable. Therefore, the endogenous switching probit model is more appropriate than the independent regression models.

We first examine the impact of social capital and the stability of land management rights on family farms’ GCT adoption. The estimated results are shown in the endogenous switching probit Model I presented in Table 3. Then, we display the impacts on GCT adoption of embedded and disembedded social capital separately, which are shown in the endogenous switching probit Model II presented in Table 3.

Table 1
Variable definitions and descriptive statistics.

Variable type	Variable	Definition	Measure	Mean	Standard Deviation
Dependent variable	GCT adoption behavior	Whether the family farm adopts GCTs	1 = adoption, 0 = non-adoption	0.393	0.441
Main independent variable	Social capital composite index	Six weighted indicators	Actual numerical value	0.442	0.308
	Stability of land management rights	Whether family farm signs a written contract for three years or more	1 = yes, 0 = no	0.352	0.478
Control variable	Gender	Householder's gender	1 = male, 0 = female	0.867	0.435
	Age	Householder's actual age in 2018	Actual numerical value	46.745	8.150
	Degree of education	Householder's number of years of education	Actual numerical value	8.002	2.905
	Village cadre status	Whether householder is a member of a village cadre	1 = yes, 0 = no	0.142	0.349
	Risk preference	Degree of risk tolerance	1 = very low, ..., 7 = very high	3.562	1.835
	Funding status	The family farm's funding status	1 = very poor, ..., 7 = very abundant	3.217	1.554
	Planting scale	Actual area of cultivated farmland	Actual numerical value	180.336	62.621
	Planting structure	Ratio of grain crop planting area to total cultivated area	1 = more than 50%, 0 = 50% or less	0.711	0.500
Identification variable	Distance to the nearest farmland transfer service center	Distance from the family farm to the nearest farmland transfer service center (km)	Actual numerical value	4.878	1.749

4.1. Factors influencing the stability of family farms' land management rights

4.1.1. Social capital

The results of Models I and II show that the estimated coefficients of the composite social capital, embedded social capital, and disembedded social capital indices are positive and significant at the 1%, 5%, and 5% levels, respectively, indicating that social capital contributes to the stability of family farms' land management rights, which is consistent with our expectation. The findings support the hypothesis that social capital as an informal institution may have positive externalities, not only helping family farms obtain land transfer information, funding, and legal support but also forming durable reciprocal norms with farmers and ensuring the stability of land management rights.

4.1.2. Control variables

According to Models I and II, the degree of education, village cadre status, risk preferences, funding status, land area, and distance to the nearest farmland transfer service center all significantly and positively affect the stability of family farms' land management rights, while gender and planting structure significantly and negatively affect the stability of land management rights. This finding is consistent with Huang and Du (2018) and Boué and Colin (2018). Age is not a significant factor, perhaps because most family farm household heads in China are young and energetic and, therefore, age differences are not obvious.

4.2. Factors influencing the GCT adoption behavior of family farms

4.2.1. Social capital

According to Model I, the coefficient of the social capital composite index is positive at the 1% level, indicating that family farms with more social capital are more likely to adopt GCTs; that is, H1 is supported. Social capital alleviates information asymmetries, funding constraints, labor shortages, and other impediments to GCT adoption (Wuepper and Sauer, 2016); thus, it has a positive effect on GCT adoption.

According to Model II, embedded and disembedded social capital both significantly and positively affect family farms' adoption of GCTs, but the estimated coefficient of the disembedded social capital index is greater than that of the embedded social capital index; that is, H2 is supported. Embedded social capital has strong homogeneity and closeness and is based mainly on blood, kinship and geographical relationships, while disembedded social capital has more heterogeneity, is of higher quality, has a wider range and is based on new occupational relationships as well as a wide communication space. As such, disembedded social capital helps family farms obtain more technical information, respond more quickly and accurately to information, and exchange technology with more skilled family farms and provides more diversified financing channels. These factors give disembedded social capital a significant advantage over embedded social capital in promoting GCT adoption.

4.2.2. Stability of land management rights

According to Models I and II, the coefficient of the stability of land management rights is positive at the 5% level, indicating that stable land management rights encourage family farms to adopt GCTs; that is, H3 is supported. Stable land management rights enable family farms to have positive long-term operational expectations and to focus on the sustainable development of agriculture (Yao, 1998; Nizam et al., 2019). Therefore, family farms tend to adopt GCTs.

4.2.3. Control variables

According to Models I and II, gender, the degree of education, village cadre status, risk preferences, and funding status significantly and positively affect GCT adoption, while planting structure significantly and negatively affects GCT adoption. This finding is consistent with Willy and Kuhn (2016); Gautam et al. (2017), and Kabir et al. (2017). In addition,

Table 2
Descriptive statistics for social capital.

Variable	Meaning	Measure	Mean	Standard Deviation
Embedded social capital index	Three weighted indicators	Actual numerical value	0.5314	0.2407
Networks	Total amount of money spent annually on relatives, neighbors, and friends (in log values)	Actual numerical value	7.8372	1.4254
Norms	Social atmosphere of the village	1 = very bad, …, 7 = very good	4.9163	1.8032
Trust	Whether the family farm has lent money to relatives, neighbors, and friends	1 = yes, 0 = no	0.6185	0.3093
Disembedded social capital index	Three weighted indicators	Actual numerical value	0.4165	0.3816
Spatial mobility	Whether the owner has bought a house in a city or town	1 = yes, 0 = no	0.3341	0.4728
Career transition	Whether the family farm has engaged in non-agricultural work	1 =nyes, 0 = no	0.4808	0.4001
Occupational relations	Whether the family farm has contributed to disaster relief after droughts and floods	1 = yes, 0 = no	0.8217	0.2634

Table 3
Estimation results of the endogenous switching probit models.

		Model I		Model II	
Variable type	Variable	Switching equation (Land tenure security)	Outcome equation (GCT adoption behavior)	Switching equation (Land tenure security)	Outcome equation (GCT adoption behavior)
Main independent variable	Social capital composite index	0.3967*** (0.1421)	0.3702*** (0.1412)	—	—
	Embedded social capital index	—	—	0.1549** (0.0775)	0.0953*** (0.0231)
	Disembedded social capital index	—	—	0.3516** (0.1525)	0.3026*** (0.1157)
	Land tenure security	—	0.4063** (0.1727)	—	0.4957** (0.2225)
Control variable	Gender	−0.0229* (0.0118)	0.2703* (0.1403)	−0.0169** (0.0082)	0.2676* (0.1417)
	Age	−0.0358 (0.0283)	−0.1065 (0.0691)	−0.0220 (0.0159)	−0.1073 (0.0805)
	Degree of education	0.1079*** (0.0403)	0.2543*** (0.0816)	0.1544** (0.0721)	0.2519** (0.1278)
	Village cadre status	0.2552* (0.1368)	0.4541*** (0.0955)	0.2610* (0.1508)	0.4574** (0.1784)
	Risk preference	0.1759* (0.1036)	0.1453* (0.0854)	0.1924** (0.0957)	0.1515** (0.0668)
	Funding status	0.1106* (0.0657)	0.2650** (0.1263)	0.1111* (0.0584)	0.2656** (0.1265)
	Planting scale	0.1395** (0.0678)	0.1009 (0.0745)	0.1329** (0.0635)	0.1308 (0.0971)
	Planting structure	−0.0984* (0.0573)	−0. 1056* (0.0613)	−0.0954** (0.0437)	−0.1068* (0.0633)
Identification variable	Distance to the nearest farmland transfer service center	0.3174*** (0.1215)	—	0.2082** (0.1015)	—
Correlation coefficient	ρ	—	0.3281*** (0.1193)	—	0.5357*** (0.1647)
	Constant	0.6302** (0.2531)	4.5253*** (1.6436)	0.7751** (0.3526)	4.5826*** (1.2434)
	Observations	443		443	

Note: ***, **, and * are significant at the 1, 5, and 10 percent levels, respectively; standard errors in parentheses.

householder age and land area are not significant factors. Age is nonsignificant for the same reasons discussed in Section 4.1. Land area may be nonsignificant because most family farms have reached the scale standard stipulated by local governments in China; additionally, driven by the scale effect, family farms have adopted GCTs (Gao et al., 2017).

4.3. Strengthening effect of social capital on the relationship between the stability of land management rights and GCT adoption by family farms

As shown in Table 4, the coefficients indicate that the composite social capital, embedded social capital, and disembedded social capital indices have positive indirect effects on family farms' GCT adoption, indicating that social capital strengthens the effect of stable land management rights on GCT adoption. Therefore, H4 is supported.

Table 4
Impact of types of social capital on the GCT adoption behavior of family farms.

Type of Social Capital	Impact Type	Calculation	Result
Social capital composite index	Direct impact	γ_{21}	0.3702
	Indirect impact	$\gamma_{11}\varphi$	0.1612
	Total impact	$\gamma_{21} + \gamma_{11}\varphi$	0.5314
Embedded social capital	Direct impact	γ_{22}	0.0953
	Indirect impact	$\gamma_{12}\varphi$	0.0768
	Total impact	$\gamma_{22} + \gamma_{12}\varphi$	0.1721
Disembedded social capital	Direct impact	γ_{23}	0.3026
	Indirect impact	$\gamma_{13}\varphi$	0.1743
	Total impact	$\gamma_{23} + \gamma_{13}\varphi$	0.4769

Based on the coefficient size, the indirect effects of embedded and disembedded social capital on family farms' GCT adoption are $\gamma_{12}\varphi = 0.0768$ and $\gamma_{13}\varphi = 0.1743$, respectively, indicating that different types of social capital have different strengthening influences on the relationship between the stability of land management rights and GCT adoption, and disembedded social capital has a stronger influence. Therefore, H5 is supported (Table 4).

5. Conclusion

We apply endogenous switching probit models to survey data from 443 family farms in Shandong and Henan Provinces in China in order to analyze the influence of social capital and land tenure security on family farms' adoption of GCTs. We test whether social capital strengthens the positive effect of land tenure security on GCT adoption. To reduce endogeneity, we avoid simultaneity in our indicators for social capital and land tenure security and for social capital and GCT adoption. We use endogenous switching probit models in order to obtain more robust estimation results. Our main conclusions are as follows. First, both social capital and land tenure security have significant positive effects on family farms' adoption of GCTs, and social capital strengthens the positive effect of land tenure security. Second, embedded social capital and disembedded social capital have different strengthening effects.

The extension and application of GCTs are important for the development of cleaner and more sustainable agriculture. The role of land tenure security and social capital in this process requires more research. Based on our results, we make the following policy recommendations.

First, more attention should be directed to the instability in family farms' land management rights. The government should establish and improve land transfer transaction services, encourage land transfer parties to sign long-term written contracts and strengthen the supervision and review of land transfer contracts to ensure that each transaction is recorded, searchable and traceable. These reforms will strengthen the legal security of family farms' land management rights. Policies and regulations should include clauses safeguarding family farms' investment rights for infrastructure, production facilities and soil quality protection. They should also strengthen land-leveling rights on transferred land to improve the actual security of family farms' land management rights. Land transfer contracts should include a clause for renewal after the contract's expiration. Family farms should have the renewal right of "the same price priority" upon expiration to strengthen the perceived security of their land management rights. Second, to promote GCT, the government should cultivate and allow family farms to take full advantage of social capital to improve the adoption speed of GCT and assist family farms in "learning by seeing" and "learning by doing." Third, the government should recognize that, following transformations in the rural social structure, disembedded social capital has become the main form of family farms' social capital. The government should promote the accumulation and efficient use of family farms' disembedded social capital by reforming and innovating the household registration system, investing in education and training, and expanding rural information and infrastructure construction. This approach would alleviate the constraints on family farms' adoption of GCT.

Like China, other developing countries are also facing the challenges of chemical pesticide overuse and low levels of IPM adoption. Farmers' social communication networks have gradually eliminated regional restrictions, and the methods and scope of communication networks are becoming increasingly disembedded. Therefore, this study's analytical framework is applicable to other developing countries, and the conclusions have important implications for these countries to implement IPM promotion policies.

This study has certain limitations. First, the conclusions are based on family farms in Shandong and Henan Provinces; whether similar conclusions can be drawn for other areas of China remains an open question. Second, Sen (1962) has noted that whether family farms employ labor has an impact on their investment behavior. However, this study does not include "labor" as a control variable in the model, and its effect on the estimation results remains to be verified.

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Appendix A

Since different components of social capital have different impacts on GCT, it is necessary to determine reasonable weight assignments for the separate indicators. The factor analytic method is a common weighting method, but it has limitations, such as overdependence on the nature of the data and neglect of the structural contribution of each indicator to the overall goal. Therefore, we introduce the entropy method and use the actual sample utility value reflected in the information entropy to modify the weight obtained by the factor analytic method. We obtain the composite social capital, embedded social capital, and disembedded social capital indices as follows.

First, because the indicators used to measure embedded and disembedded social capital are both positive, the data are standardized according to Eq. (A.1):

$$Z_{ij} = \frac{X_{ij} - X^i_{min}}{X^i_{max} - X^i_{min}} \tag{A.1}$$

Where Z_{ij} is the normalized value of the i-th indicator of the j-th sample after standardization treatment. X_{ij} is the original value of the i-th indicator of the j-th sample. X^i_{max} and X^i_{min} are the maximum and minimum values of the i-th indicator original value, respectively.

Second, the information entropy of the indicator is calculated according to Eq. (A.2):

$$E_i = -k \sum_{j=1}^{n} (x_{ij} \times \ln x_{ij}) \tag{A.2}$$

Where E_i is the information entropy of the i-th indicator, n is the number of samples, $k = 1/\ln n$, and $x_{ij} = Z_{ij}/\sum_{j=1}^{n} Z_{ij}$.

Third, the entropy weighting of the indicator is calculated according to Eq. (A.3):

$$EW_i = \frac{1 - E_i}{\sum_{i=1}^{m} (1 - E_i)} \tag{A.3}$$

Where EW_i is the entropy weighting of the i-th indicator. $1 - E_i$ is the difference coefficient of the i-th indicator, and a larger value indicates more effective and more important information. m is the number of indicators.

Fourth, the indicator's weight obtained by the factor analytic method is modified according to Eq. (A.4):

$$W_i = (FW_i \times EW_i) \Big/ \sum_{i=1}^{m} (FW_i \times EW_i) \tag{A.4}$$

Where W_i is the modified weight of the i-th indicator. FW_i is the weight of the i-th indicator based on the factor analytic method.

Fifth, the composite social capital, embedded social capital, and disembedded social capital indices can be obtained by weighting the standardized values according to Eq. (A.5):

$$S_j = \sum_{i=1}^{m} W_i \times Z_{ij} \tag{A.5}$$

If m is the number of embedded social capital indicators, then S_j is the embedded social capital index of the j-th sample; if m is the number of disembedded social capital indicators, then S_j is the disembedded social capital index of the j-th sample; if m is the number of composite social capital indicators, then S_j is the social capital composite index of the j-th sample.

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