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Research

Migration and collective action in the commons: application of social-ecological system framework with evidence from China

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ABSTRACT. Much is known about collective action in the commons but little is known about the effects of migration as an exogenous shock. We study the case of China where at least 280 million people have migrated from the rural areas to the cities over the last four decades. We apply the social-ecological system (SES) framework along with the theory of collective action using survey data from 1985 households in 20 provinces throughout China. Data was analyzed using confirmatory factor analysis, ordered probit regression with instrumental variables, structural equation modeling, and interaction effects analysis. We find that migration exerts a significant negative effect on collective action in the commons and its effect is mediated by four mechanisms: resource dependence, leadership, social capital, and sense of community. Of these, resource dependence and leadership account for about two-thirds of the total effect. The SES framework has been shown to be a useful tool for empirically studying complex, multi-variable, nonlinear, cross-scale, and dynamic social-ecological systems.

Key Words: *collective action; commons; irrigation; migration; social-ecological system framework*

INTRODUCTION

Much is known about collective action in the commons (Agrawal 2001, Agrawal and Ostrom 2001, Araral 2009), but little is known about the effects of migration as an exogenous shock. This paper uses the social-ecological system (SES) framework to study how migration affects collective action in the commons. We focus on the case of China where at least 280 million people have migrated from the rural areas to the cities over the last four decades. Beyond China, rural-to-urban migration is also accelerating in much of India and Africa. The nascent literature suggests that rural-to-urban migration exerts a negative effect on collective action in the commons (Baker 1997, Rudel 2011, Liu and Li 2017). Wang et al. (2016) hypothesized that leadership, social capital, sense of community, economic heterogeneity, and resource dependence mediate the effects of labor out-migration on collective actions in the commons in China. However, there are few empirical studies to examine the mechanisms through which rural labor out-migration affects collective action in the commons.

The SES framework is appropriate to empirically study the effects of migration on collective action in the commons, because it allows for the study of "complex, multi-variable, nonlinear, cross-scale, and changing systems" (Ostrom 2007:15181). Moreover, studying interaction effects using the SES framework has been gaining ground over the past decade (Cash et al. 2006, Ostrom 2009, Hinkel et al. 2015, Vogt et al. 2015, Partelow and Winkler 2016, Amblard 2019, Su et al. 2020, Wang et al. 2020). Likewise, interest on studying the dynamics and effects of internal and external disturbances on an ecological system is also growing (Yu et al. 2014, Martone et al. 2017, Tenza et al. 2017, Xenarios et al. 2019).

As a big country with a massive rural population, China has undergone rapid urbanization at an unprecedented rate since the reform and opening up in 1978 (Liu et al. 2014). Over the past four decades, more than 280 million rural workers migrated to cities in China (Cheng et al. 2019). This massive migration has yielded positive consequences: liberating and developing productive forces, promoting rural sustainable development, and enabling the rapid development of the rural market economy. However, similar to other countries in East Asia (Liu et al. 2010), this high speed of urbanization has not only yielded numerous benefits, but also forced China to face an intensified crisis. This has led to a general stagnation of the development capacity of villages and threatened their sustainability and resilience (Li et al. 2014, Liu et al. 2018). The fall of rural irrigation collective action is a typical manifestation of the rural sustainability crisis in China. It has raised the economic cost of agricultural production and social risk in rural society, which has generated a huge negative impact on rural sustainability (Wang et al. 2016, 2019, Wang and Wu 2018).

In this paper we aim to understand the links between institutions, governance, and ecological systems in a changing SES faced with an exogenous shock. In particular, we examine how labor out-migration—an exogenous shock to the SES—affects the ability of local communities to solve collective action problems in the irrigation commons. It also examines how this effect is mediated by other variables in the SES framework. Scholars of collective action in the commons have used the irrigation system as a unit of analysis because it is a natural experiment to study collective action problems such as free riding, defection, coordination, and the tragedy of the commons (Ostrom 1990, Bardhan 1993, Araral 2009, Wang and Wu 2018, Xenarios et al. 2018, Zang et al. 2019, Su et al. 2020, Xenarios et al. 2020).

Using survey data from 1985 households of 20 provinces throughout China, four mechanisms were identified to potentially explain the decline of collective action in the rural commons in China: resource dependence, leadership, social capital, and sense of community. We found that resource dependence and leadership account for about two-thirds of the total effect. These findings

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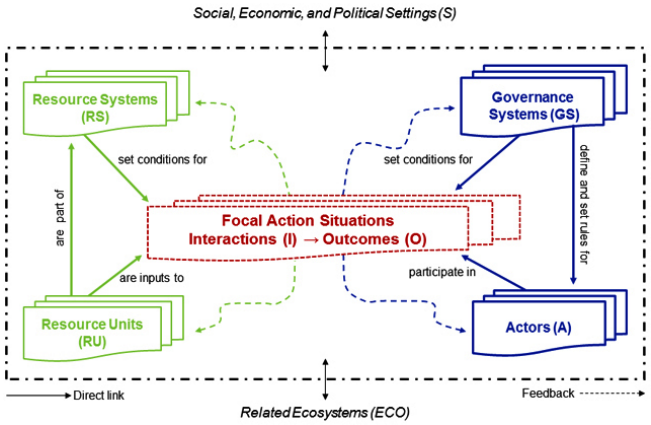
add new theoretical insights, especially the effects of an exogenous shock such as migration, to the literature on collective action in the commons. They also have important implications for the governance and resilience of rural commons worldwide in the face of increasing urbanization and migration.

FRAMEWORK, BACKGROUND, AND THEORETICAL HYPOTHESIS

SES framework

The SES framework (Fig. 1) is employed to build both theory and hypotheses. This framework builds on the work of Anderies et al. (2004, 2016) and Ostrom (2007:15181) and allows for the study of "complex, multivariable, nonlinear, cross-scale, and changing" SES.

Fig. 1. Social-ecological system framework (Source: McGinnis and Ostrom 2014).



The solid boxes in Figure 1 denote first-tier categories of variables such as resource systems, resource units, governance systems, and actors, each of which can be decomposed into second-tier variables (McGinnis and Ostrom 2014). Focal action situations transform inputs into outcomes by the interactions of various actors. Dashed arrows denote feedback from focal action situations to each of the top-tier categories. The dotted-and-dashed line enclosing most of Figure 1 indicates that the focal SES can be considered as a logical whole, but that exogenous influences from related ecological systems or social-economic-political settings can affect any component of the SES simultaneously (O'Brien et al. 2000). These exogenous influences might emerge from the dynamic operation of processes at larger or smaller scales than that of the focal SES.

When applying the SES framework, second-tier variables can be further characterized by third-tier variables (and so on), if relevant for the analysis (Amblard 2019). As a contextual variable, labor out-migration (S2-a) was incorporated into the social, economic, and political settings (S) subsystem (Table 1). Prior research indicated that labor out-migration can be treated as an external force from economic change (Anderies et al. 2004), which will significantly reduce the capacity of rural villages to engage in irrigation collective action (Baker 1997, Rudel 2011). This can happen through its effects on factors that are known to affect collective action: village leadership (A5), social capital (A6-a), villagers' sense of community (A6-b), farmers' dependence on agricultural resources (A8-a), and economic heterogeneity in the village (A2-a; Wang et al. 2016). These factors can be used as third-tier variables within the second tier of the actor (A) subsystem, including socioeconomic attributes (A2), leadership/entrepreneurship (A5), social norms / social capital (A6), and resource dependence (A8).

The three variables of leadership (A5), social capital (A6-a), and sense of community (A6-b) are not easily observed, but can be described through other, more observable variables. First, following Kouzes and Posner (2006), leadership (a second-tier variable) can be described by third-tier variables measuring the legitimacy (A5-a), effectiveness (A5-b), and credibility (A5-c) of village leaders. Second, according to Putnam et al. (1993), social capital (the third-tier variable A6-a) can be measured on three dimensions: trust (A6-a-1), relationship network (A6-a-2), and reciprocity (A6-a-3). Third, Kasarda and Janowitz (1974) and Fischer et al. (1977) defined the sense of community in terms of four aspects: whether residents feel that they belong to the community and identify themselves as residents of the community (group membership identification); whether they are interested in what is happening in the community and consider these things relevant to themselves; whether, if residents were to move away, they would feel nostalgia for the community they left; and whether they are willing to contribute to the construction and development of the community. Thus, under the third-level variable of sense of community (A6-b) the following three fourth-tier variables are added: dedicate time to village construction (A6-b-1), dedicate money to village construction (A6-b-2), and group membership identification (A6-b-3); the counterfactual about nostalgia is neglected.

Thus, the process by which labor out-migration affects rural irrigation collective action (O1) through affecting village leadership, social capital, sense of community, dependence on agricultural resources, and economic heterogeneity forms the basic scenario of the SES framework used in this paper. After this preliminary establishment, the factors collectively in resource units, resource systems, government systems, and related ecosystems are treated as controlled variables. Therefore, the relationship between labor out-migration and irrigation collective action can be analyzed under the condition that other conditions remain unchanged.

Background of irrigation commons in China: a perspective of SES framework

Resource systems (RS) and resource units (RU) of China's irrigation commons

China is one of the countries suffering from water-scarcity, causing irrigation systems (RS1-a) in China to play a vital role for securing adequate food production. Irrigation systems also reduce China's vulnerability to the uncertainty of rain-fall levels and the resulting water scarcity (RU5-a). Irrigated lands occupied 54.7% of China's farmland in 2016 and produced three-quarters of its grain as well as more than 90% of its cash crops (RS3-a). Historically, surface irrigation systems (RS1-a-1) were dominant, but their use declined during the modern era. They were gradually replaced by groundwater-based, smallholder irrigation systems (RS1-a-2), especially in northern China (Calow et al. 2009).

Table 1. Variables and descriptive statistics.

Variable		Description	Data source	Mean	Std. Dev.
Dependent variable		N = 1985			
Irrigation collective action		Frequency of villagers' participation in the construction and repair of irrigation facilities (1 = seldom, 5 = often, ordinal variable)	HQ	2.79	1.17
Core independent variable					
LMIGRATION		Migrant workers as a proportion of total village population (continuous variable)	VQ	0.23	0 .16
Mediators					
LS	LS1	Villagers' evaluation of village affairs (1 = very unfair, 5 = very fair, ordinal variable)	HQ	3.41	0.97
	LS2	Villager's evaluation scoring to the village leader (the score is on a scale of 1–11, ordinal variable)	HQ	7.88	1.60
	LS3	Villagers' trust in the village committee (1 = very distrustful, 5 = very trustful, ordinal variable)	HQ	3.69	1.19
SC	SC1	Number of people you can trust in the village (continuous variable)	HQ	6.23	10.48
	SC2	Number of visits from other villagers in the last two weeks (continuous variable)	HQ	5.80	10.97
SOC	SOC1	whether a villager would spend their time on village construction (1 = be willing to spend time, 0 = never, binary variable)	HQ	0.64	0.48
	SOC2	whether a villager would spend their money on village construction (1 = be willing to spend money, 0 = never, binary variable)	HQ	0.46	0.50
RD		whether eager to attend meetings or discussions about irrigation water (1 = yes, 0 = otherwise, binary variable)	HQ	0.54	0.50
EH		there is a big wealth (income) gap between your village's residents (1 = large, 0 = otherwise, binary variable)	HQ	0.26	0.44
Community attributes					
ECONOMY		The relative economic development of the village (1 = bad, 3 = good, ordinal variable)	VQ	1.66	0.54
POP		Number of residents of the village (thousands) (continuous variable)	VQ	0.68	0.67
Natural conditions					
RESOURCE		Is the village facing a moderate water scarcity situation (1 = modest water scarcity, 0 = otherwise, binary variable)	VQ	0.51	0.50
Institutional arrangements					
PETITIONS		Are there frequent petitions and conflicts over water allocation in the village (1 = no conflicts, 6 = many petitions and conflicts, ordinal variable)	VQ	4.76	1.39
SANCTIONS		Does the village punish the stealing or intercepting of water? (1 = very weak, 5 = very strong, ordinal variable)	VQ	3.39	1.26
Household characteristics					
FAMILYLAB		The proportion of labor force on total family number (continuous variable)	HQ	1.37	0 .41
SHORTAGE		frequency of farmers' inability to irrigate in recent years (1 = seldom, 5 = often, ordinal variable)	HQ	2.96	1.20
NEAR		proximity to irrigation facilities (1 = moderate distance, 0 = otherwise, binary variable)	HQ	0.25	0.44
AGE		Age of household head (continuous variable)	HQ	47.59	14.75
EDU		education level of the household head (1 = never attended school, 8 = graduate level, ordinal variable)	HQ	2.84	1.34
Instrumental variable					
DIS		The distance between the village and the county center (kilometers) (continuous variable)	VQ	22.50	18.53

Notes: HQ represents the data were collected from household questionnaires; VQ represents the data were collected from village questionnaires.

In the 1950s, groundwater irrigation was virtually non-existent in northern China. In the mid-1970s, groundwater provided approximately 10–15% of the irrigation supply to northern provinces facing water shortages. However, by the mid-1990s, this figure had increased to approximately 40%, and in specific downstream provinces, e.g., Hebei, Shanxi, Henan, and Shandong, the share of groundwater-irrigated areas increased to approximately 70% (Wang et al. 2007, 2009).

As a result, the prevalence of individual irrigation (RS-a-3) dramatically increased over the past half-century. According to official estimates, the numbers of wells (RS4-a) in China were

138,300 in 1964 2.7 million in 1980, and 4.45 million in 2000. By 2011, this number had increased to approximately 5.08 million. In contrast, according to the Chinese Rural Survey conducted by the China Institute for Rural Studies (CIRS) in 2012, the proportion of households relying on canal (RS4-b) irrigation had decreased to less than 40%.

Governance systems (GS) changes of China's irrigation commons

Since the founding of the People's Republic of China, profound changes in the structure and characteristics of rural governance in China have hugely impacted rural irrigation commons governance. Since 1949, the governance of the irrigation commons in China's rural areas has witnessed the following three stages: compulsory cooperation, semi-compulsory cooperation, and voluntary cooperation.

The period from 1949 to 1981 was the period of irrigation governance based on compulsory cooperation. During this period, water conservancy facilities, e.g., reservoirs, pumping stations, pond dams, and ditches needed for irrigation, were provided by governments at all levels, which realized unified management of farmland water conservancy throughout the country. Numerically, by 1976, more than 80,000 kinds of reservoirs had been built across the country, and the irrigated area of farmland had increased from 15.93 million hectares in 1949 to 44.89 million hectares in 1980.

The period from 1982 to 2002 was a period of irrigation governance based on semi-compulsory cooperation. During this period, the household contract responsibility system (GS4-a) enabled individuals to acquire the right to contract farmland that belongs to the collective. The decentralization of farmland property rights has led many large and medium-sized irrigated areas to adopt market-oriented reforms oriented by self-responsibility for profits and losses. At the same time, villagers were still obligated to participate in collective working; therefore, farmers' participation in the construction of water conservancy facilities represents a kind of semi-compulsory cooperation. In this case, the semi-compulsory participation in water conservancy construction and the economic model of the rural household contract system established in the market economy were seriously unsuitable. This caused problems for the semi-compulsory cooperation in irrigation management. The cooperation scale shrank continuously, and large water conservancy facilities were gradually replaced by small and medium-sized water conservancy facilities.

The period from 2003 to today is a period of irrigation governance based on voluntary cooperation. During this period, the compulsory requirement for farmers to participate in water conservancy construction was abolished. However, this makes it increasingly difficult to carry out irrigation and water conservancy constructions using the village community (GS2-a) as the basic organizational unit. More and more farmers choose to dig their own wells or weirs and buy irrigation facilities to meet their own irrigation needs.

Since 2011, the central government's (GS1-a) investment in irrigation and water conservancy facilities has continuously increased. Furthermore, the conditions of large and medium-sized irrigation and water conservancy facilities, represented by reservoirs, have been greatly improved. However, the "last mile–of irrigation and water conservancy efforts cannot be provided by the state, but rather, require the cooperation of farmers and collective action. Under the condition of the decline of rural irrigation collective action (GS5-a), high input from the state and local governments to the irrigation and water conservancy infrastructure (GS6-a) still cannot fundamentally solve the challenges associated with water shortages for agricultural production and the low efficiency of irrigation.

Theoretical analysis of possible mechanisms guided by SES framework

To better understand the mechanisms that link leadership, social capital, sense of community, resource dependence, and economic heterogeneity with migration and collective action, in-depth interviews were conducted in villages in the provinces of Henan and Jiangxi in China. These provinces were chosen for two reasons: First, their rates of out-migration are among the highest in China. Second, the economies of both provinces mainly depend on scaled wheat and rice cultivation, both of which are strongly dependent on collective irrigation.

To generate more convincing hypotheses, we present the mechanisms that link these five variables, i.e., leadership, social capital, sense of community, resource dependence, and economic heterogeneity, with migration and collective action based on prior literature and field observation. We also present how the interview materials were used to help to form proposed hypotheses.

Mechanism 1: labor out-migration → leadership → collective action

Leadership can be interpreted as a process of social influence in which a person may enlist the aid and support of others toward the accomplishment of a common task. Leadership is a key factor in collective action (Meinzen-Dick et al. 2002). When a virtuous or trustworthy individual participates in collective action, both collective communication costs and organizational costs fall, and other members of the community become more willing to participate (Kolavalli 1995, Baland and Platteau 1999). Meinzen-Dick (2007) examined Indian irrigation systems and showed that leadership by university graduates and local elders played a great role in the establishment and maintenance of local irrigation systems.

Labor out-migration may lead to changes in village leadership and thus affect collective action in the commons. For example, in the villages of Yangang, Yanglou, and Wangzhai in Henan Province, labor outflow has depleted leadership talent. People with a talent for organizing collective action tend to migrate to cities in search of better job opportunities and a higher salary. As a result, villages are left with a population of mostly children and the elderly, who generally have less leadership talent to organize collective action. These observations are in line with the conclusion of existing literature, which pointed out that the increased rate of rural-urban migration causes a massive brain drain, leading to a lack of rural elite talent (Wang et al. 2016, Liu and Li 2017, Su et al. 2020).

Mechanism 2: labor out-migration → social capital→ collective action

Following Putnam et al. (1993), the present paper defines social capital in terms of three dimensions: trust, relationship network,

and reciprocity. Social capital can affect the confidence of participants in collective action. Higher social capital makes citizens more confident in collective action, thus making the emergence of collective action more likely (Pretty 2003). In a study of irrigation and water conservancy, Li et al. (2012) argued that the greater the social capital, the stronger the collective irrigation capacity of water user associations will be. Likewise, in communities characterized by close social proximity (which benefit from low transaction costs and frequent communication), where community members put a greater stock in social norms, collective action in common property resource management may succeed (Runge 1986). It has also been shown that a larger number of exit options reduces cooperative capacity, as these weaken social cohesion (Bardhan 1993) and increase the cost of enforcing rules, which further negatively affects collective resource management (Stern et al. 2002).

Labor out-migration may change the amount of social capital among villagers and thus affect collective action in the commons. In the conducted interviews, villagers complained about the decline in trust as a result of labor outflow. In particular, the village directors of Liantang and Huangni Villages in Jiangxi Province mentioned that the hollowing out of villages caused by the out-migration of labor has made the relationship among villagers more problematic (i.e., conflictual). The same situation was also observed in interviews in Yangang, Yanglou, and Wangzhai Villages in Henan Province.

Mechanism 3: labor out-migration → sense of community → collective action

Based on the research of Kasarda and Janowitz (1974) and Fischer et al. (1977), dedicating time to village construction (A6-b-1), dedicating money to village construction (A6-b-2), and group membership identification (A6-b-3) were used to represent the "sense of community" according to the SES framework in Table 1. Unlike social capital, the sense of community is a type of link between people and the village. Even if a social network among villagers cannot be created, they can still commit themselves to the welfare of the village (civic spirit). The sense of community is a catalyst for villagers to participate in collective action (Wandersman 1990, Klandermans 2002, Mannarini and Fedi 2009). Fostering a sense of community can promote participation in collective action (Cicognani et al. 2008).

Labor out-migration may alter the sense of community, thereby affecting collective action. The conducted interviews showed that the people who remain in the village did not change the community identity of residents, nor their concerns about community affairs; however, their willingness to commit themselves to village development has changed. Interviews in Huangni and Liantang Villages in Jiangxi Province showed that with the outflow of workers, the rest of the villagers yearn to follow their neighbors who have already left to seek higher non-agricultural income. Thus, the commitment to the further construction and development of their village by the people who still live there decreased. The same situation was also found in interviews with the residents of Wlasitai Village in Xinjiang Province and Wangzhai Village in Henan Province.

Mechanism 4: labor out-migration → resource dependence → collective action

Collective action becomes more likely if the livelihood of resource users depends strongly on common pool resources (Runge 1986, Ostrom 2000, Acheson 2006). Conversely, lesser dependence on the resource weakens the incentives for people to participate in collective action, such as the maintenance of the irrigation system. Large-scale labor out-migration caused a sharp decrease of the scale of agricultural production in the village; thus, the dependence of the people remaining in the village on agricultural infrastructure and agricultural resources decreased. Therefore, labor out-migration reduces the dependence of villagers on irrigated agriculture, making it more difficult to mobilize them for irrigation repair and maintenance. In Huangni Village in Jiangxi Province, the village leader reported that the increase in labor out-migration has made it difficult to organize collective action related to irrigation. The reason is that the people who left the village no longer need the collective irrigation infrastructure.

Mechanism 5: labor out-migration → economic heterogeneity → collective action

The effect economic heterogeneity exerts on collective action is well known (Adhikari and Lovett 2006, Janssen and Anderies 2013). Poteete and Ostrom (2008) argued that the relationship between heterogeneity and collective action is nonlinear and contingent on many factors. Many studies confirmed that a greater heterogeneity of household income makes it more difficult to induce collective action (Chambers and Conway 1992). In India (Easter and Palanisami 1986), with decreasing heterogeneity of farmers, more farmers participate in irrigation organizations, making it easier to achieve collective irrigation action.

Labor out-migration exacerbates the economic heterogeneity amongst villagers, and thus affects collective action in the commons. In Wangzhai Village, Henan Province, migrant workers can earn tens of thousands of Yuan per year working in construction or in assembly plants in nearby cities. However, farmers remaining in the village can only earn an average of 5000 Yuan per year from agricultural planting. Well-off villagers tend to choose individual irrigation systems, e.g., by using pumps to extract groundwater individually, because they can bear higher irrigation costs (150–200 Yuan per mu). Low-income farmers must rely on the lower-cost collective irrigation (20-30 Yuan per mu). Richer farmers have no incentive to contribute to community irrigation maintenance. Figure 2 summarizes the applied framework following Figure 1.

Hypotheses

Based on the context and mechanisms described above, the following six hypotheses on the relationship between out-migration and collective action in the irrigation commons are proposed and will then be tested (Fig. 3).

H1: Labor out-migration reduces rural collective action in the commons.

H2: Labor out-migration depletes leadership talent in villages, which reduces rural collective action in the commons.

H3: Labor out-migration depletes villagers' social capital, which reduces rural collective action in the commons.

H4: Labor out-migration erodes villagers' sense of community, which reduces rural collective action in the commons.

H5: Labor out-migration weakens farmers' dependence on agriculture and irrigation, thus reducing rural collective action in the commons.

Fig. 2. Operational framework based on decomposed social-ecological systems (SES).

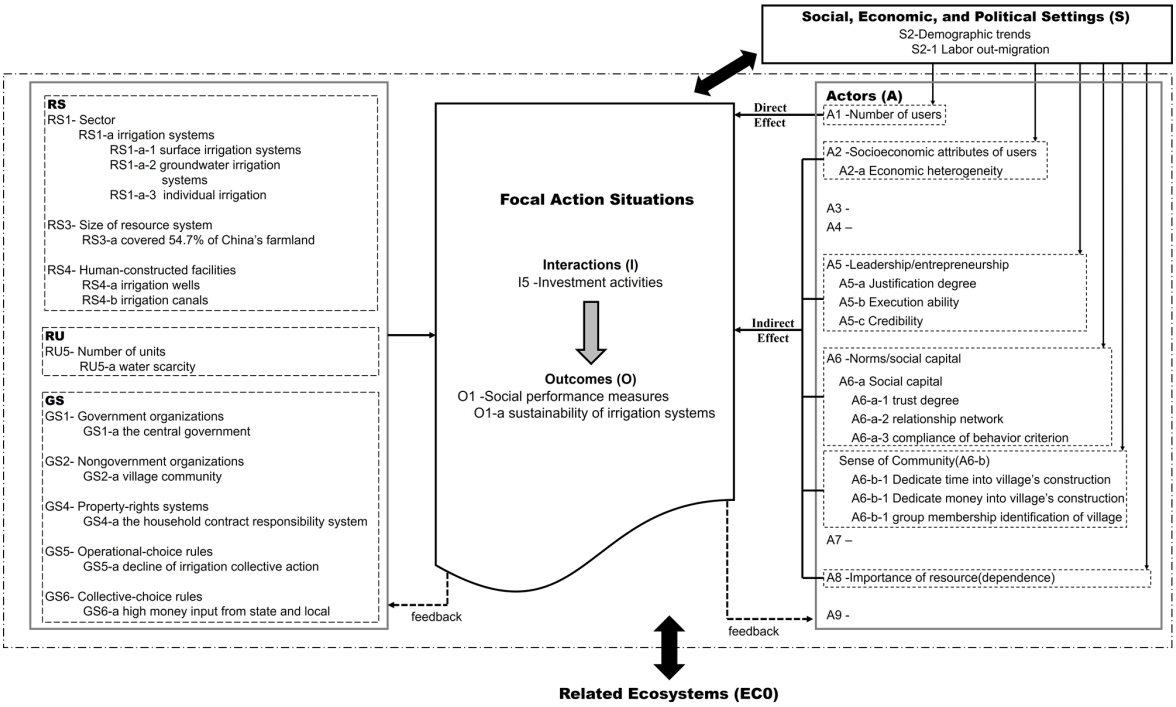
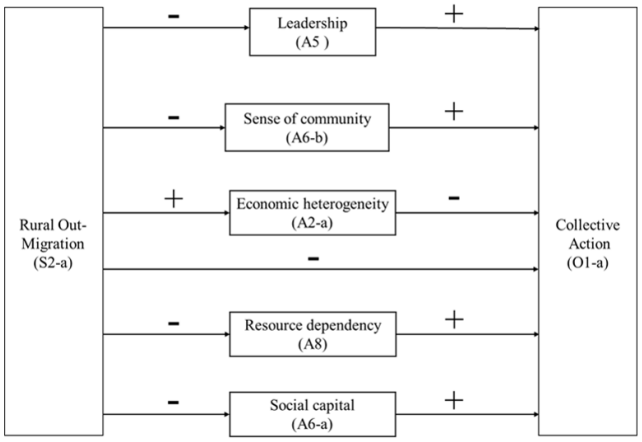


Fig. 3. Hypotheses regarding the relationship between rural labor out-migration and collective action.



H6: Labor out-migration exacerbates economic heterogeneity among villagers, thus reducing rural collective action in the commons.

DATA AND VARIABLES

Survey

Survey data collected in 2016 by the China Institute for Rural Studies (CIRS) of Tsinghua University was used. The survey aimed to build a comprehensive database on rural China, including agricultural production, farmers' income and expenses, the rural environment, implementation of agricultural policies, and irrigation, e.g., the construction, maintenance, investments, and benefits associated with irrigation facilities.

Separate village-level and household-level questionnaires were employed, both of which were framed according to the SES framework. The village-level questionnaire was primarily filled in by leaders who are familiar with the village (e.g., the village head, village director, or village accountant). This questionnaire asked for basic information about the village, including land and house property, infrastructure and public service, economy, irrigation and water conservancy, as well as labor migration and employment. The household-level questionnaire was primarily filled in by household heads, who were randomly selected by the interviewer. This questionnaire asked for basic information on family members, their living environment, the land and house property, irrigation, consumption and expenses, as well as participation in village governance.

From April to May 2016, the CIRS recruited university students across China to conduct the survey. More than 400 students were recruited, mostly from agricultural universities, such as China Agricultural University and Sichuan Agricultural University. In June 2016, four experts at CIRS trained the students regarding sample selection and interviewing.

The survey was conducted from June to September 2016, when most Chinese universities were on summer vacation. The 400 students, who were split into 60 groups, went back to their towns and provinces to conduct the interviews. In summary 277 village-level questionnaires and 5778 household samples were obtained.

Because the research focus is the community level, village data had to be matched to household survey data. After this matching, 1985 households in 169 villages in 20 provinces remained (out of China's 31 provinces).

Dependent variables

There are two ways to measure collective action: the output method and the process method. The output method measures results. For example, Bardhan (2001) and Su et al. (2020) assessed the actual maintenance of irrigation facilities. The process method measures engagement. For example, Fujiie et al. (2005) measured the number of collective activities, e.g., lobbying and channel maintenance, of successful organizations. Following the process approach, for the present study we defined irrigation collective action (ICA) as the frequency of farmers' participation in the construction and repair of irrigation facilities.

Irrigation maintenance has been widely employed as an indicator of collective action (see, for example, Ostrom 1990, Bardhan 1993, Araral 2009, Wang and Wu 2018, Wang et al. 2019) because of the many problems associated with collective action arising from irrigation maintenance. First, because village irrigation in China consists of miles of earthen canals that are commonly not lined with cement, these canals need to be cleaned of grass, debris, and silt regularly (at least twice a year) to ensure their adequate function. This requires a high level of collective action. Second, irrigation infrastructure, e.g., irrigation valves, weirs, and small dams, require a high degree of operation and maintenance even if they are of high quality. There are dozens if not hundreds of these units that need to be operated and maintained, which in turn requires a high degree of collective action among villagers. Third, even if infrastructure is well built, there are still many collective action problems in irrigation such as who will operate and monitor the infrastructure, how much fees need to be paid, how much water to allocate, and how to resolve conflict (see Ostrom 1990). All of these issues require a high degree of collective action, and if dilemmas exist in one of these collective actions, the maintenance situation of irrigation infrastructure will deteriorate rapidly.

Despite the broad economic shift from rural agriculture production to urban factory work, and the use of new infrastructure on rural farms, which eliminates the need for traditional forms of collective action, the implementation of the household contract responsibility system still retains the wide use of the traditional form of irrigation collective action in China's rural areas. This is particularly the case for the maintenance of irrigation systems. The implementation of the household contract responsibility system partitioned China's rural land into small and scattered areas in the past (Zang et al. 2019). This partitioning made it necessary to coordinate the large number of smallholders and smallholders' land in the process of the transformation of China's agricultural economy. This coordination process is often most effective in the traditional collective action form of house-to-house coordination (Wang et al. 2020). For example, in irrigation management, irrigation water needs to flow through the land of each household; therefore, a great deal of collective action is needed to coordinate the use of irrigation water and the maintenance of the irrigation system. Even in areas where advanced irrigation facilities have been installed, the property rights of the land covered by irrigation equipment are scattered among households. Consequently, when irrigation equipment needs to be maintained, free riders are likely to emerge. Therefore, the traditional collective action form of house-to-house coordination is still needed to meet the needs of the maintenance of such irrigation facilities. Although China's rural areas have indeed been impacted by external economic development, the unique land system of China's rural areas did not weaken people's demand for irrigation collective action with economic development.

Core independent variable

The core independent variable is the proportion of migrant workers to the total population of the village (LMIGRATION). The definition of a migrant worker is someone who has been engaged in non-agricultural production in urban areas for six months or more, whose permanent residence is in an urban area, and whose income mostly originates from non-agricultural work, while the official residence remains in a village. The proportion of migrant workers to the total population of a village represents the "hollow effect" of the village, meaning that people still live in the village and participate in agriculture but with fewer relatives, neighbors, and friends. This study assessed how the people who still live and work in the village will act during the cooperation when they have fewer partners available.

Mediating variables

Leadership (LS)

Based on the mechanism of "labor out-migration → leadership → rural collective action," and according to exploratory factor analysis (EFA, see Appendix 1) and confirmatory factor analysis (CFA, see Appendix 1), three indicators from the questionnaires were used to measure leadership: villagers' evaluation of village affairs (LS1), villagers' evaluation of the village committee's daily work (LS2), and villagers' trust in the village committee (LS3).

LS1 is an ordered discrete variable with values ranging from 1 to 5, denoting the villagers' evaluation of the fairness of village leaders in the process of hosting public affairs. A value of 1 represents that the leader is very unjust in presiding over public affairs and a value of 5 represents that the leader is very just when hosting public affairs. LS2 is an ordered discrete variable with values ranging from 1 to 12, denoting villager's evaluation scoring of the village leader. Twelve affairs the village leaders should resolve for the villagers were listed according to the preliminary investigation, and the villagers were asked to point out how many of these 12 affairs their leaders did for them. Each of these was assigned one point. LS3 is also an ordered discrete variable with values ranging from 1 to 5, denoting villagers' trust in the village committee. A value of 1 represents very distrustful and a value of 5 represents very trustful. Kouzes and Posner (2006) divided the indicators of public leadership into five categories: leading by example, sharing vision, engaging, inspiring, and challenging innovation. LS1 is actually a measure of village leadership from the perspective of engaging, and LS2 measures village leadership from setting by example. Kouzes and Posner (2006) regarded the honest credibility measured by LS3 as the cornerstone of good leadership.

Social capital (SC)

Social capital is a latent variable and difficult to measure. Based on the mechanism of "labor out-migration → social capital →

rural collective action," and according to both EFA and CFA (Appendix 1), this study used two indicators from the questionnaires for social capital: "the number of villagers you can trust" (SC1), and the "number of times other villagers visited you in the last two weeks" (SC2). Ostrom and Ahn (2003) divided the dimensions of measuring social capital into trust, networks, and institutions. SC1 measures the dimension of trust in social capital, whereas SC2 measures the network dimension of social capital.

Sense of community (SOC)
Sense of community is also a latent variable that is difficult to measure. Based on the mechanism of "labor out-migration → sense of community → rural collective actions," and according to both EFA and CFA (Appendix 1), this study used two indicators from the questionnaires for sense of community: whether a villager would spend their time on village construction (SOC1), and whether a villager would spend their money on village construction (SOC2).

Kasarda and Janowitz (1974) and Fischer et al. (1977) defined people's sense of community via four aspects: first, the sense of identity, which refers to whether residents feel that they belong to the community, are willing to live there for a long time, and recognize themselves as residents of their community; second, the sense of identity, which refers to whether residents are interested in what happens in the community and consider these affairs as closely related to themselves; third, the sense of nostalgia, which refers to whether residents want to move out of the community; fourth, the sense of dedication, which refers to whether residents are willing to contribute to the construction and development of the community. SOC1 and SCO2 measure the sense of identity and dedication in a community sense.

Resource dependence (RD)
Lesser dependence on resources will weaken the incentives for people to participate in collective action, such as meetings that discuss irrigation water distributions (Ostrom 2000). Therefore, based on the mechanism of "labor out-migration → resource dependence → rural collective action," this paper uses answers to the question "Are you eager to attend meetings or discussions about the distribution of irrigation water?" to represent villagers' dependence on agricultural resources. We select this variable to represent resource dependency for two reasons. On the one hand, irrigation water is an important resource that agricultural production depends on, but reasonable distribution of irrigation water resources needs to be negotiated through group meetings. Therefore, the more the household depends on irrigation water resources, the more they are eager to engage in irrigation affairs. On the other hand, people attending meetings around irrigation affairs will have to pay opportunity cost, i.e., they could save time to do other income-generating activities if not engage in irrigation affairs, which was confirmed in our survey. Those who are willing to forgo other revenue-generating activities and spend their time on irrigation affairs are actually more dependent on agricultural resources, for considerations such as income security and risk aversion (Cardenas et al. 2017). Based on the above two reasons, we think villagers' willingness to engage the affairs around irrigation water distribution can indirectly represent villagers' dependence on agricultural resources.

Economic heterogeneity (EH)
Based on the mechanism of "labor out-migration → economic heterogeneity → rural collective action," answers to the question "Do you think there is a big wealth (i.e., income) gap between your village's residents?" were used to represent economic heterogeneity.

Control variables
Considering the studies of Ostrom (2011), McGinnis and Ostrom (2014), Wang et al. (2016), the control variables of this study were set based on the four categories of factors known to affect collective action: community attributes, natural conditions, institutional arrangements, and household characteristics. According to Anderies and Janssen (2013), these four categories of factors can also be included in the SES framework.

Community attributes of actors
Two variables were employed to account for community attributes at the village level: the relative economic development level and the number of residents in the village who may influence the collective irrigation preference at the household level. The effect of the economy development level on collective action remains a complex and controversial issue (Su et al. 2020). On the one hand, a higher level of economic development implies that villages can provide good infrastructure to reduce the cost of residents conducting collective actions, thus promoting irrigation collective actions. On the other hand, a higher level of economic development implies that individuals can gain more benefits from the market. This makes them more likely to abandon their participation in collective actions for the pursuit of higher individual interests. This paper uses the evaluation variable ECONOMY with an integral value ranging from 1 to 3 to denote the relative economic development level. A value of 1 represents poor economic development level compared to neighboring villages, 2 represents equivalent economic development level with the neighboring villages, and 3 represents better economic development level than neighboring villages.

The effect of the number of residents in the village (POP) on collective action remains a complex and controversial issue (Poteete and Ostrom 2004). As Meinzen-Dick et al. (1997) argued, group size represents a trade-off between potential economies of scale and an increase in transaction costs. On the one hand, the larger the community, the more difficult it is to maintain institutions and rules governing local collective resources or commons because of mounting coordination costs and free rider problems associated with an increased number of participants. Because collective irrigation frequently exhibits characteristics of economies of scale, in communities and villages with large populations, collective irrigation may be increasingly preferred as it is beneficial for more individuals because of the feature of decreased unit costs. In this sense, the impact of village size on collective irrigation is uncertain and contingent upon the relative forces of mounting coordination costs and benefits obtained from economies of scale (Araral 2009).

Natural conditions
Water resource conditions were included to control for the natural conditions affecting collective irrigation arrangements. Consensus implies that collective action among resource users is unlikely unless they perceive that the resource is moderately

scarce. In the case of irrigation systems, Agrawal (2002) and Bardhan (1993) suggested that resource scarcity and collective action are related in a curvilinear manner, i.e., farmers are more willing to manage and maintain systems when water is neither extremely scarce nor extremely abundant but rather, when it is only moderately scarce. A subsequent study by Araral (2009) also showed that water scarcity exerts a curvilinear effect on collective action. For this study, a dummy variable was introduced to denote the relative water scarcity of farmland, with RESOURCE either equaling 1 for moderate water scarcity or 0 otherwise.

Institutional arrangements
The empirical literature presents rich evidence that the governance structure of an irrigation system affects the likelihood for collective action (Ostrom 1990, Araral 2009). According to the data of this survey and that presented by Wang et al. (2016), the present paper constructs two variables denoting the institutional arrangements at the village level.

The first variable is the ordered discrete variable PETITIONS, which denotes the village governance level. Values range from 1 to 5, denoting the frequency with which villages had petitions over the last three years over land circulation and water distribution, from rarely to frequently, respectively. The need for frequent petition indicates that many conflicts had to be resolved at the village or local level, which reflects governance failure in the village, which may jeopardize collective irrigation.

The second ordered discrete variable SANCTION denotes monitoring and sanctioning rules, with values ranging from 1 to 5, indicating the level of the imposition of sanctions against the private cutting of channels or the evasion of irrigation fees. A value of 1 represents very weak imposition of sanctions and a value of 5 represents very strong imposition of sanctions.

Household characteristics and regional differences
According to Wang et al. (2016), five variables were used to represent variations in household characteristics: the proportion of labor force among the total of family members (FAMILYLAB), the frequency of farmers' inability to irrigate crops in recent years (SHORTAGE), the proximity to irrigation facilities (NEAR), the age of the household head (AGE), and the education level of the household head (EDU). Moreover, provincial dummy variables were incorporated into the model to control for the impact of regional differences on the estimated results.

Instrumental variable
The proposed hypothesis on the effect of migration on collective action may suffer from an endogeneity problem. For example, if the failure of collective action could also trigger an outflow of rural labor, then baseline regression would be affected by the endogeneity problem, which is named reverse causality. This study introduced "the distance from the village to the county center" (DIS) as the instrumental variable (IV) for LMIGRATION to control the impact of endogeneity on the estimation results.

According to Wooldridge (2016), the impact of endogeneity on the estimated results can be controlled by introducing instrumental variables (IV). According to this study, an effective IV must meet three necessary conditions: (i) correlation criterion: DIS should exert a casual effect on LMIGRATION; (ii) independence criterion: DIS is uncorrelated with the variables that may affect the ICA but are not observed by us; and (iii) exclusion criterion: DIS affects the outcome variable ICA only through LMIGRATION, i.e., DIS does not directly influence ICA.

This study select DIS as the IV for LMIGRATION because it has the potential to satisfy all the above three necessary conditions for a valid IV. On the one hand, there is a correlation between DIS and labor out-migration, because DIS represents the cost of farmers' participation in non-agricultural employment, and would thus directly affect people's out-migration decisions (see Wang et al. 2016 on how this was used in a previous study). On the other hand, DIS is exogenous to factors that could affect collective action, like the weather and other natural characteristics of the village. Meanwhile, our empirical test as shown in Appendix 2, finds that DIS affects collective action solely through its impact on out-migration. The descriptive statistics of key variables are shown in Table 1.

METHODOLOGY

Ordered probit regression and IV-OPROBIT regression
Because the dependent variable is a discrete variable, the distribution of which does not meet the requirements of the OLS model, ordered probit regression was used to estimate the effect of labor out-migration on irrigation collective action (the principle of ordered probit regression is summarized in Appendix 3). As mentioned above, when estimating the effect of labor outmigration on irrigation collective action, the ordered probit regression could be influenced by endogenous problems, which results in inconsistent and biased estimates. These kinds of problems can be mitigated by using instrumental variables. Based on ordered probit regression, continuous IV-OPROBIT regression is introduced to mitigate the impact of endogenous problems with the ordinal explanatory variable (see Roodman 2011 for a discussion and application of the IV-OPROBIT principle).

Mediation effect model and structural equation model
Hypotheses H2–H6 assume that labor out-migration affects rural collective action through the following five mediating mechanisms: leadership, social capital, sense of community, resource dependence, and economic heterogeneity. Therefore, mediation effect models respond well to the proof of the mechanism effect (the principle of the mediation effect model is explained in Appendix 4).

However, only a group of simple mediation effect models may be able to handle the case of this study. When the mediation effect model is used, hypotheses H2–H6 are tested by running the model five separate times, while under the SES context, all mediating variables coexist in the SES. Therefore, labor out-migration will lead to simultaneous changes in leadership, social capital, sense of community, resource dependence, and economic heterogeneity. Ultimately, these common changes alter the effect of labor migration on rural collective action in the commons. Thus, these five mediating effects must be estimated simultaneously by using structural equation modeling (SEM) based on the mediation effect model. In addition, the employed empirical test faces the challenge of estimating the relationship between latent (or unobserved) variables, such as LS, SC, and SOC (which are latent variables in this paper). SEM is applied to estimate the relationship between latent variables.

Table 2. Estimation of total effect of migration on collective action. Robust t statistics in parentheses.

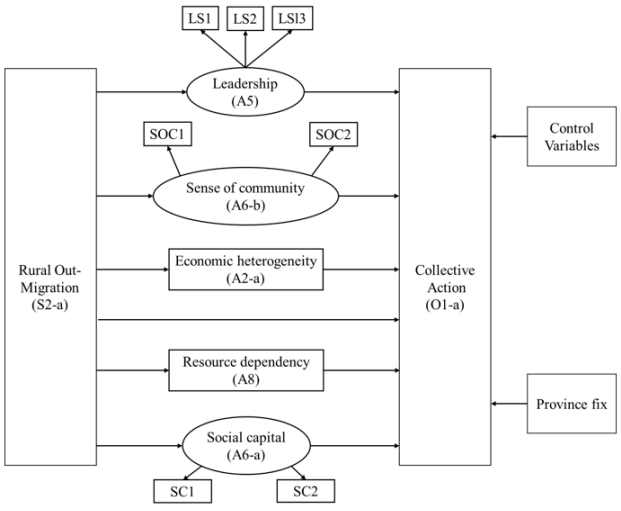
Variables	Dependent variable: ICAP				
	(1) ordered probit regression	(2) ordered probit regression	(3) ordered probit regression	(4) ordered probit regression	(5) IV-oprobit regression
LMIGRATION	-0.593***	-0.623***	-0.634***	-0.615***	-2.706***
	(-4.29)	(-4.38)	(-4.44)	(-4.26)	(0.986)
Community attributes					
ECONOMY		0.070	0.084	0.092	0.003
		(1.43)	(1.71)	(1.87)	(0.076)
POP(log)		0.137***	0.128**	0.130**	0.199***
		(3.44)	(3.21)	(3.26)	(0.053)
Natural conditions					
RESOURCE		0.043	0.029	0.034	0.086
		(0.85)	(0.57)	(0.64)	(0.052)
Institutional arrangements					
PETITIONS			-0.045*	-0.045*	-0.041
			(-2.25)	(-2.20)	(0.020)
SANCTION			-0.038	-0.027	-0.033
			(-1.51)	(-1.04)	(0.022)
Household characteristics					
FAMILYLAB(log)				-2.212	-3.03*
				(-1.33)	(1.550)
SHORTAGE				0.044	0 .060***
				(1.73)	(0.023)
NEAR				0.056	0.0001
				(1.01)	(0.064)
AGE(log)				-0.159	-0.194
				(-0.80)	(0.199)
EDU				0.024	-0.002
				(1.15)	(0 .026)
Province fix	YES	YES	YES	YES	YES
P > chi-squared	0.000	0.000	0.000	0.000	0.000
Observations	1985	1985	1985	1985	1985

* p < 0.1, ** p < 0.05, *** p < 0.01.

Figure 4 illustrates the SEM constructed in this paper. The measurement equation of SEM represents the relationship between variables and indicators. In this case, this is the relationship between village leadership (a composite of legitimacy, effectiveness, and credibility), social capital (a composite of trust, network of relationships, and reciprocity), and the sense of community (the dedication of time and money to village development).

Based on Preacher and Hayes (2004, 2008) and Bolin (2014), the bias-corrected percentile bootstrap confidence interval is used to test the estimation result of the SEM. This confirms whether certain mechanisms exist that mediate the effect of labor out-migration on collective action in the commons.

Fig. 4. Structural equation model for labor migration and collective action.

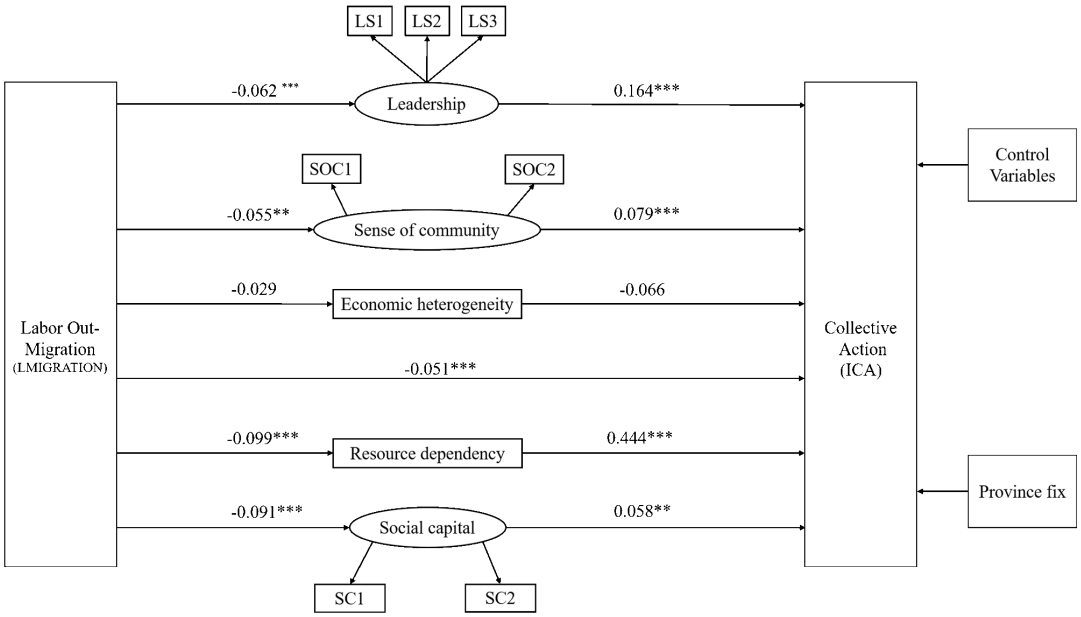


RESULTS AND DISCUSSION

Overall effect of labor out-migration

Table 2 shows the overall effect of labor out-migration on rural collective action using ordered probit regression and the CMP command in Stata 13.0. Models 1 to 5 present the baseline regression results of ordered probit regression, and Model 6

Fig. 5. Estimates of multiple mediation effects in how labor migration affects rural collective action in the commons.



Note: * p < 0.1, ** p < 0.05, *** p < 0.01.

presents the estimation results using IV-OPROBIT regression to control the impact of endogenous problem (see Appendix 2 for the test results of the instrumental variable). In all six models, the coefficients of LMAGRATION are significantly negative, indicating that labor out-migration significantly reduces irrigation collective action. These results are consistent with the core conclusion of Wang et al. (2016), indicating that labor out-migration indeed significantly reduces rural collective action, which supports H1.

Mediated effects analysis

MPLUS 7.0 is used to estimate the mediated effects. Figure 5 shows the results of mediated effects analysis. The summary of the model fit shows that the SEM yields a reasonable explanation after modification. All statistics suggest that the intrinsic quality of the model is acceptable (CMIN = 4112.887, DF = 535, P = 0.000, GFI = 0.905, RMSEA = 0.058, SRMR = 0.055). The EFA and CFA results of the latent variables in the applied SEM are shown in Appendix 1.

Figure 5 shows that first, labor out-migration significantly affects rural collective action by reducing farmers' dependence on agriculture and irrigation as sources of their livelihood. Specifically, in the mechanism "labor out-migration → resource dependence → collective action," the coefficient of the impact of labor out-migration on resource dependence is negative (-0.099), which is significant under bias-corrected bootstrapping with 99.5% CI. This indicates that labor out-migration weakens farmers' dependence on agriculture and irrigation. Furthermore, the coefficient of the impact of resource dependence on irrigation collective action is positive (0.444) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that a reduction of farmers' resource dependency would further reduce the capacity for forming effective irrigation collective action. Thus, the mediating effect of the mechanism "labor out-migration → resource dependence → collective action" is negative (-0.099 × 0.444 = -0.044) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that labor out-migration significantly affects rural collective action by reducing farmers' dependence on agriculture and irrigation as sources of livelihood. Thus, hypothesis H2 is proved.

Second, labor out-migration exerts a negative and statistically significant effect on rural collective action through its effects on village leadership. This is expected. In the mechanism "labor out-migration → leadership → collective actions," the coefficient of the impact of labor out-migration on leadership is negative (-0.062) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that labor out-migration depletes leadership talent in the village. Moreover, the coefficient of the impact of leadership on irrigation collective action is positive (0.164) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that the depletion of leadership in the village further reduces the probability of cooperation in irrigation management. Thus, the mediating effect of the mechanism "labor out-migration → leadership → collective actions" is negative (-0.062 × 0.164 = -0.010) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that labor out-migration depletes leadership talent in the village, which reduces rural collective action in the commons. Thus, hypothesis H3 is proved.

Third, labor out-migration reduces rural collective action by weakening villagers' social capital. In the mechanism of "labor out-migration → social capital → collective actions," the coefficient of the impact labor out-migration exerts on social

capital is negative (-0.091) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that labor out-migration weakens social capital among villagers. Moreover, the coefficient of the impact of social capital on irrigation collective action is positive (0.058) and significant under bias-corrected bootstrapping with 99.5% CI. This indicates that the depletion of social capital in the village will further reduce the capacity of irrigation collective action. Thus, the mediating effect of the mechanism "labor out-migration → social capital → collective actions" is negative (-0.091 × 0.058 = -0.005) and significant under bias-corrected bootstrapping with 95% CI. This indicates that labor out-migration depletes villagers' social capital, which reduces rural collective action in the commons. Thus, hypothesis H4 is proved.

Fourth, labor out-migration reduces rural collective action by eroding the sense of community among villagers. In the mechanism of "labor out-migration → sense of community → collective action," the coefficient of the impact of labor out-migration on the sense of community is negative (-0.055) and significant under bias-corrected bootstrapping 97.5% CI. This indicates that labor out-migration erodes villagers' sense of community. Moreover, the coefficient of the impact of the sense of community on irrigation collective action is positive (0.079) and significant under bias-corrected bootstrapping 99.5% CI. This indicates that the loss of sense of community will further reduce irrigation collective action. Thus, the mediating effect of the mechanism "labor out-migration → sense of community → collective actions" is negative (-0.055 × 0.079 = -0.004) and significant under bias-corrected bootstrapping 97.5% CI. This indicates that labor out-migration weakens farmers' dependence on agriculture and irrigation, reducing rural collective action in the commons. Thus, hypothesis H5 is proved. The fifth hypothesized mediator, i.e., economic heterogeneity, did not yield any statistical significance. Thus, H6 is rejected.

According to the SEM estimation results, the sum of mediation effects with which labor out-migration impacts irrigation collective action is negative (-0.044 + -0.010 + -0.005 + -0.004 = -0.063) and significant under bias-corrected bootstrapping 99.5% CI. The mediation of resource dependence accounts for 46.32% of the total effect (the most of all mediators). Thus, labor out-migration reduces rural collective action mainly by reducing the dependence of villagers on agriculture and irrigation. This result is intuitive, expected, and consistent with the literature. The mediation of leadership accounts for 16.3% of the total effect (the second strongest of all mediators). Moreover, the mediation of social capital and sense of community account for 8.93% and 7.27% respectively; therefore, their mediation effect is significant but not large compared to the mediators of resource dependence and leadership.

CONCLUSION AND IMPLICATIONS

This study makes four main contributions to the literature. First, it shows that labor out-migration exerts a negative and statistically significant (but mediated) effect on collective action in the irrigation commons. This effect is mediated by resource dependence, leadership, social capital, and the sense of community. Resource dependence and leadership contribute nearly two-thirds of the total effect. This is important because so far, how migration drives local and global environmental change is little understood. Second, this paper demonstrates the usefulness of the SES framework as a tool for studying local and global environments. In the case of this paper, it was used for decomposition analysis as an example to study "complex, multivariable, nonlinear, cross-scale, and changing" SESs (Ostrom 2007:15181). Third, in contrast to past studies, the present paper explains and tests five mechanisms for how labor out-migration affects collective action in the commons. For this, a robust set of methods is used, including VFA, ordered probit regression, SEM, IV, and interaction effects analysis. Finally, this paper uses original survey data from China, and thus presents an interesting case study for migration because of its huge scale. In China, more than 280 million people have migrated to cities in the last four decades.

Labor migration from rural areas caused by urbanization is a process almost all developing countries in the world have undergone. This process has had a huge impact on the sustainable development of rural areas in developing countries. China is the country with the largest scale of rural labor outflow in the world; therefore, the impact of labor outflow on the sustainable development of rural areas is particularly important in China. The continuous operation of irrigation systems is an important mechanism for the sustainable development of rural areas. Irrigation systems are typical common pool resources that require much collective action to maintain operability over time. Therefore, studying the effects of labor outflow on rural irrigation collective action can help to better understand the contradictions between urbanization and rural sustainable development.

The results of this study suggest that resource dependence and leadership contribute nearly two-thirds of the total effect. Better solutions should improve the farmers' dependence of agricultural resources and the leadership talent in the village. Specifically, developing countries should attach importance to promoting the development of modern agriculture in the process of urbanization, and integrate more modernization elements into the agricultural development. This can enhance the dependence of farmers on modern agricultural resources, and thereby revitalize rural collective action. Furthermore, it is necessary to cultivate leadership inside the village from both internal and external levels. Internal training includes the development of villagers' autonomous organizations, by strengthening autonomous governance to form new leadership. External injection can be reflected in that the government selects and sends outstanding talents to participate in rural construction, thus providing an external supplement to rural leadership.

Given the increasing pressures of urbanization and labor out-migration, the findings of this study have implications for the governance of food systems, land use, and water resources in particular and the commons in general. For example, in China, out-migration has left many farms and surface irrigation systems abandoned, which has significant implications for food security. Prior research identified a correlation between migration and a significant drop in groundwater tables as ageing farmers and large-scale commercial farms shift to the use of groundwater for agriculture (Wang et al. 2016). In response to the problem of abandoned farmland, in 2014, the Chinese government introduced a new policy that allows farmers to trade their land use rights. Initial studies suggested that this policy exerts positive

effects in terms of land consolidation and the emergence of a new breed of rural entrepreneurs as well as new socioeconomic dynamics in China's rural economy (Su et al. 2020).

Finally, China is highly dependent on its large agricultural SESs, and anything that affects land, water, and food security in China will have global repercussions. To satisfy the growing appetite of its 1.4 billion people, China will have to further diversify its food supply from other countries, thus putting more pressure on their land and water resources and increasing China's vulnerability to climate change (Smit and Cai 1996). Thus, research on migration and commons governance under SESs will also yield useful insights for the discussion of the migration-climate change nexus (Rogers and Xue 2015).

This study may have three limitations: First, a larger sample size would improve the robustness of the findings, and a greater accumulation of time series data would provide more convincing evidence of the causal mechanisms. Second, the effects of recent policy changes in rural China, which could counteract the effects of migration, were not investigated. Third, this study is limited to the irrigation commons and needs to be generalized to other commons such as fisheries, groundwater, or forests and grasslands, each of which has its own logic and dynamics. More research can be conducted in other contexts and for other types of commons to better understand the consequences of migration for collective action.

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/13008

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Data Availability:

The data/code that support the findings of this study are available in our research team's working cloud on internet. These data/code were derived from the following resources available in the public domain: https://pan.baidu.com/s/1BbFw1t82J1TSdJWHQShzhw Password:sess

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Appendix 1. The Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) results of the latent variables

Before we perform the SEM, we first perform EFA and CFA on the observed variables we are using to represent latent variables. These two types of factor analysis are theoretically based on ordinary factor analysis models to condense data. According to studies on a large number of related variables, the hypothetical few variables (factors and latent variables) can be used to represent the main information of the original variables (observed variables). Specifically, EFA focuses on identifying observed variables that affect the latent variables and measuring the correlation between the observed variable and latent variables. CFA aims at assessing the fit of factor models defined in advance to the actual data, to test whether the factor quantity and loads of the observed variables are consistent with expectations based on pre-established theories.

Thus, EFA and CFA tell us the extent to which the observed proxies of latent variables are good estimators—in this case, how well leadership (a latent variable) is represented by legitimacy, effectiveness, and credibility (as measured by the survey), and how well social capital (a latent variable) is represented by trust, networks and reciprocity (as measured by the survey).

Tables A4-1 and A4-2 show the results of the EFA and CFA, respectively, for each latent variable in our paper. EFA require that each latent variable's Cronbach's α should greater than 0.6, and CFA require that each variable's loading value, composite reliability, and average variance extracted are all greater than 0.5 for reliable estimation. In accordance with the EFA and CFA data test principles, we can see both EFA and CFA yield better results.

Table A4-1. Exploratory factor analysis

	LS	SC	SOC
	α = 0.775	α = 0.690	α = 0.774
LS1	0.842		
LS2	0.780		
LS3	0.624		
SC1		0.790	
SC2		0.788	
SOC1			0.820
SOC2			0.614
Variance explained	35.997%	22.357%	17.646%
KMO value		0.642	
Bartlett test significance		0.000	

Notes: 1) Extraction method: principle axis factor; 2) Rotation method: varimax with Kaiser normalization; 3) α means Cronbach's α.

Table A4-2. Confirmatory factor analysis

Latent variables	Observed variables	Indicator loading	Composite reliability	Average variance extracted
LS	LS1	0.854	0.8063	0.5841
	LS2	0.775		
	LS3	0.650		
SC	SC1	0.943	0.7972	0.6691
	SC2	0.670		
SOC	SOC1	0.720	0.6909	0.5278
	SOC2	0.733		

Appendix 2. Test results of instrumental variable

1. Test for the correlation criterion

The CMP command in STATA 13.0 was used to handle the IV-OPROBIT model. To test the validity of the instrumental variable, this paper uses the first-stage regression of 2SLS to test the correlation between the instrumental variable DIS and the core independent variable LMIGRATION. The statistical value of the F-test is 44.487, which satisfies the empirical rule that the statistical value of the first-stage F-test should exceed 10 (Wooldridge 2016). This result indicates that the instrumental variable DIS is well correlated with the core independent variable LMIGRATION and there is no weak instrumental variable problem.

2. Test for the independence criterion

To further verify whether the instrumental variable is uncorrelated with the stochastic disturbance term, after the estimation results of IV-Oprobit are output, the DIS is used to carry out regression on the residual predicted value of model (5). The result in Fig. A3-1 shows that the regression fitting values are all close to horizontal lines, indicating that DIS is almost uncorrelated with the stochastic disturbance term. Therefore, the authors believe that the selected instrumental variable is reasonable.

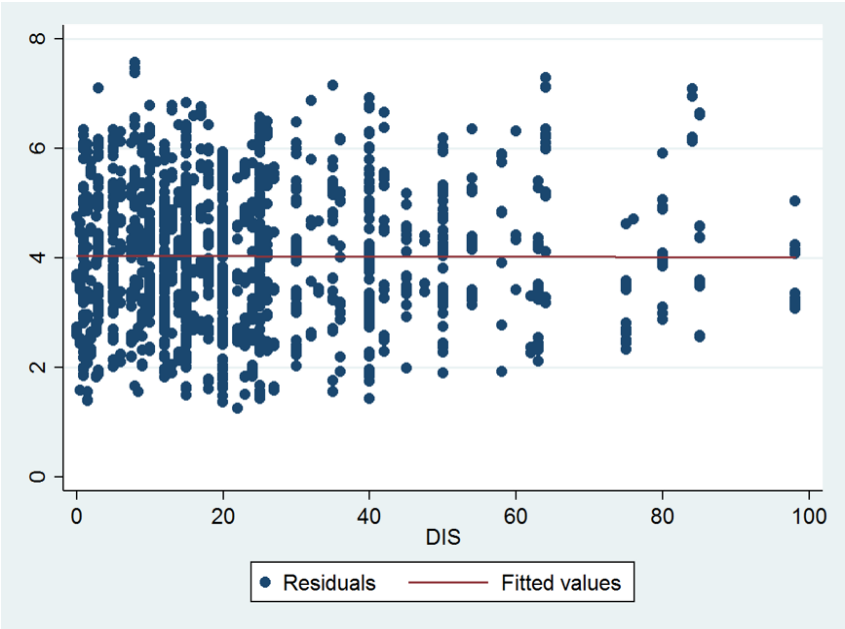


Fig. A3-1 Test results of the correlation between instrumental variable and error terms

3. Test for the exclusion criterion

Theoretically, "the distance from the village to the county center" (DIS) belongs to the geographical distance variable, which will not change with changes of time, space, economy, and society over time. Thus, the authors assumed that there is no evidence that the geographical distance and dependent variable "the frequency of farmers' participation in the construction and repair of irrigation facilities" (ICA) are directly related.

According to existing literature, the distance between village and county center does not constitute a reasonable factor affecting farmers' participation in irrigation collective action. For example, while it has been shown that collective action on irrigation is better organized in areas close to market centers (Wang et al. 2021), other scholars showed that irrigation collective action can also be successful in mountainous areas far from the county center (Chai and Zeng. 2018).

From the sample selected in this paper, as shown in Fig. A3-2, if DIS is divided into five sections of 0-20 km, 20-30 km, 40-60 km, 60-80 km, and above 80 km, there is no significant difference in the degree of farmers participating in irrigation collective action in each section. This implies that there is no case where a certain degree of participation is concentrated in a certain distance section. Therefore, there is no significant evidence for a direct correlation between DIS and ICA.

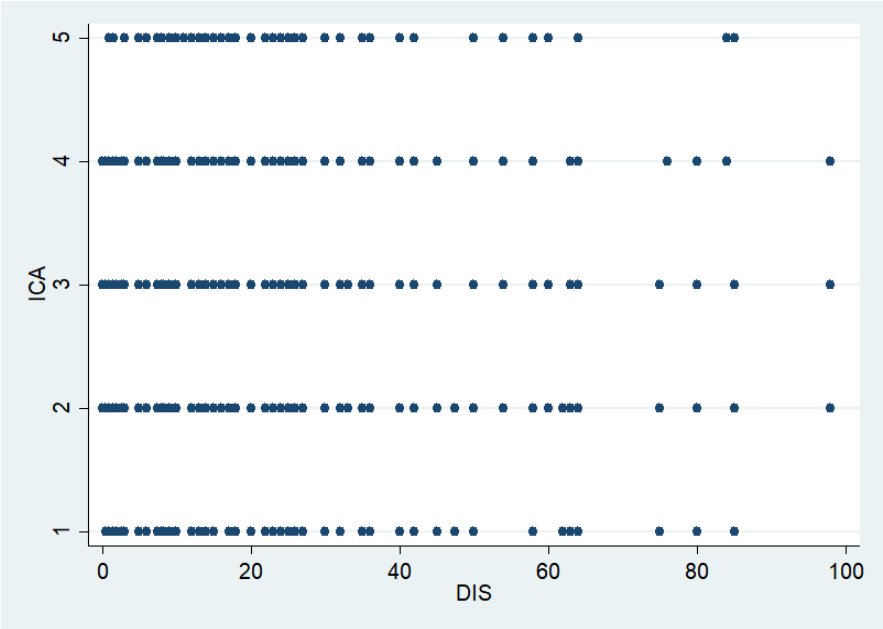
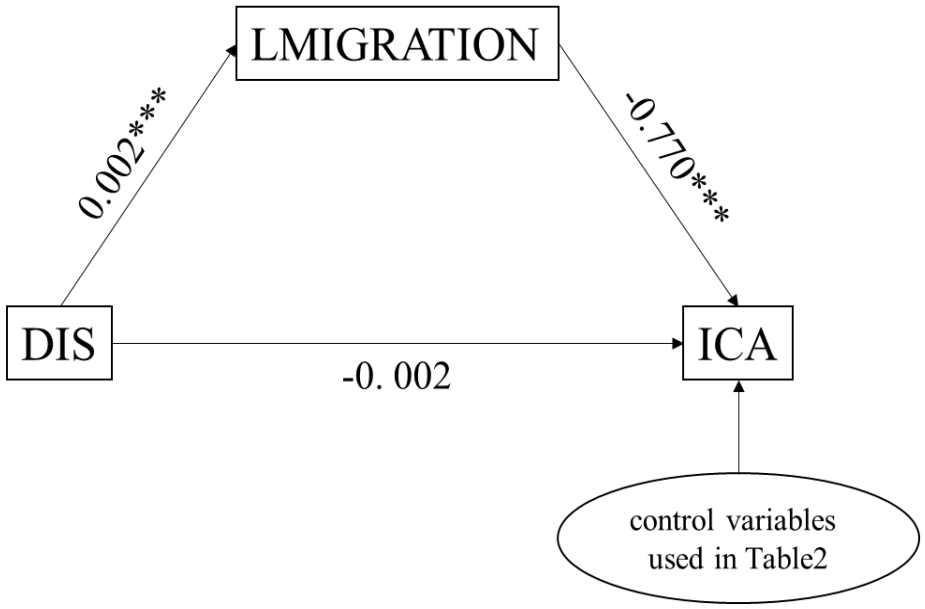


Fig. A3-2 Correlation test between instrumental variable and independent variable

Finally, From the perspective of empirical testing, the mediating effect model (see in Appendix 2) can also be used to verify whether the DIS affects ICA solely through its impact on LMIGRATION (based on the utilized samples). With ICA as dependent variable, DIS as independent variable, and LMIGRATION as mediating variable, a mediating effect model is constructed as shown in Fig. A3-3. This figure also reports the estimated results. The estimated results of the correlation between DIS, LMIGRATION, and ICA show that the direct effect of DIS on ICA is not significant, indicating that no evidence has been found that DIS directly affects ICA. The impact of DIS on LMIGRATION and the impact of LMIGRATION on ICA are statistically significant, indicating that DIS will impact ICA through LMIGRATION. Such a result is called a complete mediation effect in the estimation of the mediation effect model, namely, DIS only affects the outcome variable ICA through LMIGRATION.



* p < 0.1, ** p < 0.05, *** p < 0.01

Fig. A3-3 The distance from the village to the county center (DIS) only affects the outcome variable irrigation collective action (ICA) through LMIGRATION.

4. Test summary

Based on the above discussion, the authors believe that the instrumental variable selected in this paper meets all requirements of a reasonable instrumental variable.

Appendix 3. The principle of Ordered Probit Regression

Due to our dependent variable is a discrete variable in order, and its distribution does not meet the requirements of the OLS model. Therefore, we use ordered probit regression to estimate the coefficient β1 and thus the total effect.

Assuming $y^* = \mathbf{x}'\boldsymbol{\beta} + \varepsilon$ (y^* is an unobservable variable), the selection rule is given by:

$$y = \begin{cases} 0, & y^* \le r_0 \\ 1, & r_0 \le y^* \le r_1 \\ 2, & r_1 \le y^* \le r_2 \\ \cdots\cdots\cdots\cdots & \\ J, & r_{J-1} \le y^*_2 \end{cases}$$

where $r_0 < r_1 < r_2 < \cdots < r_{J-1}$ are the parameters to be estimated, and are called "cutoff points .

Assuming $\varepsilon \square N(0,1)$ (normalize the variance of the perturbation term ε to 1), we have:

$$\begin{aligned} \mathrm{P}(y=0 \mid x) &= \mathrm{P}\left(y^* \le r_0 \mid x\right) = \mathrm{P}\left(\mathbf{x}'\boldsymbol{\beta} + \varepsilon \le r_0 \mid x\right) \\ &= \mathrm{P}\left(\varepsilon \le r_0 - \mathbf{x}'\boldsymbol{\beta} \mid x\right) = \Phi\left(r_0 - \mathbf{x}'\boldsymbol{\beta}\right) \\ \mathrm{P}(y=1 \mid x) &= \mathrm{P}\left(r_0 \le y^* \le r_1 \mid x\right) = \mathrm{P}\left(y^* \le r_1 \mid x\right) - \mathrm{P}\left(y^* < r_0 \mid x\right) \\ &= \mathrm{P}\left(\mathbf{x}'\boldsymbol{\beta} + \varepsilon \le r_1 \mid x\right) - \Phi\left(r_0 - \mathbf{x}'\boldsymbol{\beta}\right) \\ &= \mathrm{P}\left(\varepsilon \le r_1 - \mathbf{x}'\boldsymbol{\beta} \mid x\right) - \Phi\left(r_0 - \mathbf{x}'\boldsymbol{\beta}\right) \\ &= \Phi\left(r_1 - \mathbf{x}'\boldsymbol{\beta}\right) - \Phi\left(r_0 - \mathbf{x}'\boldsymbol{\beta}\right) \\ \mathrm{P}(y=2 \mid x) &= \Phi\left(r_2 - \mathbf{x}'\boldsymbol{\beta}\right) - \Phi\left(r_1 - \mathbf{x}'\boldsymbol{\beta}\right) \\ &\cdots\cdots\cdots\cdots \\ \mathrm{P}(y=J \mid x) &= 1 - \Phi\left(r_{J-1} - \mathbf{x}'\boldsymbol{\beta}\right) \end{aligned}$$

In this way, the sample likelihood function is obtained to further obtain the MLE estimator, i.e. the ordered probit model.

Appendix 4. The principle of mediation effect model

We hypothesize that labor out-migration affects rural collective action through five mediating mechanisms: leadership, social capital, sense of community, resource dependence, and economic heterogeneity. Following Baron and Kenny (1986), we use the following econometric model:

$$ICA = \beta_0 + \beta_1 MIGRATION + \sum_k \theta_k X_k + \varepsilon \quad (1)$$

$$M = a_0 + a_1 MIGRATION + \mu \quad (2)$$

$$ICA = c_0 + c_1 MIGRATION + b_1 M + \sum_k \lambda_k X_k + \eta \quad (3)$$

$$ICA = c_0 + b_1 a_0 + c_1 MIGRATION + (a_1 b_1) MIGRATION + \sum_k \lambda_k X_k + b_1 \mu + \eta \quad (4)$$

In Equations (1), (3), and (4), ICA is the propensity for rural collective action; MIGRATION is the proportion of migrant workers in the village's population; M_i is the set of mediating variables (leadership, social capital, sense of community, resource dependence, and economic heterogeneity); and X_i are the control variables. Equation (1) gives the total effect of labor out-migration on rural collective action, with magnitude β_1. Equations (2) and (3) show how the effect of labor out-migration is mediated by other variables; the coefficient a_1 measures the effect of labor out-migration on the mediator, and b_1 measures the effect of the mediator on rural collective action. Substituting Equation (2) into Equation (3) gives Equation (4), where c_1 measures the direct effect of labor out-migration on rural collective action, and $a_1 b_1$ measures how much labor out-migration affects rural collective action through the mediating mechanisms.