



Research

Changing collaborative networks and transitions in rural sustainable development: qualitative lessons from three villages in China

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ABSTRACT. Promoting rural sustainable development requires improving rural systems' self-organization to reduce dependence on external resources, which is inherently difficult in peasant economies due to low rural household income. Bottom-up collective action can help address these issues. However, few studies have examined how networks of elite and non-elite actors influence collective action and system transitions toward sustainability. This study scrutinizes the changing structures of collaborative networks in three Chinese villages through analysis of elite and non-elite actor groups and their relationships. We also examine the key elements that influence system transitions at every phase of rural sustainable development. The three case studies demonstrate that (1) elites play a vital role in the formation of collaborative networks and facilitate actor awareness; (2) spatial relationships are as essential as institutional design for successful collective action in response to sustainable development problems; (3) highly centralized collaborative networks help to improve the efficiency of the reorganization, renewal, and innovation of the village system, but the collective action outcome depends on the leadership and spatial relationships of the central actors; and (4) social memory and human capital are the most important system elements needed to exploit technology-driven windows of opportunity and achieve strong sustainability. These results provide important insights for enhancing rural systems' capacity to self-organize and capturing windows of opportunity to achieve sustainable development.

Key Words: *collective action; environmental governance; structural characteristics; sustainability transitions; system elements*

INTRODUCTION

Promoting rural sustainable development is an important step toward human sustainability as it is inextricably linked to multiple issues such as energy, health, education, water, food, gender, and economic growth (United Nations 2021). Over the last few decades, international organizations and national governments have strengthened their commitment and investment to alleviate poverty, stimulate economic growth, create social cohesion, conserve the environment, and counter climate change (World Bank 2020). In order to achieve these development outcomes, their strategies have gradually shifted from centralized and top-down to decentralized, incremental, and bottom-up community-driven approaches (Mason and Beard 2008). An increasing focus is being placed on rural systems' capacity to self-organize to reduce their dependence on external development. Reducing the dependence of rural development on external resources is inherently difficult partially because peasant economies and smallholder agriculture yield lower household income (Douwe van der Ploeg 2016). In the face of such challenges, understanding what factors influence collective action for rural development is important.

Local collective action has been recognized as conducive and often necessary for economic growth, market participation, and local governance (D'Exelle et al. 2018). Yet, this is not enough. To sustain rural development, local collective action needs to address developmental contradictions, including conflicts between growth and equity, economic growth and environmental conservation, and decentralized decision making and equitable outcomes (Li et al. 2021, 2023). There is less evidence related to how collective action influences the organization of actors and

system elements in response to these sustainable development problems. Exploring the dynamic interplay between human and natural systems can help address these conflicts (Fu et al. 2022). A useful theoretical perspective in this regard is the "collaborative network," which includes a variety of interconnected, largely autonomous, and heterogeneous entities (e.g., organizations and people) collaborating to co-manage various resources and better achieve compatible or common goals (Camarinha-Matos and Afsarmanesh 2005, Ben Yahia et al. 2021, Mariño and Rozenblat 2022). The collaborative network lens leads to questions about (1) who the actors are, (2) what system elements they influence, and (3) how the structures of collaborative networks relate to the effectiveness of organizing actors and elements to achieve rural sustainable development.

Achieving sustainable development may also require taking advantage of "windows of opportunity," tipping points in the process of rural sustainable development capable of fostering social-ecological system transition (Sullivan et al. 2019). Although windows of opportunity open in many ways, they are categorized into two types: problem driven and policy driven (Kingdon 1995, Folke et al. 2005). It has been proposed that the capacity of utilizing windows of opportunity to transform a social-ecological system draws on agency and structures from multiple levels, recombining sources of experience and knowledge (Olsson et al. 2004, Folke et al. 2010, Herrfahrdt-Pähle et al. 2020). Based on previous research, flexible, heterogeneous, polycentric, and cross-scale structures of social coordination and informal social networks that are based on social capital are more likely to allow for learning and innovation to respond to and shape change (Folke et al. 2005, Hirschi 2010, Di Gregorio et al. 2019, Chen et

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al. 2022; M. Lee 2011, *unpublished manuscript*). Building on this theoretical background, this study further investigates the structure of collaborative networks with a new framework analyzing the role and relationships of elite and non-elite actor groups. System elements critical to exploiting windows of opportunity to support rural sustainable development will also be examined in this study.

Our conceptual framework for analyzing the three case studies in rural China concentrates on capturing (1) how the structure of collaborative networks influences the ability of actors to leverage windows of opportunity to transition toward more sustainable development and (2) the key system elements that prepare rural systems for the transition toward sustainability. We begin by identifying phases of rural sustainable development in three case-study villages based on the three pillars of sustainability: environmental, social, and economic. Then, we scrutinize the structure of collaborative networks by studying the role of elite and non-elite actor groups and highlight four collaborative network characteristics—the degree of network cohesiveness, degree of network centralization, degree of network fragmentation, and degree of connectivity across different types of actors (Bodin 2017). Finally, we compare the changing structure of collaborative networks and the key system elements that are influential in the three villages to explore potential reasons for system stasis or transitions toward sustainable development.

CONCEPTUAL FRAMEWORK

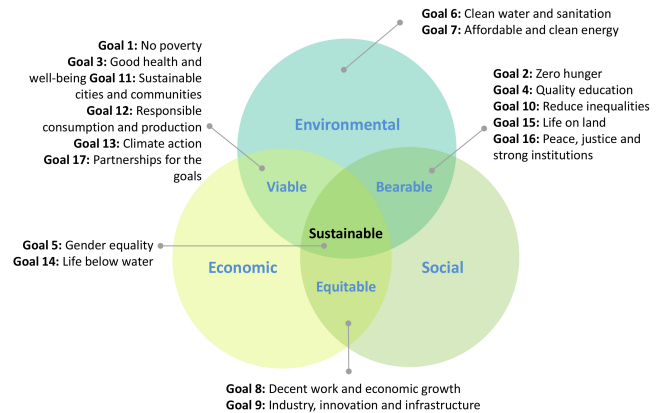
Rural systems can be viewed as coupled social-ecological systems composed of actors and resources. Their development is rooted in human–natural interactions as well as external driving forces (Zang et al. 2021). In this study, we develop a novel framework to capture desirable actor networks and internal/external elements that facilitate the transition to rural sustainability.

Rural Sustainable Development

Sustainability is an integrative, multifaceted concept with myriad interpretations and context-specific understanding, but many models begin with the three pillars of economy, society, and environment (Purvis et al. 2019). Economic sustainability implies a system of production that satisfies present consumption levels without compromising future needs; social sustainability is the ability of society, or any social system, to persistently achieve good social well-being; environmental sustainability entails maintaining natural capital as both a provider of economic inputs (sources) and an absorber of economic outputs (wastes) (Basiago 1998). This tripartite paradigm serves as the conceptual foundation for a large portion of existing sustainability models (Moldan et al. 2012, Schoolman et al. 2012, Asche et al. 2018, Clune and Zehnder 2018, Dalampira and Nastis 2020, Fu et al. 2022).

The 2030 Agenda for Sustainable Development (United Nations 2015) includes 17 Sustainable Development Goals (SDGs) that provide explicit goals tied to the three pillars of sustainability. These SDGs guide real-world decisions at the global, national, and even individual consumer levels (Li et al. 2021). These interrelated SDGs can be re-mapped to the three intersecting pillars of sustainability following Dalampira and Nastis (2020) (see Fig. 1). We employ the three-pillar framework to qualitatively identify the phases of rural sustainable development in the three

Fig. 1. Seventeen SDGs mapped to the three-pillar framework of sustainability (Dalampira and Nastis 2020).



case studies with the 17 SDGs serving as indicators. Specifically, leveraging qualitative analysis of interviews and other available materials, three experts involved in the survey evaluate the specific targets associated with each SDG outlined by the United Nations. The achievement of all targets within a SDG indicates its successful accomplishment. Furthermore, the attainment of all goals within a particular pillar signifies the achievement of that pillar of sustainable development.

We assume that the relationship between the three pillars of sustainability remains unchanged in a stable developmental phase of a rural system. Thus, the transition of the system to meeting more of these pillars represents the rural system moving from one phase to another that is more sustainable overall. Based on this assumption, we simplify the process of sustainable development into three phases: weak sustainability, moderate sustainability, and strong sustainability. We define weak sustainability as the lack of all three pillars of sustainable development, moderate sustainability as the presence of only two of the three pillars of sustainable development (environmentally viable and bearable, economically equitable and viable, and socially equitable and bearable), and strong sustainability as the presence of all three pillars of sustainable development (true sustainability).

Framework Layer 1: Internal and External System Elements that Shape Rural Sustainable Development

Many rural studies have established systematic models for rural development, indicating components, factors or elements of a rural development system (Lakshmanan 1982, Terluin 2003, Sachs 2005, Ploeg and Marsden 2008, Li et al. 2019). However, many of these models are based on regional economics and focus on elements of urban and rural markets. Our conceptual framework, therefore, integrates elements derived from regional economic research with social elements that are commonly discussed in the governance literature on social-ecological system resilience. In this study, we identify the elements that actors use to capture and exploit windows of opportunity and assist rural sustainable development. We group these elements into two categories: internal elements and external linkages (Table 1).

Table 1. Internal elements and external linkages identified as important for rural sustainable development.

Element	Description	Effect on collective action and rural sustainable development	References
Internal element			
Geographical location	Absolute geographical location that entails climate, topographic features, etc.; relative geographical location that entails access to markets	Affects the formation of collective action and collaborative networks, and the flow of labor, money, technology and information	(Li et al. 2019, Qin et al. 2020, Li and Gong 2022)
Natural capital	The elements of nature that directly or indirectly produce value to people, including landscape, natural resources, environmental stability	Actors exploit and maintain natural capital simultaneously to achieve sustainable development	(Ekins et al. 2003, Burdon et al. 2022)
Physical capital	Tangible assets such as roads, irrigation systems, schools	Overcoming collective-action problems needs sufficient investment in physical capital; conversely, unequal distribution of the ownership of physical capital causes growth-equity conflicts that directly undermine sustainability	(Ostrom and Ahn 2007)
Human capital	Assets like education, intelligence, and personal skills	A property of local actors that directly affects the outcome of collective action	(Ostrom and Ahn 2007)
Social capital	Socially accessed resources, or goods acquired through networks; social trust and civic norms	Enhances outcome of collective action through trustworthiness, networks, and formal and informal rules or institutions	(Ostrom and Ahn 2007)
Social memory	The arena in which captured experiences with change and successful adaptations, embedded in a deeper level of values, is actualized through community debate and decision-making processes into appropriate strategies for dealing with ongoing change	Enhances the capacity of social-ecological systems to adapt to change	(Folke et al. 2005)
External linkage			
Institutional arrangements	Policies, systems, and processes that are used to legislate, plan and manage activities efficiently	Robust institutional arrangement guides equitable resource allocation	(Ayana et al. 2017)
Macroeconomic environment	The broader condition of an economy as opposed to specific markets	A stable macro-economic environment supports the stability of market demand and supply that fosters sustainable development	(Li et al. 2019)
Planning frameworks	Translated into land use and building regulations	Affects peoples' rights to use their land and guides future development	(Lakshmanan 1982)
Government policies	Prescriptive regulation or incentive-based policies	Supplies local actors with publicly available materials and timely financial or project support	(Li et al. 2019)

Internal elements define the “inside” of the system and the last “environment” of the system (Lakshmanan 1982). Geographical location is a fundamental element that shapes many other aspects of the rural system through its impact on transportation as well as the flow of labor, money, technology, and information (Li et al. 2019, Qin et al. 2020, Li and Gong 2022). Simultaneously, geographical space can be linked to conflict and cooperation among geographically dispersed actors, as well as the formation of a cross-boundary collaborative network (Sullivan et al. 2017). Capital in various forms underpins collective action and rural development. Natural capital provides raw materials for production as well as climate and ecosystem stability for life-support activities (Burdon et al. 2022). It is critical for actors to maintain natural capital in order to achieve environmental sustainability (Ekins et al. 2003). Physical capital is one of the three components of production that contribute to the rural economy’s growth. Unequal distribution of physical capital ownership leads to growth-equity conflicts, which directly undermine sustainability (Lakshmanan 1982). Local actors’ human capital includes assets such as education, intelligence, and talents, all of which have a significant impact on the outcome of collective action. Social capital may be the most widely explored factor associated with collective action. It contributes to successful collective action by enhancing trust among the actors (Ostrom and Ahn 2007). Social memory, as a part of cultural capital, is vital for linking past experiences with present and future policies, as it captures a diversity of experiences concerning management practices and rules in response to change at the collective level (Folke et al. 2005).

External linkages shape the interaction between rural systems and the larger economic, social, and ecological settings. Robust institutional arrangements can be nested in local practices to help resource users share rewards equitably and effectively over long periods (Ayana et al. 2017). A stable macro-economic environment ensures the relative stability of market demand and supply, both of which are important for economic and social sustainability (Li et al. 2019). As development strategies and practices at the micro level are mostly determined by the national or regional policy framework, larger-scale planning frameworks and government policy should be regarded as external elements.

Framework Layer 2: Processes within Collaborative Networks that Shape Rural Sustainable Development

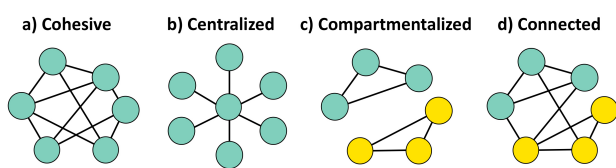
The constellation of actors and their interactions within windows of opportunity are critical to achieving a successful transition to rural sustainable development. Either when decision makers recognize the urgency of the problems confronting village systems and seek change and policy support, or when decision makers adjust the management and planning of village systems in response to a new government policy, they are better prepared to act during windows of opportunity. We investigate the structure of collaborative networks within windows of opportunity to explore who the actors are and the impact of their connections on collective action for rural sustainable development.

Previous collaborative network literature provides many approaches to depicting and quantifying collaborative network structure (Bouma and Jones 2001, Eschenbacher et al. 2009, Rabelo et al. 2015, Bodin 2017, Bodin et al. 2017, Plummer et al.

2017, Chatfield and Reddick 2018). Among them, one widely accepted strategy is to break a collaborative network into closed or open building blocks, which may then be quantified by the degree of cohesion, centralization, fragmentation, and connectivity (Bodin et al. 2016).

The degree of cohesion refers to the density of relations among all actors. A cohesive collaborative network has a high degree of cohesion as its greatest distinguishing feature with no prominent central actor (see Fig. 2). The degree of centralization relates to how much one or a few actors act as hubs. A centralized collaborative network may have prominent central actors as its major distinguishing feature. The degree of fragmentation refers to whether and to what extent the network is divided into separate subgroups with homogeneous actors. A compartmentalized collaborative network has a significant degree of fragmentation as its major distinguishing feature. The degree of connectivity refers to the density of relations between actors across distinct subgroups based on the presence of compartmentalization. A connected collaborative network has a high degree of connectivity as its greatest distinguishing feature.

Fig. 2. Structural characteristics of collaborative networks. Note: The colors of nodes symbolize actors with different social attributes, and the lines connecting nodes depict social ties.

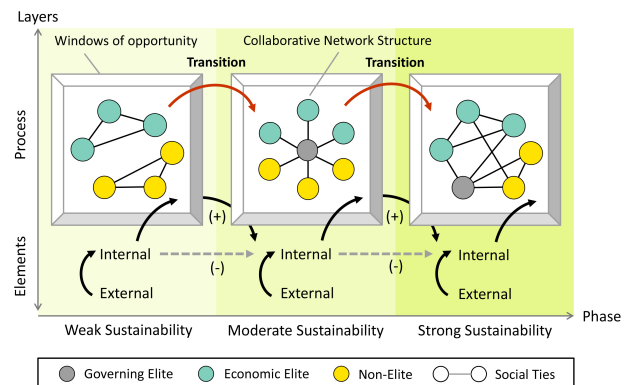


Research has demonstrated that these four collaborative network characteristics are closely related to the capacity of collaborative learning, cooperation, and problem solving (Berardo 2014, Barnes et al. 2016, Lubell et al. 2016). Here, we expand this research by exploring how these four collaborative network characteristics link to sustainable development in the context of rural systems. In particular, elite groups, or groups of actors with disproportionate resources or connections within a network, merit further investigation in rural sustainable development (Olson 1965, Li et al. 2019, Qin et al. 2020). It is unclear how elite actors' diverse identities and roles in the collaborative network affect collective action outcomes in the context of pursuing sustainable development. Thus, to better understand the structure of a collaborative network, we distinguish (1) the governing elite, with political power useful for exerting authoritative power on other actors to comply; (2) the economic elite, with economic power useful for shaping resources; and (3) the non-elite.

The governing elite is defined as village leaders with political power and direct responsibility for village development strategies. An economic elite within a rural community is defined as a resident who specializes in a particular type of agricultural production or has access to a mature business network. Both types of elites enjoy a position of power and are influential in economic and political activities. Although individuals may present as both types of elites at the same time, we classify actors exercising authority in an administrative role as governing elites.

As shown in Fig. 3, we present a conceptual framework that integrates the phase of rural sustainable development (weak, moderate, and strong sustainability) with two layers of rural systems (internal/external system elements and processes). We hypothesize that (1) different collaborative network structures affect the capacity to capture and exploit windows of opportunity to promote rural sustainable development, (2) some elements are more significant in distinct phases of rural sustainable development, and (3) if the system fails to transition during the window of opportunity, negative feedback on system elements may result. Our framework allows us to understand human–nature feedbacks by analyzing actors within collaborative networks and understanding which system elements are catalyzing system transitions during the phases of rural sustainable development.

Fig. 3. Rural sustainable development as a multi-phase and double-level process.

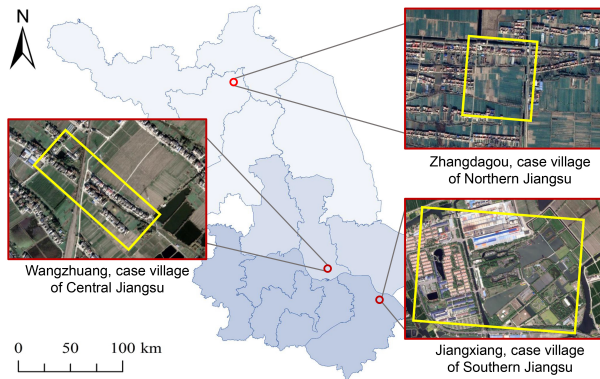


METHODS

Selection of Case Studies

Jiangsu Province is a developed coastal area in eastern China. China began market economy reforms and an opening-up policy in 1978, allowing foreign investors to enter the Chinese market, gradually establishing market-based institutions and systems and stimulating development in all major sectors, including manufacturing, international trade, and transportation infrastructure. Since then, Jiangsu Province's economic development has progressed from poverty to wealth, from agricultural dominance to industrial dominance, and from domestic orientation to export orientation, exemplifying China's development. However, the rural–urban divide and within-rural inequality remain prominent in Jiangsu Province. Southern, central, and northern Jiangsu have distinct cultures and economies. Southern Jiangsu rural residents' per capita disposable income in 2021 (37,430 CNY) was 1.33 and 1.61 times that of central Jiangsu (28,165 CNY) and northern Jiangsu (23,204 CNY), respectively. Meanwhile, despite its rapid industrialization, southern Jiangsu faces challenges of sustainable development, such as the degradation of natural resources. These distinct regions and challenges make it an ideal place for a comparative analysis of rural sustainable development.

Fig. 4. Case-study villages in Jiangsu Province.



Field surveys and semi-structured interviews were carried out in the southern, central, and northern Jiangsu Province. We select three representative villages in each region—Jiangxiang, Wangzhuang, Zhangdagou—as case villages for analysis (see Fig. 4). An overview of case villages can be found in Append. 1.

Qualitative Data and Analysis Methods

Semi-structured interviews were conducted to elicit a comprehensive and in-depth understanding of the three case villages in this study. Detailed qualitative data were collected for analytical interpretation. All procedures performed in this study were in accordance with the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study.

In each village, we interviewed one governing elite (the standing member of the local Communist Party), two economic elites (e.g., new professional farmers and self-employed business owners that governing elites and villagers held in high regard and whose income was in the top 5% of the village), and 11 randomly selected non-elite farmers. Given Jiangxiang village's relatively advanced industrial development, we additionally included an economic elite respondent in this village to ensure a comprehensive understanding of the collaborative network. In total, our research involved 43 interviews, with 15 interviews conducted in Jiangxiang, and 14 interviews each in Wangzhuang and Zhangdagou. The interviews consisted of four sections: (1) village development history; (2) local collective actions for development; (3) various groups' roles and relationships in collaborative networks; and (4) key progress and obstacles toward sustainability. We conducted the semi-structured interviews mainly in Mandarin. In some cases, we sought local translators to conduct the interview in local dialects. We emphasized to respondents that participation was voluntary and that efforts would be made to keep data confidential and anonymized.

We embedded network maps, an important tool of qualitative network analysis, in our semi-structured interviews. This approach has been widely used in previous research and has demonstrated its efficacy in capturing both formal and informal networks (Ahrens 2018). Initially, respondents were provided with a sheet of paper and encouraged to create unstructured maps using drawings in response to specific questions. For instance, they were prompted to illustrate the interactions among individuals contributing to the

development of the village. Following this, they received another sheet of paper featuring a limited number of concentric circles to develop structured network maps. These circles included predefined categories such as governing elites, economic elites, and general villagers, with distinct fillings representing actors from agricultural, industrial, and service industries. As a result, the network maps created by different individuals were highly comparable. Additionally, the mapping process allowed the authors to engage in discussions with respondents, facilitating the generation of narratives concerning the collaborative networks within the village. These narratives could then be further analyzed using narrative network analysis. Ultimately, the network maps were merged as a visualized output following two steps: (1) examining the maps of each respondent to assess the mentioned contacts within different categories, such as identity and industry, and verifying their alignment with the village context; (2) comparing the network maps across respondents to identify prominent actors present in all maps, as well as those who appeared infrequently, and to identify any unexpected gaps that necessitated further analysis through interview narratives. The structure of the visualized networks could be further examined by assessing their degree of cohesion, centralization, fragmentation, and connectivity.

Given the impossibility of conducting interviews with all elites and non-elite farmers involved in the village's production network, it is inevitable that our survey may be susceptible to potential sampling biases. To mitigate such errors, we employed a mixed sampling approach, randomly selecting households and interviewing villagers until the desired sample size was achieved (Ferlie et al. 2017, Kirchherr and Charles 2018). The objective of our qualitative study was to obtain a sufficiently large sample size to capture diverse perspectives. In our specific cases, we observed data saturation with a respondent count of 14. Up to that point, individuals who appear to be "bridge nodes," i.e., those who demonstrated substantial interconnections with others within the collaborative network, had been nominated by other respondents included in the sample. Adhering to these criteria for determining our sample size serves to enhance the validity of our research findings.

In addition to the primary data obtained from the interviews, we took field observation notes during the surveys. The outcome of field surveys is mainly presented in Append. 1, an overview of case villages. Our primary focus revolved around an in-depth analysis of the collective economy and the developmental history of the three case villages. We also collected secondary data, including (1) materials obtained directly from village committees, such as historical records, village profile brochures and maps, activity reports, and management regulations; and (2) public data such as media reports from different periods.

Our research employs two data analysis methods tailored to the content and type of data. Firstly, a qualitative, thematic analysis approach was used to examine the semi-structured interview data, field observation notes, and relevant documents and secondary data. This method facilitated the identification of developmental phases within the village under study. Secondly, we employed narrative network analyses using the semi-structured interview data, enabling us to identify the key actors and their respective roles and visualize the collaborative networks. To ensure systematic and organized analysis, all qualitative coding

Table 2. Economic, social, and environmental dimensions in every developmental phase of Jiangxiang, Wangzhuang, and Zhangdagou correspondent to SDGs.

	Jiangxiang			Wangzhuang		Zhangdagou
	Weak sustainability (1968~1983)	Moderate sustainability (1983~2008)	Strong sustainability (2008~)	Weak sustainability (1978~2000)	Moderate sustainability (2000~)	Weak sustainability (1980~)
Sustainable						
Goal 5: Gender equality	×	√	√	×	√	√
Goal 14: Life below water	×	×	√	×	×	×
Economical and environmentally viable						
Goal 1: No poverty	×	×	√	×	√	√
Goal 3: Good health and well-being	×	√	√	×	√	√
Goal 11: Sustainable cities and communities	×	√	√	×	√	×
Goal 12: Responsible consumption and production	×	×	√	×	×	×
Goal 13: Climate action	×	×	×	×	×	×
Goal 17: Partnerships for the goals	√	√	√	×	√	×
Environmentally and socially bearable						
Goal 2: Zero hunger	√	√	√	×	√	√
Goal 4: Quality education	×	×	√	×	√	√
Goal 10: Reduce inequalities	×	√	√	×	√	×
Goal 15: Life on land	×	×	√	×	√	×
Goal 16: Peace, justice and strong institutions	√	√	√	×	√	×
Socially and economically equitable						
Goal 8: Decent work and economic growth	×	√	√	×	√	×
Goal 9: Industry, innovation and infrastructure	×	√	√	×	×	×
Environmental						
Goal 6: Clean water and sanitation	×	√	√	×	√	√
Goal 7: Affordable and clean energy	×	√	√	×	√	√

Note: √ means achieving the sustainable goal; × means not achieving the sustainable goal.

procedures were conducted using NVivo. All of the materials were reviewed and transcribed into textual data. We created a codebook to discover the actors, connections, and development that emerged from the data. These coding results enable us to craft the collaborative networks and support the findings.

RESULTS

Phases of Development and Structures of Collaborative Network in Three Villages

Jiangxiang

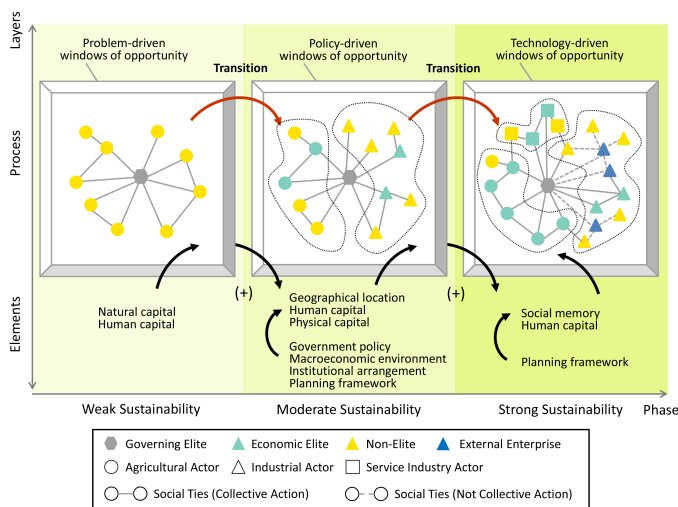
We identify Jiangxiang from 1968 until 1983 as in a phase of weak sustainability, mainly due to its extreme poverty, prominence of disease, and poor sanitation. The economic and environmental state of Jiangxiang village has greatly improved since 1983 as a result of a number of measures. Around 1983, Jiangxiang saw a shift from agriculture to industry, and more villagers were able to secure basic housing and sanitation. However, the industrial development in Jiangxiang resulted in air, water, and soil pollution. Thus, we classify Jiangxiang as being in a state of moderate sustainability from 1983 to 2008. Since 2008, Jiangxiang has steadily achieved multifunctional and balanced economic, social, and environmental development through an innovative collective economic model, and thus, we consider it to be in a phase of strong sustainability post-2008. An extensive analysis of economic, social, and environmental states in Jiangxiang corresponding to 17 SDGs can be found in Table 2. We provide further details about Jiangxiang's three sustainability states and system elements and network structures that drive the transition in Append. 2.

Collaborative networks in Jiangxiang at each phase showed the structural characteristics of high centralization, fragmentation, and connectivity (see Fig. 5). Our case-study results reveal that, despite changing social, economic, and ecological environments and diverse collective action goals, Jiangxiang's collaborative networks are always highly concentrated. In most networks, governing elites served as the central actor. Given their significant influence on collective decision making, their leadership and judgment are closely related to the outcomes. Jiangxiang's industrial development has become more diverse. When actors in collaborative networks are separated into groups based on their social attributes, such as the industry in which they engage, the collaborative network appears highly compartmentalized. However, in Jiangxiang, groups of actors with varying social and economic characteristics are highly connected due to the village committee, led by the standing member of the local Communist Party (a working studio led by the governing elite, the standing member of the local Communist Party, to serve villagers and external enterprises in the village and industrial innovation), and public meetings that allow villagers to socialize. For instance, in the village collective and farmer cooperative, actors of different occupations may act together during decision making.

Wangzhuang

From 1978 to 2000, Wangzhuang village had not yet addressed extreme poverty, and residents were living in inadequate housing. As a result, we define this period as one of weak sustainability. Since 2000, Wangzhuang has seen a significant transition in industry and community infrastructure, becoming economically viable (moderately sustainable). An extensive analysis of the

Fig. 5. Collaborative networks in Jiangxiang village. Note: The circular, triangular, and square nodes in the picture indicate actors involved in agriculture, industrial, and service industries, respectively. Additionally, the colors of the nodes symbolize the social attributes of the actors, with the black, green, yellow, and blue nodes representing a governing elite, economic elite, non-elite, and external enterprise, respectively. The social ties are depicted separately. The solid line connecting the nodes depicts the social ties within the scope of collective action (such as the business information exchange and cooperation with the village development as the common goal). Dashed lines between nodes represent social ties that are not subject to collective action (such as employment relations, or cooperation that does not take village development as a common goal).



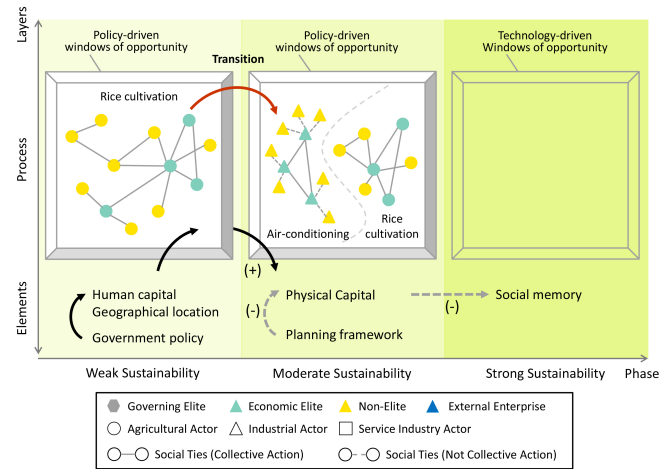
economic, social, and environmental state in Wangzhuang correspondent to 17 SDGs can be found in Table 2. Further details about Wangzhuang's development process in these two phases can be found in Append. 2.

Wangzhuang's collective actions for village development include governing elite-led village collectives and seasonal collective actions in air-conditioning production and rice cultivation. The farmer cooperative in this village operates ineffectively. The collaborative network in this village is clearly centralized, and the decision makers tend to be governing elites.

During the phase of weak sustainability, the collaborative network of rice cultivation was characterized by strong cohesion and low centralization, and no obvious fragmentation could be seen (see Fig. 6). Following the transition to moderate sustainability, the collaborative network of air-conditioning production and rice cultivation remained highly cohesive and decentralized. However, the connection between industrial and agricultural actor groups is weak.

Collective action in rice cultivation in Wangzhuang is a seasonal collaboration based on a social network of local actors. These network linkages are relatively weak and lack formal institutional constraints. They have little impact on farmers' negotiating power,

Fig. 6. Collaborative networks in Wangzhuang village. Note: Figs. 5, 6, and 7 share the same legend.



increasing food prices, or adapting to disasters and market risks. Kinship and geographical proximity influence the collaborative network's strong cohesion and stability. Although Wangzhuang moved from the phase of weak to moderate sustainability, the degree of cohesion of the collaborative network in rice cultivation did not change considerably. Second, economic elites are crucial players in the collaborative network of air-conditioning production. The collaborative network within this industry is primarily composed of economic elites with the goal of lowering raw material purchase prices and expanding sales channels.

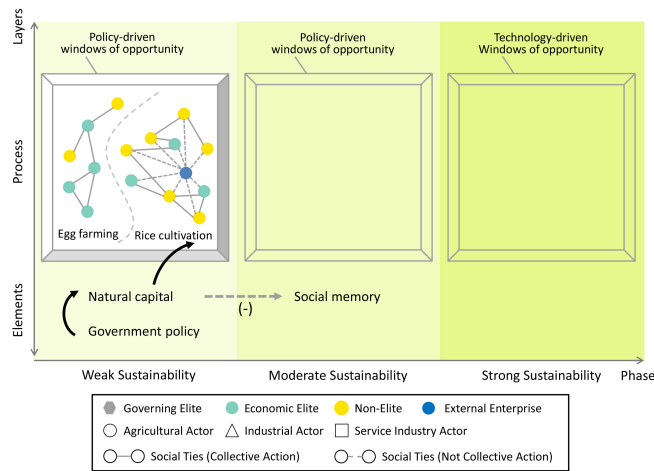
Zhangdagou

Zhangdagou village remains in a state of weak sustainability. Villagers' per capita disposable income in 2018 was only 15,466 CNY. Slow economic growth, low levels of farmer production and consumption, lagging infrastructure and community development, and a failure to improve sanitation are all problems in this village. As a result, we classify Zhangaagou as not achieving the phase of moderate sustainability. An extensive analysis of economic, social, and environmental states in Zhangdagou correspondent to 17 SDGs can be found in Table 2. In Append. 2, we examine Zhangdagou's system elements in detail.

Zhangdagou possesses a weak collective action capacity for village development. In the process of egg farming and rice cultivation, the villagers participate in seasonal collective action based on their local acquaintances.

In the phase of weak sustainability, the collaborative network in Zhangdagou village is less centralized, highly cohesive, and significantly compartmentalized, but the connectivity between actor subgroups is weak (see Fig. 7). The collaborative network of egg farming and rice cultivation in Zhangdagou is less centered on economic elites. Although a few large households of egg farming organize small-holder farmers to jointly purchase chicks, feed, and other production materials, the farming industry in this village relies on larger farming operations. Information sharing and cooperation in purchasing raw materials among large farmers

Fig. 7. Collaborative networks in Zhang Dagou Village. Note: Figs. 5, 6, and 7 share the same legend.



is more frequent. However, the centrality of large rice farmers is not prominent, and there is seasonal mutual assistance among small farmers. Second, whether it is egg farming or rice cultivation, the density of reciprocal cooperative relations among farmers is high and the network's degree of cohesion is high, which may be related to the comparatively small population size of the village and the homogeneity of the villagers engaged in agricultural production. Third, the collaborative network of the village is composed of two groups of actors engaged in egg farming and rice cultivation. The degree of connectivity between the two groups of actors is low. Large farmers supply manure to flower and tree farmers outside the village, but have no direct production contact with the rice farmers inside the village.

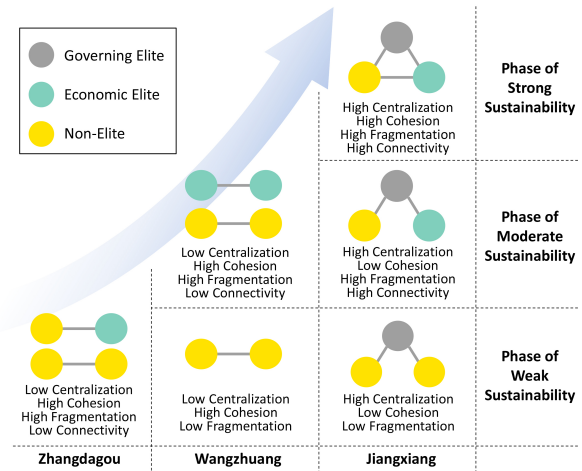
Changing Structures of Collaborative Networks in Rural Sustainable Development

After analyzing the developmental process and system elements in each case-study village, we compare the degree of cohesion, centralization, fragmentation, and connectivity of the collaborative networks to inform what structures may be more effective for rural sustainable development (Fig. 8).

Centralized collaborative networks: strong leadership of governing elites and spatial relationships

We find that centralized collaborative networks enhance the capacity of capturing and exploiting various windows of opportunity. The Jiangxiang village system transitioned from weak sustainability to strong sustainability. The distinct feature of the collaborative network of Jiangxiang is high centralization and connectivity. Strong leadership by the governing elite makes the collective action capacity of Jiangxiang higher than that of Wangzhuang and Zhangdagou. The leadership of governing elites in Jiangxiang is reflected in their ability to transition away from a zero-sum game and instead move toward collaboration among economic elites, villagers, and external actors (such as enterprises and higher-level government). The governing elites accomplish this through system design and communication, but also by consolidating the collaborative network and stabilizing it

Fig. 8. Changing structures of collaborative networks in case villages.



through attention to land management. This finding is supported by previous research that discovered land consolidation promoted socioeconomic restructuring and rural vitalization (Long 2014, Rao 2022). As the rural regional system is a spatial system formed by the interaction of humans, the economy, resources, and the environment (Liu et al. 2020), rural governance is inevitably a coupling process of policy management, population regulation, resource development, and environmental governance. The village cooperative of Jiangxiang leads the collective management of land and implements the development, revitalization, redistribution, and sustainable management of land resources through land engineering arrangements, village planning, land circulation, and other means. They lead land management such that it can adapt to the changing social-ecological environment and improve the sustainability of the village system. In the strong sustainability stage of the village, the governing elites of Jiangxiang prioritized land management for sustainable development, coordinated with policy management and environmental governance, and actively adjusted the relationship between people and the environment. Although the internal collaborative network of Wangzhuang and Zhangdagou also has a governing elite as the central actor, in terms of land management, these villages often only pursue income from land leasing at the expense of other social and environmental gains. Thus, it is hard to resolve the conflict between population growth, economic development, and natural resources.

Cohesive collaborative networks: networks of local, non-elite actors

The cohesion of a collaborative network does not always imply a greater capacity to improve rural sustainability, which is in line with previous literature (Uzzi and Spiro 2005). The networks of Wangzhuang and Zhangdagou are embedded in the local traditional social network of non-elite actors, which are characterized by high cohesion. Various forms of social capital built between the economic elites and non-elites in the village form expectations for trust and reciprocity, increase actors' ability to share and access information, and reduce the transaction cost and

uncertainty of interacting with external actors. In cohesive networks containing ties represented by kinship, social norms and customs support the implementation of collective action. However, the formal institutional environment of the cohesive network is weak, as it does not contain legal provisions and protections for non-elite actors (Webb et al. 2020). Due to the absence of formal legal contracts for cooperation and transactions within the network, problems such as incomplete markets, imperfect information, and environmental externalities often lead to market failure.

Compartmentalized collaborative networks: industrial diversification and system resilience

Jiangxiang transitioned from weak sustainability to strong sustainability. The number of actors engaged in different industries gradually increased, and the degree of network fragmentation increased. As there are more different types of actors in the highly fragmented collaborative network, the knowledge contributed to collective action is more abundant and diverse. Thus, when the village system is faced with economic shocks and environmental crises, such as market price fluctuations, droughts, and other disasters, actors can generate solutions more quickly. Simultaneously, industrial diversification within the village system can also effectively reduce the risk of damage caused by external shocks, making the system more resilient. Yet, network fragmentation also means incremental competition for resources among actors. For instance, there is competition among large rice growers, ecotourism developers, and industrial enterprises for land resources in Jiangxiang. A lack of cooperation between actors or a lack of resource planning and distribution may result in unfair resource allocation and environmental damage. In order to improve the resilience of the fragmented network, increased connectivity between different groups of actors is important.

Connected collaborative networks: compatibility of various rural functions

When several groups of actors emerged in Wangzhuang and Zhangdagou, the degree of network fragmentation rose, but network connectedness did not improve due to the absence of a centralized leader. A network that is highly compartmentalized but disconnected is not conducive to capturing windows of opportunity for system transition. The case of Jiangxiang shows that informal meetings organized by the village Party branch can become an effective platform for information sharing, collaborative learning, and trust enhancement, so that villages with different economies and cultures (e.g., agricultural, industrial) can still maintain high connectivity among network groups. Enhancing network connectivity will help to achieve more efficient industrial and land regulation within the village, and improve the compatibility of economic, social, and environmental goals in rural areas.

Key Elements that Prepare Rural Systems for Sustainable Development

In our case-study villages, social memory appeared to be one of the most critical elements that prepared rural systems for the transition to sustainability. Social memory helps actors recall successful adaptive practices and knowledge to support innovation in ongoing local governance. This is in line with many cases examining transitions around the world, including those in New Orleans (Colten and Sumpter 2009), England (Cooper

2012), and Africa (McIntosh 2000). How can decision makers foster the development of social memory in rural communities that have failed to transition to more sustainable development, such as Wangzhuang and Zhangdagou? Previous literature has proposed that exchanging staff can help break with the past (Foster et al. 2011). In a similar vein, our research on collaborative networks suggests a possible solution: appointing new governing elites as leaders to strengthen centralized collaborative networks and rebuild social memory. The role of skillful governing elites is to bring in new institutions and construct new interpretations and narratives of the past (Foster et al. 2011).

Human capital is another critical internal element present in the three case villages to support rural sustainable development. It has played an important role at every stage of development, particularly when a rural system needs to form collective actions, exploit technology-driven windows of opportunity, and transition to the phase of strong sustainability. This indicates that it is important to reduce the rural “export” of human capital. Other types of capital, such as financial, physical, and social capital, must also be harnessed and developed so that human capital can be used to its full potential, to create growth, wealth, and opportunity (Jischke 2000).

DISCUSSION AND CONCLUSION

This research explores the transition of rural villages to different stages of sustainable development by scrutinizing three case-study villages in China. The case-study analysis demonstrates that villages move toward sustainability by exploiting problem-, policy-, and technology-driven windows of opportunity. This finding adds to the framing of windows of opportunity in the existing literature on transitions (Folke et al. 2005, Herrfahrdt-Pähle et al. 2020). In 1978, a crucial policy-driven window of opportunity (Reform and Opening-up) opened, allowing market demand to rise significantly and industry technology to progress. Previously, governing elites in Jiangxiang conducted collective action to remediate the environment, as well as alleviate poverty, which helped strengthen human capital and collective action, and prepared the rural system for transition. Jiangxiang effectively exploited this window of opportunity and transitioned to moderate sustainability. Years later, this window of opportunity was gradually closing as rural industrial land became inefficient, the industry struggled, and environmental issues worsened. Jiangxiang decided to focus on sustainable production and consumption, investing extensively in environmentally sound, energy-efficient products. Thus, Jiangxiang leveraged technology-driven windows of opportunity and achieved strong sustainability. On the other hand, Wangzhuang and Zhangdagou, central and northern Jiangsu areas respectively, were unable to transition to more sustainable systems due to insufficient preparation. The previous window of opportunity, Reform and Opening-up, did not result in system transition. This is partially because villages were competitive, less preferential policies were implemented, and status quo policies were not adapted in central and northern Jiangsu (Long and Ng 2001). When a new window of opportunity arose, the system was not prepared to take advantage of it.

The three case studies also provide insight into the system transition process from the perspective of collaborative networks. The actors build a collaborative network within the window of opportunity to mobilize system elements and transition. Our

network analysis approach was effective for scrutinizing the interplay between humans and the remainder of the environment, and it can also be adapted to explore other case studies. We find that elites play important social roles among actors because they generate social capital, form collaborative networks, facilitate collective action, and raise actor awareness, which extends Laumann's findings on the function of elite subgroups (Laumann and Pappi 1976). Governing elites may serve not only as leaders, but also as a link between actors. They can improve weak ties between various types of actors and expand the knowledge base of social networks. Furthermore, the structural characteristics of collaborative networks are closely related to collective action capacity and a rural system's developmental phase. A highly centralized collaborative network aids in the efficiency of rural system reorganization, renewal, and innovation, but whether the window of opportunity can be leveraged is dependent on the central actors' leadership. In the initial phases of development, the collaborative network's high degree of cohesion may impede system transition. The largely closed system limits innovation, and the lack of formal institutions may also result in market failure. The social and economic structure of the system is more complex as the village's development phase progresses, and the collaborative network tends to compartmentalize. A lack of shared information and a central actor may result in a collaborative network with poor connectivity, which has a negative impact on collective action capacity and action efficiency. Increasing connectivity across actor groups aids in the spread and learning of knowledge, as well as the system's ability to transition when windows of opportunity open.

Our comparison of three rural development scenarios highlights internal elements and external linkages that are critical to exploiting windows of opportunity to support rural sustainable development. The most significant system elements are social memory and human capital, particularly in the area of technology-driven windows of opportunity and achieving strong sustainability. Natural capital is relatively important in the initial phases of sustainable development.

Humans manage resources through collective actions, resulting in a complex human–environment relationship. Simultaneously, environmental change has a direct impact on human activities and behaviors, which in turn influence the ecosystem (Werdiningtyas et al. 2020). Our analytical framework, which combines an analysis of multiple phases of development with an analysis of the elements and processes of a rural system, was useful to compare actors' collaborative networks and system elements during rural sustainable development across cases.

One limitation of our study is that we did not compare cases across national, regional, and other geographical scales. Our three case-study villages exhibit heterogeneity in the economy, society, and environment, making them useful cases for comparative analysis of rural development. But our cases do not depict collective action issues in rural areas characterized by high-intensity exploitation of natural resources, poor rural environmental quality, and major human–land conflicts. This suggests that future theory about transitions in rural sustainable development and collective action would be strengthened and produce insights relevant to decision makers by focusing on the impact of different resource and environmental governance contexts and investigating these from

a dynamic perspective. For example, how do collaborative networks develop and, importantly, evolve over space and time to achieve desired structural attributes and adapt to the changing environment? Ultimately, the insights into these questions will contribute to advancing our understanding of collective action and rural sustainable development, paving the way for more informed strategies and policies.

Data Availability:

The data code that support the findings of this study are available, on request, from the corresponding author, Xiaofei Qin. None of the data code is publicly available because they contain information that could compromise the privacy of research participants, namely the residents in Jiangsu Province, China.

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Appendix 1. An overview of case villages

Case study 1: Jiangxiang village

Jiangxiang is subordinate to Changshu City, Jiangsu Province, located in the south of Jiangsu. The registered residence population of Jiangxiang is 875. The total area of the village is 3 square kilometers, including about 1,500 mu of arable land. In 2020, the per capita net income of farmers was 50,000 Yuan, and the total income of the village cooperative was 26 million Yuan, mainly from asset leasing, enterprise financing, and agricultural tourism, which were basically equivalent. The per capita income of the village residents from the village cooperative economy was 10,000 Yuan. Thirty years ago, Jiangxiang relied on the geographical location advantage close to Shanghai and the rural policy preference. Driven by village branch secretary, the elites, the farmers collectively established the first industrial production line in the village, and then developed into a highly competitive industrial enterprise and group. Seizing the opportunity of undertaking the industrial transfer in Shanghai, the village turned from the traditional natural agricultural economy to the rural industry, and the village economy began to grow rapidly. As a result, the transformation and development of Jiangxiang is the epitome of the “Southern Jiangsu Model” of this period, that is, farmers depend on self-organization to develop township enterprises, and realize rural non-agricultural development through the development of rural industries. The ownership structure of township enterprises is dominated by collective economy, and the township government leads the enterprise development. Based on the village collective economy supported by industrial enterprises, the industry of Jiangxiang continues to develop a variety of industries, including tourism. About 10 years ago, Jiangxiang replanned and constructed the village’s living environment, and set up complete tourism infrastructure service facilities. The green coverage rate reached more than 90%, accomplishing the coordinated and sustainable development of the primary, secondary, and tertiary industries within the village. The collective economy of the village is far beyond the public service and infrastructure supply of ordinary villages. The installation and construction of 196 villas and 158 elderly apartments in the village, including telephones, high-definition TV, cable broadcasting, gasification cookers, solar water heaters, sanitary ware and small wells, are all invested by the collective. The elderly population enjoys a pension of 600-2,300 Yuan paid by the village cooperative every month. The development process of Jiangxiang can be seen as a composite system of “economy, society, and ecology” coordinated development driven by elites through strong collective actions, which has promoted the multi-functional transformation of the village.



Fig.A1 Spatial planning in Jiangxiang Village



Fig.A2 Habitat of Jiangxiang Village

Case study 2: Wangzhuang village

Wangzhuang belongs to Jingjiang City, Jiangsu Province, located in central Jiangsu. The registered residence population of Wangzhuang is 3,580. The village covers an area of 3.2 square kilometers, including 1,648 mu of arable land. In 2020, the per capita net income of farmers in the village was 16,000 Yuan, and the total village cooperative income was 500,000 Yuan, which mainly came from the income of the state-owned enterprises shares and the rent of the transfer after land consolidation. The income was utilized for infrastructure construction and village governance, and there was no dividend for the villagers. The industry of Wangzhuang has shifted from agriculture to coexistence of agriculture and industry. Most of the farmers are engaged in rice and wheat planting, a small number of farmers engaged in aquaculture. In recent years, Wangzhuang has vigorously encouraged the transfer of arable land. By 2020, about 46% of the arable land (766 mu) in the village has been transferred to the large farmers of rice and wheat. The village Party branch has organized villagers to renovate the village living environment for three consecutive years, focusing on recycling, renovating and transferring idle land. This collective action not only directly improves the village environment, but also increases the available arable land for agricultural planting in the village. The transfer income can raise the village collective income. In the first half of 2021, the village collective gained 59,000 Yuan from land transfer. Since the beginning of the 21st century, driven by he

rapid development of the air-conditioning industry in the Chengbei Park of Jingjiang City and the economic elites of the village, small-scale enterprises producing air-conditioning end products have begun to gather in Wangzhuang. The development course of Wangzhuang can be regarded as the establishment of enterprises by elites and the reconstruction of villages by enterprises, which is worth rethinking the current mode of rural industrialization in China.



Fig.A3 Research process



Fig.A4 Factory diagram of air conditioning end products in Wangzhuang Village



Fig.A5 Habitat of Wangzhuang Village

Case study 3: Zhangdagou village

Zhangdagou belongs to Shuyang County, Jiangsu Province, located in northern Jiangsu. The registered residence population of the village is 4,765. The total area of the village is 39 square kilometers, including 6,120 mu of arable land. In 2020, the per capita net income of farmers was 18,000 Yuan, and the total village cooperative income was 500,000 Yuan, which mainly originated in the rent from land consolidation and circulation. The income flew towards infrastructure maintenance (power facilities and road maintenance), and there was no dividend for villagers. The village has outstanding grain production functions and has a decades of grain planting history. The existing rice and wheat planting area is 5,300 mu. Since 2004, China has implemented the price support policy based on the minimum protection price of grain and the direct subsidy. The income of farmers in Zhangdagou has been guaranteed, and the number of farmers planting grain in the village has gradually ascended. In recent years, the economic elites of the village began trying to raise laying hens by absorbing the information and experience of the outside world, and led other professional farmers to start the development of laying hens breeding industry with considerable profits. The development of Zhangdagou can be recognized as a traditional agricultural village driven by agricultural economic elites and with informal agricultural cooperation.



Fig.A7 Habitat of Zhang Dagou Village



Fig.A8 Agriculture and farmers' livelihood in Zhang Dagou Village

Appendix 2. Details about sustainability phases of the three case study villages

Jiangxiang

(1) Phase of weak sustainability (1968~1983)

Jiangxiang is in a low-lying area where floods severely limit local agricultural production. The land is severely fragmented, and food production is insufficient to meet the villagers' basic needs. Prior to 1949, schistosomiasis caused a critical public health crisis in the Yangtze River Basin, resulting in poor overall health of the inhabitants and overwhelming poverty in the hamlet. Since 1968, Jiangxiang's brigade leader has mobilized and organized the local healthy young and middle-aged labor force to carry out collective land consolidation and environmental governance actions with the goal of ensuring food security and preventing infectious diseases. According to Jiangxiang's historical record, the main missions of this period were, first and foremost, dredging river channels, leveling land, implementing the water control and soil improvement project. At that time, they filled 113 hectares of low-lying land by 1 meter and successfully transformed low-lying land into high-yield fields. And another main mission of them is reclaiming wasteland, such as digging old ditches, excavating new canals, deep plowing soil, spraying drugs, etc. The outcome was significant because snails were cleared and eradicated, and schistosomiasis infections were effectively controlled. Jiangxiang village took advantage of the problem-driven window of opportunity at the time by improving natural capital, eventually resolving the villagers' food and nutrition health problems.

Following the Reform and Opening-up in 1978, the Household Contract Responsibility System (HCRS) transformed the family into the primary body of land management and distribution, and mobilized farmers' production initiative. Despite the fact that the farmland crop system reform disrupted the economic pattern of "great unification" during the People's Commune period, Jiangxiang's collective action capacity did not decline significantly. Rice experts were invited to Jiangxiang in 1979 to provide guidance on planting and farmland regulation. A year after Jiangxiang began to develop a spatial plan, old houses were demolished and new ones were built. In the 1980s, the leaders continued to lead the villagers in the construction of village roads and remediation of cultivated land, including field normalization, drainage and irrigation channel systematization, poor soil improvement, planting fragmentation, and field mechanization. At this stage, these actions have laid a solid foundation for spontaneous land circulation among farmers and large-scale grain field management. Simultaneously, this process reflects the critical role of human capital in developing village development strategies and promoting cooperative governance among villagers.

(2) Phase of moderate sustainability (1983~2008)

Since China's Reform and Opening-up, the transportation and construction industries have recovered, and market demand has expanded rapidly. Taking the advantage of geographical location, Jiangxiang first absorbed advanced information, technology, and management experience from Shanghai city. In 1983, the central and all-level local governments successively

implemented land management right reform, loans, and tax preferential policies to encourage rural industrial development. By that year, policy-driven windows of opportunity opened.

The head of Jiangxiang village committee (the former leader of the village production brigade) advocated, rallied, and led the villagers to collectively establish the first village enterprise, Zhennan plastic factory. 9 years later, two colour steel composite plate production lines were also established. Jiangxiang's village-level industry has grown significantly as a result of the government policy, geographical location, and macroeconomic environment. Farmers' livelihood has shifted from traditional agriculture to rural industry, and household income has substantially risen. Furthermore, rural infrastructure is being rebuilt so that clean water, affordable energy, adequate power, and convenient transportation are all a reality in the village.

The market-oriented reform was pushed even harder in the mid-1990s. The township firms that arose in the early stages of industrial development in southern Jiangsu eventually lost their advantages against the backdrop of an export-oriented economy driven by foreign capital and urban expansion led by the development zone. Rural industries have gradually downsized and relocated, whereas agricultural production functions have been restored and reinforced.

Motivated by the village director and other elites, Jiangxiang transformed the original material factory into Jiangsu Changsheng Group (four joint-stock companies) in 1995, seizing the critical opportunity provided by the stock cooperative system reform. The scale of village-level industry has been expanded further, and Jiangxiang has constructed the first village industrial park in Changshu city. By 1997, Jiangxiang's total agricultural and industrial output value was about 100 million CNY, with self-owned assets exceeding 50 million CNY. This suggests that the key to capture policy-driven windows of opportunity and enhance the economic viability and equity of rural system is the reform of institutional arrangement and the deployment of human capital.

Furthermore, Jiangxiang Village developed a village plan for the period 1995-2010 that redefined the residential area, cattle area, grain and oil production area, industrial park, and recreational area. The village's planning framework guided its gradual establishment of a sustainable community. After the year 2000, Jiangxiang Village began to establish a cooperative for the collective community, raising cash to construct standardized factories, commercial buildings, and other leasable properties. A huge number of businesses began to settle in Jiangxiang, and the physical capital of the village substantially grown.

(3) Phase of strong sustainability (2008~)

From 2008, Jiangxiang began implementing the community shareholding system and developing effective and unambiguous rules and regulation. We find that Long-term positive cooperative

experiences effectively transfer to social capital, including trust and reciprocity norms, facilitating further communication, coordination, and collective action. This demonstrates that social memory is the driving force behind the continual innovation of local governance.

Since 2010, Jiangxiang virtually had managed to develop harmonious linkages between the community's environmental, economic, and social aspects. The village's upgrading strategy and spatial planning have been altered to achieve ecological livability and sustainable development. Asset privatization was implemented in the industrial sector, transforming the firms under Changsheng Group from village collective ownership to enterprise outsourcing. In terms of agricultural production, fragmented farmland was centralized to farmer cooperatives before being transferred to economic elites for large-scale farming through contrast awarding. A grain and oil production base of 80 hectares was planned to guarantee community food security. In addition, ecologically-friendly plantations and breeding farms were envisioned as places for smallholders to prosper and develop as economic elites. Village tourism has thrived since the construction of Youth Science Museum, sport and leisure centers, and agricultural practice area. In 2018, the overall output value of Jiangxiang's three industries was 1,000 million CNY, and the per capita household income rose to 49,500 CNY. The village collective's income was 22.76 million CNY, which effectively supported public services such as pension and medical subsidies, infrastructure supplies, and village affairs management. So far, Jiangxiang has largely realized its visions of multi-functional rural community, intelligent management, governance democratization, industry concentration in parks, and farmland aggregation to elites.

Jiangxiang dedicated its attention to sustainable production and consumption in 2021, investing heavily in environmentally sound, energy-efficient products such as village energy cycle systems, green low-carbon micro-grids, and rooftop photovoltaic. This suggests a new windows of opportunity that is distinctive from the policy-driven and problem-driven windows of opportunity proposed in previous literature (Kingdon 1995, Folke et al. 2005): Technology-driven windows of opportunity open when decision makers in a transition economy recognize changing market needs and technical breakthroughs and optimally upgrade the structure of the village system. Capturing and exploiting them require the better preparation of system elements such as human capital. Generally, at this phase, the most important system elements for the village to achieve transition to strong sustainability are social memory, planning framework, and human capital.

Wangzhuang

(1) Phase of weak sustainability (1978~2000)

Wangzhuang is relatively inferior in location compared to Jiangxiang. During the initial period of Reform and Opening-up, 1978~1991, when the policy-driven window of opportunity opened, Wangzhuang failed to industrialize as Jiangxiang and transition to moderate sustainability. Since the end of the twentieth century, the predominant industry is still grain planting, mainly rice and wheat. Based on the in-depth interviews with local farmers, the farmer cooperative in Wangzhuang

has no actual operation and is in name only. Most of the rice planted and produced in Wangzhuang is directly transported to the rice factories and rice trading center in surrounding towns for rough processing then sold in supermarkets and retailers.

The principal cause for the difficulty in forming collective action in Wangzhuang is the loss of human capital and social capital—a large quantity of surplus labor forces have migrated to urban departments, leaving the rural system with a severe aging problem. Another reason is that Wangzhuang did not have enough development and governance experience during the policy-driven window of opportunity, Reform and Opening-up. The absence of social memory also leads to the deterioration of collective action capacity. In most cases, governing elites control decision-making in a top-down manner in this collective action context, although the planning and development process is partially participatory and democratic. For example, villagers rarely disagreed to the community's public affairs choices at monthly public meetings of village collectives. Only until the villagers could see tangible benefits from village public affairs will they be willing to engage. As a result, to reduce the cost of mobilizing, lobbying, and organizing the villagers for collective actions, the village collective tended to outsource the majority of village construction, environmental governance, asset management, and other affairs. In general, Wangzhuang was still a long way from fulfilling many social and economic related sustainable development goals, such as decent work and economic growth, and partnerships for the goals.

(2) Phase of moderate sustainability (2000~)

Until the twenty-first century, another policy-driven window of opportunity opened when Jingjiang city issued preferential policies to support the small and medium-sized enterprise park, planned to build an air-conditioning town (China HVAC Trading Center), and developed a distribution center for central air-conditioning end products. During this opportunity, Wangzhuang's economic elite established the village's first air-conditioning accessory production firm, creating more than 30 jobs for the local villagers. Since then, Wangzhuang has seen the emergence of a new industry of air conditioning accessory production, with a total of ten air conditioning accessory enterprises. The enterprise shares for village collective supported public services and good provision in the village. Particularly, these funds helped Wangzhuang in eradicating poverty, upgrading local industry and infrastructure, and reducing income inequality among locals, so facilitating the village's transition to an economically viable and socially equitable system.

We believe that the fundamental bottleneck impeding Wangzhuang's transition to sustainable development is that: first, it is difficult to embed new technology innovation, namely, it is unable to capture technology-driven windows of opportunity. Despite the leadership of a small number of elites, the promotion of industrial policies, and the good trade platform and transportation logistics circumstances, the industry failed to upgrade due to a lack of human capital. Air-conditioning enterprises in other regions, on the other hand, have begun to innovate in product design,

production, and sales through the HVAC center's online e-commerce trading platform, such as building an intelligent air-conditioning control system that allows customers to control and select product features through mobile phone applications to meet various personalized customization needs. Second, the village's land use is restricted by the upper planning framework. The construction land resources are skewed toward the construction of air-conditioning towns under the authority of town land use planning. The shortage of development land in Wangzhuang has hampered the expansion of the air-conditioning business, harming the village collective economy as well as public services and goods provision.

Zhangdagou

(1) Phase of weak sustainability (1980~)

Similar to Wangzhuang, Zhangdagou also failed to achieve system transformation during Reform and Opening-up, the window of opportunity. Zhangdagou was still stagnating in the phase of weak sustainability. The lack of social memory and human capital was the main reason. The more serious population outflow and aging made it more difficult for Zhangdagou to capture new technology-driven windows of opportunity.

Zhangdagou is abundant in natural capital. The farmers plant 4000 acres of rice, wheat, and other grain crops, as well as raise laying hens. Albeit the absence of actual operation of farmer cooperatives in the village, farmers form temporary or seasonal collective actions based on a social network of acquaintances during the busy season of harvesting grain. The rice and grain production network of Zhangdagou are as follows. First, rice cultivation and raw grain cleaning are completed inside the village, while the processing is completed outside. The two miniature rice factories in the village act as middlemen to collect the grain harvested by local farmers, clean it (primary screening and stone removal), then transfer it to other large rice factories for processing, and finally sell it to supermarkets, retail stores and dealers throughout the country. Second, there is an employment relationship between large and small farmers. Large farmers usually hire small farmers to help them during planting and harvest. Third, the mutual assistance between small farmers during the busy farming season normally does not calculate the cost. Based on the kinship network and the social network between neighbors, they jointly negotiate to plant or harvest grain in turn.

When it comes to egg farming, there are also mutual assistance and cooperation among the large breeding households. First, owing to the lack of feed supply for laying hens in the county, the enterprises often need to purchase feed from other counties (Sihong County) and other provinces (Shandong Province), and the cost is high. Consequently, 10 large breeding households in the village choose to cooperate to purchase laying hens feed to reduce the cost. Second, the eggs produced are sold to Sihong County, a city outside the same province, and the feces of laying hens can be sold to villages outside the same county for flower and tree planting. In 2020, the land circulation volume in the village was 800 acres, accounting for 13% of the cultivated land. Villagers over the age of 60 planted more cultivated land than others. The high cost of chemical fertilizer and other production raw materials reduced output efficiency. However, they still chose independent farming and refused land transfer.