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Institutions and government efficiency: decentralized irrigation management in China

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Abstract: In order to improve the efficiency of government spending, it is necessary for the decentralized irrigation management to gain support from local institutions. Efficient institutions take on several distinct configurations in different irrigation districts. In this research, we upgrade Tang's (1992) framework focusing on incentives, to a framework that includes institutional incentives and coordination. Within the framework, we then classify 5 institutional variables: water pricing reform (P), government funding (F), coordination by administration (C), having formal monitors (M) and self-organized management (S). This article processes the data obtained through a field survey (2009–2011) in 20 of China's southern counties, where they implement the "Small-scale Irrigation and Water Conservancy Key Counties Construction (Key Counties Construction)", a national project supported by the central government. Next, it applies Data Envelopment Analysis (DEA) to measure the efficiency of government spending and uses Qualitative Comparative Analysis (QCA) to extract efficient institutional configurations. It concludes that there are generally three types of institutional configurations able to improve the efficiency of government spending, which are respectively: "government funding combined with coordination by administration", "water pricing reform combined with self-organized management and coordination by administration or water pricing reform combined with self-organized management and government funding and formal monitors" and "self-organized management". Among these, the second configuration is a mixed governance structure with multiple institutions coexisting, and this configuration occurs in the most efficient key counties. For that reason, it is viewed as the mainstream irrigation management approach, and we expect it to be the development trend in the future. Although Chinese irrigation policies are formalizing effective local institutions, they are still not sufficient. Future policies are needed to 1) promote institutions of government support for water laws in order to build stable expectations for both water user associations (WUAs) and farmers, 2) guide water pricing reform by ensuring farmers' water rights and regulating water markets, and 3) provide opportunities for hiring professional monitors and crafting formal rules.

Keywords: Decentralized management, government spending efficiency, institutional configuration, mixed irrigation governance

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1. Introduction and literature review

This century has witnessed two major changes in China's irrigation policy. The first change is that China's government has been investing large amount of capital to construct small-scale irrigation systems with an average annual growth rate of more than 20%. These are typically gravity irrigation systems of surface water, generally including small-scale head works, storage facilities of dams and reservoirs, distribution canals and field canals, and drainage devices etc. Among these investment projects, the exemplar is the Small-scale Irrigation and Water Conservancy Key Counties Construction (referred as Key Counties Construction), in place since 2009. In 2009, the growth rate in small-scale irrigation rose to over 48%, the highest in China's history. The second change occurred in 2003 when China's government instituted decentralized irrigation management throughout the country. This initiated the creation of water user associations (WUAs) and transferred management power to them from the government (or from the village organization). The Key Counties Construction project generates economic incentives for local government to establish WUAs, leading to more than 80,000 associations springing up across China by 2013.

The Key Counties Construction is a massive agricultural project financed by the Chinese central government during the recent period of decentralization.

It was initiated by the Ministry of Finance and the Ministry of Water Resource in 2009. Over 400 counties per year are selected to participate, with over 2450 now enrolled around China. The construction period for each county is 3 years. Each county receives a similar amount, 8 million CNY[1] per year from the central government and additional supporting subsidies of about 8 million CNY from the corresponding provincial government. Compared with other governmental-funded agricultural projects, the Key Counties Construction has six unusual characteristics (Chai 2014).

1) A prerequisite for selecting a project area in a county is that farmer water user organizations (generally WUAs) must already exist there. This aims to incentivize counties to form well-organized systems of decentralized management, with WUAs assuming small-scale facility operation and maintenance (O&M) and connecting with water supply agencies.
2) The project makes county governments responsible for building irrigation facilities. In the past it had been undertaken by town governments and village organizations, both of which are only required to provide supportive services in the new system. This has dramatically reduced the administrative costs of local agencies.
3) Farmers also have to contribute part of the money and labor. The amount depends on the balance between the investment from governments and the cost of the project. This builds farmers' ownership of the program and empowers them to support the project.
4) Additionally, farmers have veto rights on the execution of the project. They can say stop if the construction scheme and implementation is not consistent with their demands. Only after farmers accept the construction quality can the project enter to next phase. This transparent process builds farmers' trust in the plans of investment and management.
5) Water resource agencies provide training on hydrology and irrigation O&M for WUAs. Most association members, including the leaders, often lack the scientific knowledge and specialized skills required in modern irrigation O&M, such as water flow supervision, information collection, culvert repair and canal maintenance. These trainings develop long-run capacity-building of WUAs for the future.
6) Agricultural water rate reform is included in the project. Its goals include transitioning water rates from being based on land area to water volume and standardizing water use plans. This is expected to provide farmers with exact information on water withdrawal, to keep it consistent with the water fees, and to endow WUAs with accurate records of water demand and to incentivize them to precisely distribute water.

[1] 1CNY=0.163USD.

Ostrom et al. (2007) state that there are no panaceas for the governance of human-environment interactions. As a result, these changes may be expected to generate varying levels of performance of irrigation management in China. In exploring these variations, this paper has two objectives. The first is to evaluate the efficiency of government spending during the process of decentralized irrigation management. This is a difficult task because the simultaneous variation of multiple policies increases the complexity of quantification and also exacerbates the difficulty of research on irrigation governance. The second objective is to assess the roles of local institutions in government spending efficiency. This object embodies four questions: 1) how does the efficiency level of government spending vary due to decentralized management; 2) in which institutional configuration is the efficiency of government spending the highest; 3) are these local institutions for increasing the efficiency of government spending necessary or sufficient; 4) which institutions play the lead role in improving irrigation governance. These questions form the content of our study.

1.1. Simple decentralization and government spending efficiency

Decentralization has been advocated as an essential measure to improve the efficiency of government spending in irrigation (World Bank 1994; Vermillion and Sagardoy 1999). Many developing counties have tried this approach to solve the problem of inefficient government spending on public goods, which is mainly attributed to poor incentives caused by centralized management. From the 1970s to mid-1990s, through the assistance of foreign funds such as the World Bank and the Asian Development Bank, 63 central governments among 75 developing and transiting countries began to transfer management power from the government to WUAs or the private sector. Decentralization is viewed as a panacea and often applied to many public projects, such as irrigation (Ostrom 2001). Other research also demonstrates that decentralization – sharing power between the government and community associations – is good for reducing transaction costs, allocating tasks, exchanging resources, resolving conflict and sharing risk (Pomeroy and Berkes 1997; Carlsson and Berkes 2005). However recent research demonstrates that decentralization produces mixed results in irrigation. The only widely experienced positive result is that government tends to reduce its administrative cost (World Bank 2011). A small number of short-term projects sponsored by World Bank also show improved efficiency of government spending. Still, most irrigation districts continue to suffer from poor performance with facility deterioration, water supply shortages and distribution inequity (Garcés-Restrepo et al. 2007; Wang et al. 2000, 2005).

Simple decentralization has been questioned and seen as a new barrier obstructing the efficiency of government spending. Decentralization has aggravated farmers' economic burdens, reduced their interests and dampened their incentives to actively participate in irrigation management (IWMI 2003). Newly built WUAs, unfamiliar with professional techniques for modern facility, lack the ability to perform standard O&M. In addition, they fail to undertake the projects previously designed by the government. As a result, the higher the technical standards contained in the facilities, the worse the O&M of the WUAs and a further lowering of benefits produced from the project (Khwaja 2009).

Decentralized irrigation management has been recognized as a process not a final destination. It cannot automatically motivate farmers to craft rules to manage irrigation with no consideration of extra factors influencing their incentives and behaviors (Zhou 2013). Policymakers are repeatedly recommended to quit using simplified developing blueprints and instead tailor lessons from early projects to local circumstances (Merry and Meinzen-Dick 2007). They still focus on the short-term effects of decentralization reform and investing in building large-scale facilities rather than learning from local institutions or nurturing these institutions because of the long time horizon required (Gulati et al. 2005).

1.2. Linking decentralization with local institutions

Many studies on irrigation decentralization begin to discuss the prerequisites for improving the efficiency of government spending. They concur that nurturing local institutions is critical and suggest a class of alternatives (Meinzen-Dick 1997). They also clearly point out that local conditions are the main reason causing the failure of decentralization due to its inability to craft effective institutions or enforce them once established (Acheson 2006). To better explore these institutions, we upgrade Tang's (1992) framework focusing on incentives, to include coordination and management. In our view, irrigation governance is a collective action challenge, whose essence lies in motivating management entities to coordinate users to maintain facilities and allocate water. Within our framework, we classify local institutions into two types: incentive institutions (including water pricing reform and government funding) and coordination institutions (including coordination by administration, establishing formal monitors and self-organized management).

Water pricing reform. Evidence for water pricing as an effective mechanism for decentralized management is complex. Many economists consistently propose that appropriate water pricing is crucial, in order to create incentives for WUAs to engage in daily management (Wang 2012), incur infrastructure expenses (Easter and Liu 2005), and sustain irrigation O&M (World Bank 2011). Some strongly suggest developing counties should reform water pricing, from a free commodity to a scarce, economically-priced good, at least covering full O&M cost (Liao et al. 2005; Lohmar et al. 2007).

However, this view is criticized by other research (Perry 2001; Molle and Berkoff 2007). They stress that, in areas of scarce water, farmers have rigid water demands, are not responsive to increased price, and may not constrain water use. Here, water pricing achieves conservation only on a theory level, rather than in practice (Corish et al. 2004; Molle 2009). Our study in Southern China is not a scarce water area. For this reason, we adopt the logic of water pricing leading to conservation. Our rational is that water pricing reform inside WUA, at farm level, may benefit the WUA by both maintaining the water supply and regulating water demand.

Government funding. Irrigation systems have multiple externalities (Kobayashi 2005). They not only provide agricultural production and food security benefits, but also have social values such as supplying drinking water, beautifying the environment and protecting soil, and buffering water shortages suffered by the industrial sector in dry seasons. These roles create beneficiaries beyond farmers, so governments often assume responsibility to fund facility construction and maintenance. Furthermore, government funding can provide WUAs and farmers with stable input expectations and motivate them to contribute efforts as well (Yasuhiro 1998). In Japan water law fixes the investment level of government on small-scale irrigation at 70%.

Coordination by administration. Scholars agree that other than legal and political authority, the government should also provide administrative assistance for WUAs to ensure their sustainability (Pomeroy and Berkes 1997; Birner and Wittmer 2004). Similarly, studies in rural China show that successful decentralization reform requires WUAs to take on coordination responsibilities (He 2010; He and Guo 2010). However, WUAs are new entities and they generally lack the administrative capacity because China's farmers still trust the central government and village committees more than the WUAs. As a result, WUAs have difficulty raising capital, mobilizing labor, and distributing water, let alone amassing the large-scale investment necessary to build public canals. To strengthen WUAs' coordinative power, these studies suggest that government agencies are still needed to provide administrative support and coordinate irrigation plans.

Formal monitors. Research shows that formal monitors are necessary for effective irrigation governance through enforcing rules, discovering rule violators, and damping the temptation of water stealing in Spain, Japan and Nepal (Ostrom 1990, 1992). Besides this, in China, monitors generally benefit WUAs by taking additional responsibilities, such as operating sluice gate, distributing water at the farm level, collecting water fees, and recording information (Huang et al. 2008). This institution has also been identified as a successful element in other Asian irrigation systems such as in India and Taiwan region (Meinzen-Dick 1984; Lam 1998).

Furthermore, formal monitors have incentives to carry out activities under appropriate conditions (Weissing and Ostrom 1991). The most important condition is to hire them as "integrated" monitors rather than "associated" ones. The former represent that monitors are part of the community managing the irrigation system, and their payoffs are directed related to the physical success of the local farmers; and the latter indicate that monitors are appointed by external authorities and their payoffs are determined by some measure of violations detected (Weissing and Ostrom 1993).

Self-organized management. Strong WUAs can affect the success of decentralization, through social norms encouraging and constraining user behavior (Lam 1998) and building upon farmers' daily interactions and knowledge of each other for decision-making, monitoring, and sanctioning (Meinzen-Dick 1997).

Practice in Nepal demonstrates that self-organization may be more responsive to crisis as well as having a better understanding of local conditions than governmental bureaucracies (Lam 1998). Empirical study in China also shows that self-organization of farmers' clans, rather than village leaders, leads to more contribution to irrigation expenditure and better governance (Xu and Yao 2015). Certainly, WUAs should be created on the basis of existing farmer organizations, which can often design more flexible mechanisms and diverse rules than top-down government initiatives (Meinzen-Dick 2007). Self-organized management indicates that WUAs not only need to develop their own schemes of facility O&M, and craft and enforce rules of water distribution, but they also have the right to choose the governance structure (Lam and Ostrom 2010). Meinzen-Dick (1997) names it "Asian model", one which is likely to develop in areas with high levels of social capital, cohesive societies, smaller land holdings, low market penetration and less infrastructure.

2. Data and methods

2.1. Samplings and data selection

During the process of decentralized management, in order to analyze the causal relationships between local institutions and the efficiency of government spending, we conducted detailed surveys in the irrigation districts. We chose southern rather than northern China, as a study area from two reasons. The first is that southern China typically has the surface irrigation facilities in place to expand and benefit from government investment. Northern China, by contrast, has surface canals as well as private groundwater wells whose investment comes from individual farmers. This mixed approach to irrigation makes publicly financed projects more difficult. The second reason is that, unlike the individual-level relationship among farmers in northern regions, southern China has a large number of self-organized farmer organizations already in place through clans, ethnic minorities and elderly associations. These provide deep-rooted cooperative relationships among farmers and provide social bases for them to establish and operate WUAs. The study area of 20 key counties is located in the provinces of Guangdong, Guangxi, Hunan and Jiangxi, with 5 counties sampled in each province (see Figure 1). In order to ensure generalizability, we used a multistage sampling method. First, we collected input-output information from all the counties' water resource departments of each province from 2009 to 2011. We then kept the county in the analysis if it had the required information. Lastly, we selected 1 year of data for each county based on its most active time period as reported by local media. This provided context-specific details for our follow-up field surveys. In addition, these 4 provinces all irrigate fields with water from reservoirs and dams run by local water resource bureaus.[2]

[2] Note that this indicates these project areas have similar biographic characteristics, community attributes and governance environments. With these held constant, we can analyze the role of local institutions on government spending.

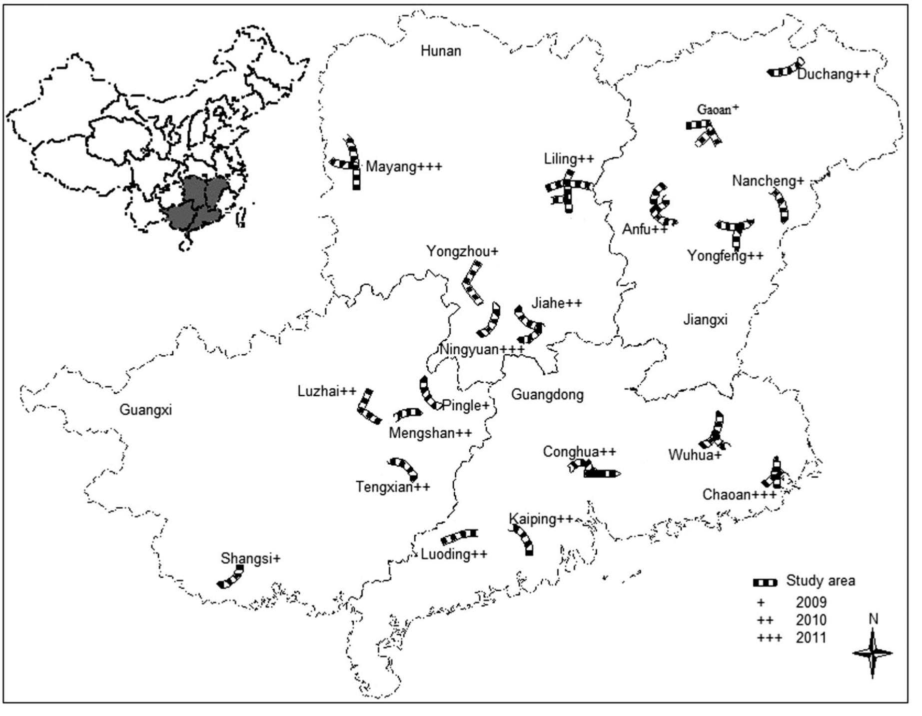

Figure 1: Locations of the 20 project areas selected in 4 southern provinces, China ($^{+}$: 2009; $^{++}$: 2010; $^{+++}$:2011).

Data collection occurred in two stages. First, the sectional data was acquired from statistical reports issued by local water resource bureaus from each of the 20 counties. For example, the county of Conghua in 2010 implemented the project in the town Aotou, but different towns in the other 2 years. As such, the data of 20 counties from different years, between 2009 and 2011, can be used to conduct a comparative analysis. The second stage of data was collected from case materials through our own fieldwork and from in-depth interviews with farmers, village leaders, WUA members and local officials. These qualitative data were aggregated at the level of a project area in one county. Generally, each project area in a county in 1 year only contains a couple of towns, about 10 neighboring villages.[3] In other years, the project area in the same county involves different towns and villages. Therefore, a project area of one county in a specific year is our analysis unit. It is necessary to note that one county project may include multiple

[3] In China, we have 5 administrative divisions: province – city/district – county--town – village. Each unit includes multiple smaller subunits. For instance, normally one town has about 5-40 villages. However, when it comes to Key County Construction projects per year, it only involves a part of the villages, part of the towns in one county.

WUAs. Normally, there are <10 within one country project. Since the WUAs within a single project are located adjacently and have homogenous institutional features, we collected project-level data regarding local institutions, based on some representative WUAs.

2.2. Research methods

We use the Data Envelopment Analysis (DEA) method (Seiford and Thrall 1990) to evaluate the efficiency of government spending. DEA is a nonparametric method, applying linear programming to measure the relative efficiency of multiple decision-making units when the production process presents a structure of multiple inputs and outputs. It is a tool used for benchmarking in management (public governance included), and the relatively efficient unit represents the best practitioner. In addition, it has the benefit of not needing to explicitly specify a mathematical form for the production function. This allows us to analyze the efficiency of government spending on irrigation across multiple objectives.

We set the input variable as total investment (CNY), which includes 8 million CNY subsidies from the central government, 8 million CNY in supporting subsidies from the provincial government, additional funds from lower-level governments as well as collective financing from the farmers. The output variables include newly added and rehabilitated irrigated area (ha), improved irrigated area (ha), added food production capacity (kg), and amount of conserved water (m^3). These calculations allow us to measure efficient government spending through effective irrigation governance and local institutional arrangements.

Since there is no singular local institutional arrangement that acts as a panacea for effective irrigation decentralization, it is necessary to analyze the multiple combinatorial effects of institutions on the outcomes. We then conducted a QCA method (Ragin 1987) to deconstruct which configurations of local institutions result in efficient government spending. Many of the debates in institutional interplay result from concerns with different methods analyzing different cases or aspects of cases. Either analyzing individual cases in depth or analyzing statistically numerous variables in one period create static views which compare individual institutions in pairs. They reveal fractional, rather than the whole, path effect of decentralization on the performance of government spending. QCA, by contrast, enables us to identify causal clusters of variables through patterns discerned across cases (Schneider and Wagemann 2012). Here, we analyze how local institutions influence the efficiency of government spending, through the combination of conventional statistical analysis with QCA, based on the data collected from the Key Counties Construction project.

QCA applies Boolean logic as well as set theory to provide a more holistic view of socio-economic phenomenon, particularly for comparatively analyzing an intermediate number of cases. It treats one case as a configuration of causes and an outcome, considers this as an analysis unit, and dissects complex causes while comparing multiple cases (Ragin and Sonnett 2005; Rihoux 2008). QCA sheds new light on our investigation of: 1) how different configurations of local institutions lead to different efficiency levels, 2) how different institutional configurations may generate similar outcomes, and 3) how combining institutional arrangements leads to discrete outcomes. QCA includes two versions: crisp-set and fuzzy-set. Fuzzy-set QCA (fsQCA) draws on fuzzy logic, and allows cases to have partial (or fuzzy) membership between 0 and 1, which will be adapted in our analysis.

3. Measurements

3.1. Measuring the efficiency of outcome

We use Deap2.0 software to evaluate the efficiency of government spending in these 20 key counties. Variable returns to scale (VRS), a measure of productive technical efficiency, was adopted to calculate performance levels. We divided VRS into four segments, which serve as the criterion of efficiency types. A county with VRS=1 is classified as efficient, 1<VRS≤0.67 as mostly efficient, 0.67<VRS≤0.33 as less efficient, and VRS<0.33 as inefficient (see Table 1).

This project reports proportionally high levels of efficiency in southern China. 6 counties attain the highest efficiency score (VRS=1), and another 6 as mostly efficient; while the remaining 8 counties scored as less efficient or inefficient, as shown in Figure 2. However, efficiency levels vary greatly across these areas, with the most successful province Jiangxi in aggregate (VRS=0.8842), followed by Hunan (VRS=0.7094) and Guangxi (VRS=0.5406) and Guangdong (VRS=0.4562).

Specifically, Jiangxi scored in the top two efficiency levels across its 5 counties. Hunan and Guangxi have similar distributions of efficiency, with both extremely highest and lowest scores coexisting. For instance, Mengshan, the lowest scoring county in Guangxi, with a VRS 0.118, is far less than the highest scoring county Pingle. Yongzhou, the lowest county in Hunan, with a VRS 0.230, lags far behind the other three highest counties of Liling, Jiahe and Mayang. This indicates that these two provinces have experienced quite unbalanced implementation and development of irrigation governance. Holding levels of investment, population and irrigation technology constant, differences in intra-provincial governance remain the only explanation for these gaps. Finally, in Guangdong, only the county Chaoan is high scoring (VRS=0.697), while the other 4 counties (Wuhua, Conghua, Luoding and Kaiping) are all low efficiency.

3.2. Measuring the institutional causes

Given similar decentralization mandates and similar levels of investment from governments, the difference played by local institution arrangements in these 20 key counties is huge, resulting in varying levels of efficiency in irrigation governance. Efficiency levels increased throughout certain provinces such as Jiangxi. Meanwhile, only parts of Guangxi and Hunan achieved efficient outcomes. At the same time, Guangdong suffered from severe inefficiency, drastically wasting government resources.

Table 1: Efficiency of government spending.

Key counties		Newly added and rehabilitated irrigated area (ha)	Improved irrigated area (ha)	Added food production capacity (10,000 kg)	Conserved water (10,000 m³)	Total investment (10,000 CNY)	Efficiency	
Province	County						VRS	Type
Guangdong	Wuhua[+]	376	1421	430	267	2148	0.289	Inefficient
	Conghua[++]	201	1528	510	30	2249	0.298	Inefficient
	Luoding[++]	938	992	129	325	1862	0.497	Less efficient
	Kaiping[++]	154	1494	207	857	2035	0.500	Less efficient
	Chaoan[+++]	1072	3015	375	750	2025	0.697	Mostly efficient
Guangxi	Mengshan[++]	34	503	134	140	1604	0.118	Inefficient
	Tengxian[++]	203	232	126	371	1627	0.247	Inefficient
	Luzhai[++]	938	469	315	698	1689	0.666	Mostly efficient
	Shangsi[+]	838	308	110	801	1690	0.672	Mostly efficient
	Pingle[+]	543	677	5000	197	1550	1.000	Efficient
Jiangxi	Anfu[++]	657	2245	4572	360	2716	0.666	Mostly efficient
	Yongfeng[++]	1387	3363	886	795	3313	0.810	Mostly efficient
	Gaoan[+]	1829	3229	4240	650	3665	0.948	Mostly efficient
	Nancheng[+]	884	2023	1,0940	2121	2526	1.000	Efficient
	Duchang[++]	2394	2870	4150	773	2385	1.000	Efficient
Hunan	Yongzhou[+]	214	858	333	321	1626	0.230	Inefficient
	Ningyuan[+++]	476	998	555	440	3320	0.317	Inefficient
	Liling[++]	1635	5280	1276	772	1602	1.000	Efficient
	Jiahe[++]	241	3022	480	1675	1215	1.000	Efficient
	Mayang[+++]	496	2868	4400	90	1601	1.000	Efficient

[+]: 2009, [++]: 2010, [+++]: 2011.

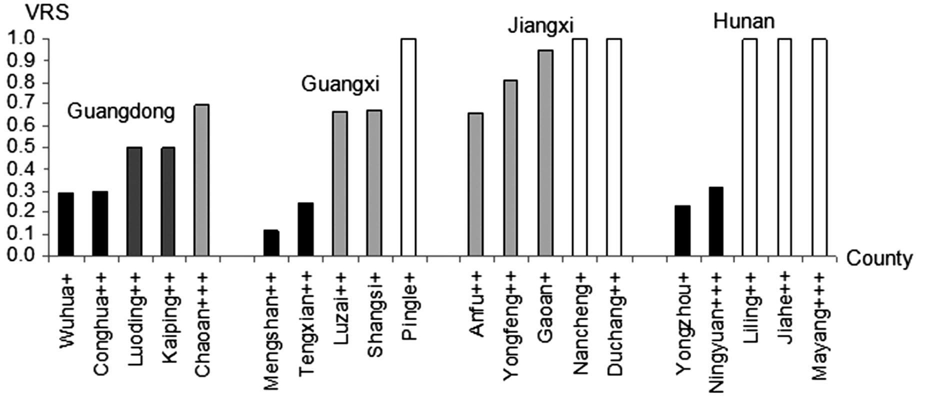

Figure 2: Comparison of the efficiency (white: efficient, light gray: mostly efficient, dark grey: less efficient, black: inefficient).

Table 2: Measurement and coding of conditions and outcome.[a]

Measurement		Coding
Conditions	Water pricing reform (P): Whether the project area of the county has reformed water pricing, normally increasing water rates to cover irrigation O&M costs.	Present: P,1 Absent: p,0
	Government funding (F): Whether the project area of the county has obtained external support of government funding for irrigation extension and maintenance.	Present: F,1 Absent: f,0
	Coordination by administration (C): Whether the local governments or village organizations of the project area in the county directly provide support WUAs' affairs e.g. making decisions, crafting and enforcing rules.	Present: C,1 Absent: c,0
	Formal monitors (M): Whether the project area of the county has formal monitors responsible for monitoring infrastructure maintenance and water distribution.	Present: M,1 Absent: m,0
	Self-organized management (S): Whether the project area of the county has authentic farmer water user organizations, e.g. WUAs, who, on their own, craft rules of operating and maintaining irrigation systems.	Present: S,1 Absent: s,0
Outcome	The efficiency distribution of (efficient, mostly efficient, less efficient, and inefficient) is calibrated by the four-value fuzzy set of (1, 0.67, 0.33, 0).	

[a]According to the procedure suggested by Basurto and Speer (2012).

To investigate how institutional factors affect irrigation governance, one important question is whether we can identify causal pathways. In the light of our theoretical framework of incentives and coordination, coupled with in-depth interviews with local participants, we identify five institutional arrangements that can affect levels of efficiency: water pricing reform, government funding, coordination by administration, employing a formal monitor and self-organized management. These qualitative data are then coded into scores for the QCA (see Table 2).

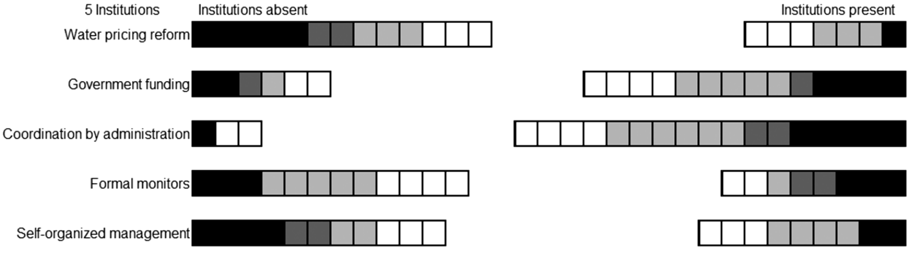

Figure 3: Layout of local institutions and efficiency (E) (cells: 20 key counties; color instruction: same as Figure 2).

Water pricing reform (P). This institution means that water rates have been reformed to cover all or part of O&M costs. In practice, this reflects increasing water rates. Generally, volume of irrigation water can only be measured at the WUA or village level. At the farm level, water quantity is only assessed by land area irrigated due to lack of measuring devices. Hence, farmers are still charged an area-based rate. Many irrigation districts relied on national water policy and charged agricultural water 20 CNY/ mu,[4] while others canceled water fees entirely and paid them via provincial finances. With subsidized water rates, farmers often wasted large amounts of water, and management struggled to cover routine costs of facility O&M. In order to rectify this situation, one of the priorities taken by some key counties has been to reform water pricing based around market forces. This aims to adjust the levels of water supply and demand simultaneously, to commercialize agricultural water use and to conserve water. Moreover, the additional revenue from commercialized water can create incentives for irrigation managers to invest more in operations and provide ongoing maintenance.

The idea that water pricing reform can result in efficient irrigation governance has proven quite successful, although not completely. Among the 20 key counties, 7 of them have reformed water rate and gradually increase the price by up to 50%, 6 of the 7 achieved scores of "efficient" or "mostly efficient" (see Figure 3). Interestingly, the remaining 13 counties do not reform water rate but 6 of them are efficient or mostly efficient as well. Thus, three issues are worth further examination: 1) whether irrigation systems with water pricing reform are associated with higher performance than the system without this institution, 2) whether the incentive function from this institution is not enough to create efficient governance, and 3) whether this institution needs to be combined with other rules to improve efficiency.

Government funding (F). This variable refers to local governments providing funds for irrigation extension and maintenance, not for the operation of WUAs. Normally these funds are transferred through village organizations in the form of subsidized public projects. This institution exists in most irrigation

[4] 1 mu=1/15 ha.

districts (see Figure 2). 14 counties have invested in large-scale irrigation facility building and maintenance at least one time before spring cultivation. Our detailed investigation also reveals two thought-provoking phenomena. 1) The farmers insisted that ongoing government input in facility repair and maintenance was required to maintain water distribution. With this support, problems with water distribution can be automatically resolved without the need for any canal monitoring. The existence of government investment in facility maintenance reduces water seepage and leakage, increases the duration of access to water and mitigates the temptation to break the rules. 2) They also recognize that the fiscal funds should be delivered directly to the village organization rather than the WUAs because the village organizations have more experience with large-scale projects than the WUAs.

For example, in Pingle, even before the implement of Key Counties Construction project, its government had invested in facility repair every winter. The village committees were responsible for supplying additional materials, motivating farmers to participate. That process did not involve obvious efforts from the WUAs, although new associations were created every year. It shows that efficient governance is more likely when one county has government funding, even without the participation of WUAs. We did find evidence of one contradictory approach in Yongzhou. There, the irrigation investment from the local governments was managed only by the WUAs rather than the village organizations, which resulted in significant inefficiency.

Coordination by administration (C). This condition examines whether or not local governments or village organizations withdraw from irrigation governance. It stresses the degree of their direct intervention in WUAs' affairs, e.g. making decisions, crafting and enforcing rules, etc. Figure 3 shows that this institution exists in 17 key counties. This makes it the most common institution under way in China, even while the amount of investment in irrigation is declining due to the decreasing revenue of the village organizations associated with the abolishment of agricultural tax. In theory, without this tax income, village organizations lack incentives to intervene irrigation affairs. Our survey reveals that it is the county governments that require the involvement of village organizations. Their participation was viewed as indispensable, not only in the whole process of decentralized management and irrigation governance, but also in the creation of WUAs.

However, on its own, the coordination by administration is not enough to generate effective irrigation governance, with only 4 out of the 17 counties achieving efficiency and another 6 mostly efficient. In particular, the craft of constructing facility has changed a lot, and modern systems have become more complex and technical. Wuhua and Luoding are the best cases to illustrate this problem. Their village committees have continued to organize farmers' participation, but this has not made much difference. Although the newly modernized irrigation system motivates the farmers to participate, the labor inputs are not enough for the facilities. The new irrigation facilities feature new hardened canal walls, which require additional large-scale capital investment and professional techniques to operate and maintain. As a result, the institution of coordination by administration is no longer sufficient for successful irrigation due to the need for additional capital inputs and professional management techniques.

Formal monitors (M). During the period of centralized irrigation management, monitors' positions were generally taken on by village leaders as part time jobs. They did not have incentives to enforce the monitoring rules, since their stipend was unrelated to irrigation performance. That is to say, informal monitors are more likely to be a position on paper rather than in practice. With the decentralization reform, the local governments regard the institution of formal monitors as a core means for WUAs to solve the problem of water distribution. A typically operative rule for many key counties is "distributing water by one hoe". This means that a monitor, using a hoe, controls all the water off-takes of the field canals. Besides this, the monitor's responsibilities also include supervising water withdrawals, collecting water fees and punishing water stealers. Accountability of monitors may be held by either the WUA or the farmers through general meetings.

This institution is present in 8 key counties, and the payment for the monitors represents both an economic reward of salary as well as respect in the community. For example, the monitors of Mengshan, also leaders of farmers groups, are paid 600 CNY each year by WUAs subsidized from the county government. The monitors of Pingle, ordinary farmers and WUA members, are paid 9 kg millets per mu irrigated area by the water users. Meanwhile, monitors in Yongfeng, also managers of the WUA, work for free.

What is more, this institution is occasionally associated with effective irrigation performance. Only 2 out of the 8 counties setting this position achieve efficient governance, and another 1 mostly efficient. The reason is that irrigation governance includes two parts of collective actions, coordinating infrastructure construction and water distribution. Both require resolution for effective governance. On these grounds, the monitoring institution generally requires additional institutions to resolve collective action dilemmas regarding infrastructure before water monitoring improves outcomes.

Self-organized management (S). In our study, self-organized management means that farmer water user organizations, on their own, craft rules to operate and maintain irrigation systems. We have counted situations in which rules were crafted with the efforts of WUAs including those contributed by farmer organizations such as clans and elderly associations. Additionally, we ruled out those WUAs, having autonomy and authority only on paper rather than in use.

Taking the clans as an example, they have authority to coordinate resources for facility O&M, and pay for these actions through farmer members sharing the total cost. Some clans, trusting the village committees, lobby and support them to form WUAs to take over the O&M responsibility, particularly in cases of canals that stretch across multiple villages. Only clans with a strong capacity to supervise the committees and have equal power to negotiate with them can guarantee that the WUA's interests are consistent with the farmers'. By gaining support from both the clans and the village committees, the WUA nicely couples the incentive and coordination functions. This process appropriately reflects the essence of efficient governance and accords with the purpose set by our analysis framework.

This institution is present in 9 key counties, 7 of them achieve efficient or mostly efficient. It is significantly associated with driving up the performance of government spending. Some efficient counties had self-governance in their WUAs even before the Key Counties Construction project, such as Mayang, Pingle and Jiahe. We take Mayang as an example to address the function and efficacy of self-organized management. In 2008, 12 WUAs were created across 38 villages, with 7015 households' participation and about 100,000 mu irrigated areas covered. These WUAs raised a total of 1.69 million CNY, a substantial increase when compared with the previous year. They also conserved 40% more water, reducing by 50% the time of water withdrawal while reducing water fees from 28 to 16 CNY/mu on average. Since the implementation of the Key Counties Construction project in 2009, the WUAs have substantially enhanced capacity related to irrigation O&M, and have grown into major management entities, capable of producing larger-scale benefits.

Other efficient counties, establishing of autonomous WUAs, completely stemmed from the project. For example, Liling actively laid a solid foundation for the creation of WUAs on the clans, after learning of the successful experiences in Mayang and Jiahe. In 2010, the project brought Liling a total investment of 16 million CNY, including 8 million CNY subsidies from the central government and the rest from local governments and farmers. This input generated huge efficiency gains with 1635 ha of newly added and rehabilitated irrigated areas, 5280 ha of improved irrigated areas, 127 million additional kg of food production capacity and 7.72 million m^3 of conserved water.

Principally, all the 20 key counties should have farmer-run water user organizations. Instead, 11 have nominal self-organized management, and these are gradually withering away. By 2011, Guangdong had established 1200 WUAs but many of these were soon disbanded. The most serious situation occurred in the county Kaiping, where 6 WUAs were revoked because they lacked incentives to engage in irrigation maintenance and struggled to sustainably operate so as to fail the annual inspection within 3 years.[5]

4. Results

4.1. Coding: causes and outcome

We use letters to mark presence or absence of condition for causes and outcome: upper case letter representing presence and lower case absence (see Table 2). The five local institutions, the causes, are coded respectively: 1) water pricing reform present P or absent p, 2) government funding present F or absent f, 3)

[5] Recently, the WUA has been formalized, which requires registration at the civil affair bureau. Only WUAs passing the annual inspection can continue to operate. If they do not pass the inspection, they are cancelled.

coordination by administration present C or absent c, 4) formal monitors present M or absent m, and 5) self-organized management present S or absent s. The efficiency of government spending is coded in the form of four-value fuzzy set, with (efficient, mostly efficient, less efficient, inefficient) meaning (present, more present than out, more out than present, absent) and correspondingly the first two being treated as present and symbolized as E.

4.2. Truth table and Boolean analysis

We use Boolean logic to clarify how configuration of local institutions may lead to efficient governance and to differentiate necessary and sufficient conditions. The first step is to understand how these 5 institutional causes were represented in the key counties. Generally they are found in combinations that vary in how they affect the efficiency of government spending. In Table 3, the existing condition is valued "Present" and the non-existing is valued "Absent". Some causal conditions are easy to code and value such as F\M\P, while other conditions like C and S are difficult to directly value "Present or Absent", which require careful judgment based on local history and case studies. We derive detailed descriptions and reviews about each case through interviews with locals in each county in order to value C and S inductively. First, two coders coded the 20 cases separately. Then, they discussed any disagreement directly and let a third coder decide the appropriate coding, in an effort to increase inter-coder reliability.

Boolean logic is then used to build a truth table and list all the configurations generated by the 5 local institutions. The truth table shows that these 20 cases generate 14 different configurations. As the last column of Table 3 shows, some configurations contain multiple counties, others include only one.

4.3. Simplifying and explaining the institutional configurations

We use fs/QCA software[6] to extract the institutional configurations leading to efficiency (E) in government spending. The truth table solution generates four simplified causal pathways ("FmC", "PFMS", "PmCS" and "pfmcS") to the given outcome E, as shown in Equation (1). The symbol of "+" represents the logic relationship "OR" and the "×" represents "AND". Two parameters of fit in QCA are consistency and coverage. Consistency measures the degree to which institutional configurations are always associated with an outcome and values >0.75 indicates high consistency. Coverage evaluates the percentage of cases with the outcome they explain and a score closer to 1 is better. In our study, the overall solution consistency value is 0.820 and solution coverage score 0.845, which demonstrate the 4 pathways a good fit to the cases.[7]

$$E = FmC + PFMS + PmCS + pfmcS \tag{1}$$

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[6] Software by Ragin is freely available at http://www.u.arizona.edu/~cragin/fsQCA/.

[7] As for the inefficient configurations, they are individual cases and not enough to represent the common features of failure. Therefore, this paper can not show their local conditions.

Table 3: Truth table of causes and outcome.

5 causal conditions					Number of key counties
P	F	M	C	S	
Absent	Present	Absent	Present	Absent	3
Absent	Present	Present	Present	Absent	3
Absent	Absent	Absent	Present	Absent	2
Present	Absent	Absent	Present	Present	2
Absent	Absent	Absent	Absent	Present	1
Absent	Absent	Present	Present	Absent	1
Present	Present	Present	Present	Present	1
Absent	Present	Absent	Present	Present	1
Absent	Present	Present	Present	Present	1
Present	Present	Absent	Present	Absent	1
Present	Present	Absent	Present	Present	1
Present	Present	Present	Absent	Present	1
Present	Present	Present	Present	Absent	1
Present	Present	Present	Present	Present	1

Considering our critical research contents, we identify and investigate three groups of questions from these results. They aim to examine the roles and relationships of the multiple participants (government, market and WUAs) and the institutions used in decentralized irrigation management. First, how important is C or F in generating efficient outcomes? Can C or F be removed from the local institutions entirely? What are the supporting conditions for C or F in order to increase irrigation performance? Second, how important is the institution P or M in improving the efficiency of government spending, and is either of them a sufficient condition? If it is not, what kind of institutional environment can support P or M in increasing efficiency? Third, since one of the main objects of the Key Counties Construction project is to promote WUAs to find ways to manage irrigation, is S a sufficient condition? In order to elaborate on these questions, we adjusted Equation (1) into a factored Equation (2) based on logic following standard QCA methodology.

$$E = \underbrace{FmC}_{\substack{\text{Government} \\ \text{governance}}} + \underbrace{PS(mC+FM)}_{\substack{\text{Mixed} \\ \text{governance}}} + \underbrace{pfmcS}_{\substack{\text{Self} \\ \text{governance}}} \tag{2}$$

Equation (2) is comprised of 3 pathways of institutional combinations. Any pathway is sufficient to generate effective irrigation governance and efficient government spending.[8] The following will analyze the statements of these pathways in detail.

[8] Fieldwork shows that self-organized management (S) embodies two kinds of capacity. The WUA with strong capacity can completely govern irrigation system on its own. In this situation, S is sufficient for efficient outcome, which is the third pathway of configuration. While the weak WUA, with no powerful authority, is not able to manage irrigation independently. Apparently in this situation, S requires support from other institutions, which is the second configuration.

We entitled the first pathway “FmC” as “government governance”, with traditional centralization making sense. The existence of both coordination by administration and government funding (FC) is a sufficient condition for efficient outcomes (E), and the use of a formal monitor may be absent (m). This configuration could contribute to illustrating two phenomena. First, in practice, this institutional condition FC has been prevalent in the efficient key counties with weak autonomy of WUAs, such as Chaoan, Liling and Luzhai. It also turns out that in the governance environment of theses remote areas, only local governments and village organizations having enough authority and capacity to engage in irrigation management. Second, comparing FmC with PSmC (the second pathway), F seems to have an equal effect with PS, which means F can be substituted by PS. That is if the government does not provide funding for irrigation O&M due to fiscal problems, the governance responsibility may be transferred to the WUAs themselves along with the reform of water pricing. This substitutable relationship may explain the initial intention of transferring management power from governments to WUAs or market forces, as has occurred in the developing and transition countries since 1970s (World Bank 1994).

The second pathway “PS (mC+FM)” indicates a “mixed governance” structure including markets, water user organizations, formal monitors and government entities. The presence of PS is necessary, not sufficient, for E, and either the presence of C or the combination of FM is indispensable for PS to work. This configuration connotes three significant points. First, the interactive relationship between P and S asserts that the debate about whether water pricing reform or self-organization is more important than the other (World Bank 2011) is not appropriate. Indeed, these two institutions depend on each other, and the presence of both can generate efficient when combined with other situations. Second, the combination of PSFM is like the “Americas model” describing governance in the Columbia Basin, Mexico and Chile (Meinzen-Dick 1997), which features the formalization of irrigation organizations, specification of professional roles and emphasizing farmers’ water rights. We can expect that the combination of PSmC may shift to PSFM in future, and the function of C could be substituted by FM. Third, comparatively, this configuration requires multiple conditions and is the most complex among the three institutional configurations that lead to efficiency. However, this mixed governance structure also dominates in the efficient key counties, with Duchang, Anfu, Mayang and Gaoan occupying 1/3 of the total. We view this as potentially a transition governance structure from government-led to a system of self-governance.

We have titled the third pathway, “pfmcS”, as “self governance” with only farmer water user organizations, generally a WUA, in the leading role. In this configuration, self-organized management (S) is the sufficient condition, and other institutions may be absent (pfmc). Obviously, a WUA could completely substitute either market or administrative intervention to work independently. However, this efficiency is a low probability event, and is only present in one key county, Jiahe. Our fieldwork further demonstrates that Jiahe takes on an equal level of power between the WUAs and the local governments. Aggregating more than 20 ethnic minorities, their leaders are also WUA chairmen and relatives of the local officials. As a result, these three parties overlap and share common social norms. This pathway to efficiency is not likely to emerge in other counties and would be difficult to duplicate around China, due to its distinct social organization and unique institutional environments. Recent research also provides evidence that these local conditions did exist in China before 2005, when the traditional villages were still poor and isolated, featured strong social institutions and were not greatly affected by globalization and market access (Xu and Yao 2015). Likewise, this configuration, as a typical "Asian model", is familiar in other developing counties such as Nepal, India, Philippines and Sri Lanka (Meinzen-Dick 1997).

5. Conclusions and suggestions

Our study assesses the efficiency of government spending and explores how local institutions affect this efficiency during the process of decentralized irrigation management. We emphasize three main conclusions. These conclusions provide insights for policymakers on which local institutions to emphasize, differentiates among the responsibilities of the government, market and farmer water user organizations, and supports WUAs in crafting rules of irrigation O&M.

(1) The diverse contexts for applying local institutions have resulted in decentralization producing rather different efficiencies in government spending. Cases of inferior performance reflect that some provinces lack the necessary conditions that decentralization requires. With a trend of continuing decentralization, the central government, not knowing about local institutions, anticipates exchanging irrigation investment for deepening decentralization and the promotion of WUAs through the Key Counties Construction project. Importantly, it has directed large-scale capital spending to build and rehabilitate irrigation systems, with unbalanced results. In some cases, inappropriate institutional arrangements are counteracting the performance of decentralization and investment.

On the other side, the Key Counties Construction project has indeed played a leading role in strengthening some local institutions. First, the capacity of coordination by administration from village organizations has improved and village leaders have strengthened their own roles. Second, the reform of water pricing has been introduced into some counties and has enhanced farmers' awareness of the full price of water. Third, WUAs have the opportunity to develop and acquire the right to supervise government projects, as well as create a platform to craft rules for irrigation O&M. This has increased the interactions among farmers and helped them to learn their own importance in irrigation governance.

(2) In our sample area of southern China, 12 counties (60%) scored as efficient or mostly efficient, with each taking one of three institutional pathways to efficiency. In some counties, such as Chaoan, Liling and Luzhai, the configuration of "government funding combined with coordination by administration (FC)" is a sufficient condition. In others "water pricing reform combined with

self-organized management institutions (PS)" are necessary, along with additional institutions to work efficiently. Both Duchang and Anfu also require coordination by administration (C), while Mayang and Gaoan require both government funding and a formal monitor (FM). As mentioned previously, in the third pathway used in Jiahe, self-organized management (S) is sufficient.

(3) Current irrigation policies are formalizing effective local institutions, but they are still not sufficient. As Meinzen-Dick (1997) addresses that the "Americas" model, featured with specialized and formal irrigation organizations, is one direction in which the "Asian" model could transit. However, current Chinese policies of Key Counties Construction and decentralization, both stress the investment institution of government funding (F) and the government structure of coordination by administration (C) and self-organized management (S). Although these policies encourage reforming water pricing (P) to regulate water demands, formal documents of new water prices have not worked out at local level across the country. So far, they have not touched on the other institution of formal monitors (M), let alone formalize it. Furthermore, the investment policy and government funding institutions are not water law and may only work in the short term.

Therefore, future policies are needed to promote the institution of government funding into water law and build stable expectations for both WUAs and farmers, guide water pricing reform by ensuring farmers' water rights and regulating water markets, and to provide opportunities for hiring professional monitors and crafting formal rules.

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