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Bureaucratising Co-production: Institutional Adaptation of Irrigation Associations in Taiwan

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ABSTRACT: In 2020, Taiwan's 17 irrigation associations were bureaucratised to become management offices of the Irrigation Agency under the government's Council of Agriculture. This change marked the end of the parastatal mode of irrigation management that has in past decades played an important role in fostering Taiwan's agricultural and economic development. As these parastatals have always been hailed by the international water research community as exemplars of co-production and state-community synergy, the change is baffling. While irrigation management in many places around the world has been moving towards a higher degree of decentralisation and self-governance, Taiwan seems to be moving in the opposite direction. How can we make sense of this change? What are the driving forces behind it? Does the bureaucratisation of the irrigation associations signify a failure of the co-production model? By tracing the evolution of irrigation institutions in Taiwan, this study examines the dynamic of institutional change as a response to the island's changing political economy. The study shows that changes in the macropolitical-economic context prompted the Taiwanese government to reconsider two imperatives that underlie the institutional design of irrigation associations: robustness trade-offs and the modus operandi of co-production. The bureaucratisation of irrigation associations was an institutional manifestation of the adjustment of the two imperatives in adapting to the changing political economy.

KEYWORDS: Irrigation associations, robustness trade-offs, co-production, institutional change, Taiwan

INTRODUCTION

Taiwan's irrigation institutions have long been hailed by the international water research community as exemplars of co-production and state-community synergy (Sakthivadivel et al., 2001; Bray, 1986; Lam, 1996, 2006; Lam and Chiu, 2016). The parastatal design of Taiwan's 17 irrigation associations (IAs) (see Figure 1) is arguably able to combine, on one hand, effective farmer participation in irrigation operation and maintenance (O&M) and, on the other, professional management of irrigation infrastructure as well as strong government support (Moore, 1989; Lam, 1996, 2001).[1] In Taiwan, however, such a rosy picture has been cast into serious doubt in recent decades. The parastatal design has been portrayed by some policy actors as a major cause of the problems facing the irrigation sector. Since the 1970s, there has

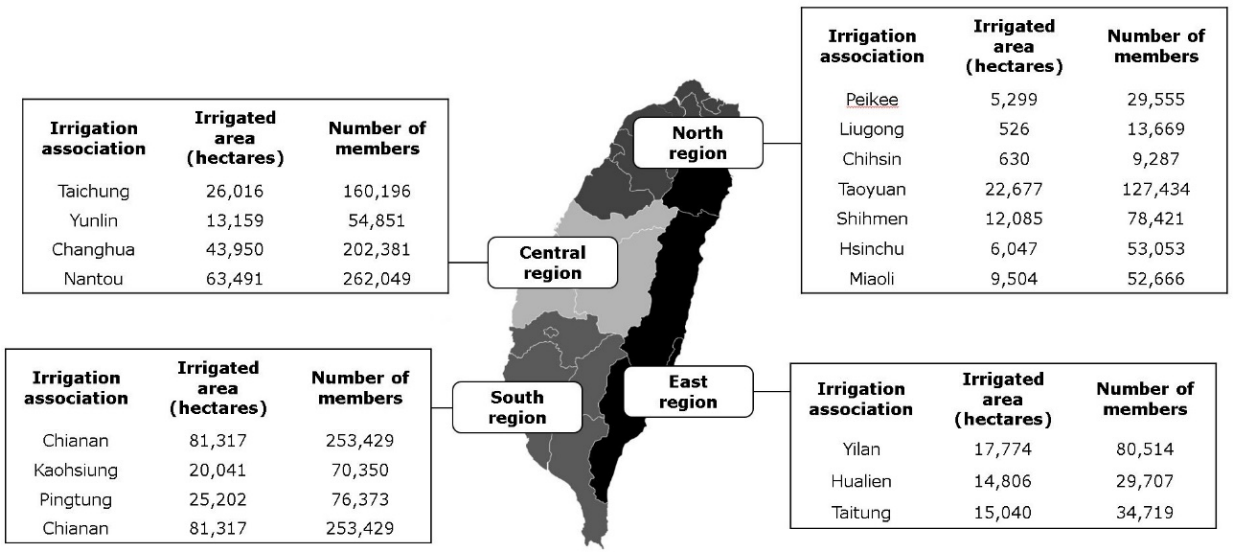
[1] Parastatals refer to organisations that are not part of the government yet perform public functions, serve public purposes, and sometimes exercise public authority and are funded by public finance. While parastatals have some characteristics of public organisations, they usually enjoy a high degree of autonomy and are subject to little government intervention in their operations (Lam, 2001: 1570).

been attempt after attempt by the national government to bureaucratise these autonomous, community-embedded institutions.

In 2018, after decades of debate and tinkering, legislation was passed that kickstarted the process of turning the parastatal IAs into government agencies. In October 2020, the 17 IAs in Taiwan were formally changed into management offices of the Irrigation Agency under the government's Council of Agriculture and, with that, the parastatal mode of irrigation management became history. Such a development is baffling; while irrigation management in many places around the world has been moving towards a higher degree of decentralisation and self-governance, Taiwan seems to be moving in the opposite direction (Shivakoti et al., 2005). How can we make sense of the change? How is this process unfolding and what are the driving forces behind it? Does the bureaucratisation of the IAs signify a failure of the co-production model? These questions pertain not only to the future development of Taiwan's irrigation, but also to the viability of co-production and self-governance and their relevance to the management of irrigation and other rural resources amid rapid economic development and urbanisation.

In this study, we document and trace the evolution of irrigation institutions in Taiwan. The paper offers conjectures about how the island's changing political economy has influenced the dynamic of institutional change. Our study shows that changes in the political economy have prompted the government to reconsider two imperatives that underlie the institutional design of IAs: robustness trade-offs and the modus operandi of co-production. The bureaucratisation of the IAs was an institutional manifestation of the adjustment of the two imperatives in adapting to the changes.

Figure 1. The 17 irrigation associations, before bureaucratisation.



Irrigation association	Irrigated area (hectares)	Number of members
Taichung	26,016	160,196
Yunlin	13,159	54,851
Changhua	43,950	202,381
Nantou	63,491	262,049

Irrigation association	Irrigated area (hectares)	Number of members
Peikee	5,299	29,555
Liugong	526	13,669
Chihsin	630	9,287
Taoyuan	22,677	127,434
Shihmen	12,085	78,421
Hsinchu	6,047	53,053
Miaoli	9,504	52,666

Irrigation association	Irrigated area (hectares)	Number of members
Chianan	81,317	253,429
Kaohsiung	20,041	70,350
Pingtung	25,202	76,373
Chianan	81,317	253,429

Irrigation association	Irrigated area (hectares)	Number of members
Yilan	17,774	80,514
Hualien	14,806	29,707
Taitung	15,040	34,719

Source: Council of Agriculture, Executive Yuan (2020).

CO-PRODUCTION AND INSTITUTIONAL CHANGE IN IRRIGATION GOVERNANCE

Co-production connotes a process in which government managers and citizens are engaged collaboratively in the production and delivery of public goods and services. Instead of being passive service recipients, citizens participate directly in service production through resource contribution, engaged collaboration, and complementary behaviours (Lam, 1996, 2006). Co-production needs not to be formally organised; citizens' daily behaviour could, advertently or not, contribute to the co-production process. In irrigation management, for example, timely and immediate repair is essential to keeping

canals in good condition and thereby minimising water seepage. Given that an irrigation system often serves a large area with extensive networks of canals and ditches, it is unrealistic to expect irrigation managers to be able to detect and fix canal damage as quickly as they should. Instead, farmers' willingness to monitor and repair minor damage during their work in the field is essential to effective system maintenance.

Research has shown that co-production can create a synergy that not only enhances service delivery efficiency but also improves citizens' satisfaction (Addison, et. al.; 2019; Goodwin, 2019). In irrigation, effective water diversion, storage, and delivery at the watershed level hinge on government managers' professional operation and maintenance of large-scale engineering infrastructure. After the water has reached the fields, however, the equitable and timely allocation of irrigation water to individual plots depends on farmers' ability to organise collective actions. Effective irrigation management, therefore, requires a high degree of complementarity between government involvement and professional management at the system level, and self-governance and extensive use of local knowledge at the local level; neither can perfectly substitute for the other.

Besides complementarity, co-production also pertains to weaving the decisions and actions of irrigation managers and farmers in a productive manner. In Taiwan, farmers engaged in close daily interactions with frontline managers of IAs; in doing so, they effectively performed the function of third-party monitoring, and any mischievous behaviour or maladministration on the part of the managers would be readily detected and conveyed to the IAs through their close social networks. By the same token, the presence of IA managers at the local level was able to help foster conflict resolution among farmers and reduce deviant behaviours in the field (Lam and Chiu, 2016). Institutions that facilitate and sustain effective co-production thus hold the key to irrigation success.

Irrigation systems and institutions, however, do not exist in a vacuum; they are embedded in the political economy of particular jurisdictions (Lansing, 1987). In other words, irrigation institutions are nested within macro governance institutions and within their particular sociopolitical context. Institutional change and evolution can take place through two mechanisms: bricolage and synoptic steering. Bricolage is the accretion of techniques and solutions produced over time by a bottom-up search process (Cartel et al., 2014). In the day-to-day operation of irrigation systems, farmers and irrigation managers encounter a host of problem scenarios. Some are one-off incidents that can be tackled through immediate ad hoc remedial actions; others, however, persist or recur over a long period of time and can be a sign of systemic inadequacies. To cope with them, farmers and irrigation managers must work together to find solutions; they must collaborate on making changes to local institutions, modifying the rules that stipulate how irrigation operation and maintenance is conducted in the field (Meinzen-Dick, 2007).

As a majority of these local institutions are rules-in-use rather than rules-in-form (Schlager and Cox, 2018; Ostrom, 2005), evolution tends to be slow and sluggish. It often requires substantial coordination, negotiation and tinkering among farmers and irrigation managers in the field, and the search for feasible solutions may require resorting to bricolage (Cleaver, 2005, 2017; Andersen, 2008; Ostrom, 1998). This is time consuming and usually takes place in a piecemeal manner; as such, it is not an effective way to respond to external shocks and macro systemic changes.

Alternatively, institutional changes can be initiated and steered by public authorities in a synoptic manner. In East Asia, governments have never hesitated to take the lead in implementing institutional change. Civil-law states such as Japan and Taiwan, in particular, consider their role to be one of steering society, whereby they can freely opt to convert civic associations into public legal entities to which they can assign specific tasks. IAs are public legal entities which have been created by the Taiwanese government and whose existence, authority and duties are all legally defined; if the government deems it appropriate, it can redefine their structure and function through revising relevant laws and regulations.

Tracing the evolution of Taiwan's irrigation institutions can shed light on how the changing political economy has modified the imperatives upon which the continued success of the parastatal model of irrigation management depends. It can also clarify how and why the government has responded to these changes by bureaucratising the IAs. Specifically, the Taiwanese government has been caught in the dilemma of, on the one hand, acquiescing to the IAs' autonomy in order to reap the benefits of co-production and, on the other, tightening its control over the IAs so as to bring them in line with efforts to cope with policy problems affecting society as a whole. The IAs, in the meantime, have been trying to strike a balance between soliciting subsidies and support from the government in order to survive, and preventing the government from reducing their autonomy.

The authors of this paper have studied irrigation governance in Taiwan – and particularly IAs – for more than two decades. The documentary data and archival information that have been collected over the years of research provided the empirical basis for the tracing of the evolution of Taiwan's irrigation governance; this data was further supplemented by detailed archival research. To capture ideas and concerns with regard to irrigation governance and institutions, in-depth interviews were conducted with key stakeholders, including farmers (landowners and tenants, organic and traditional), incumbent and retired cadres of the IAs, environmentalists, public officials in water conservation and agricultural agencies, and an assistant to a legislator.

EVOLUTION OF IRRIGATION INSTITUTIONS IN TAIWAN

The institutional foundation

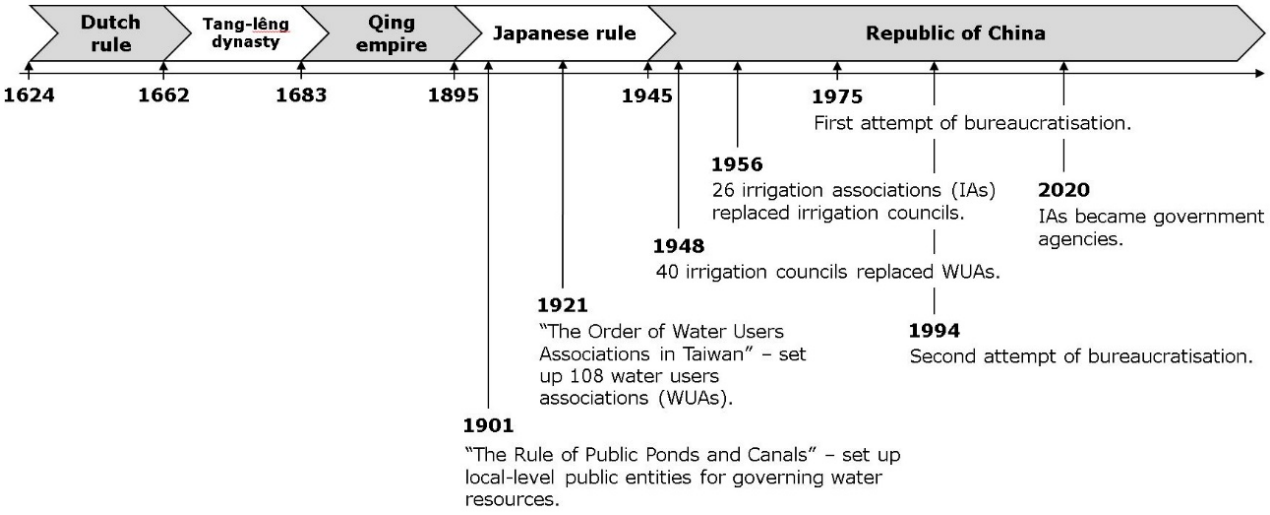
Irrigation in Taiwan has a long history. Before the Japanese established colonial rule in 1895, irrigation in Taiwan was primarily provided and managed by private individuals or entities. Under Dutch rule in the 17th century, primitive irrigation systems were built to facilitate resource plundering. Between 1661 and 1683, during the time of the Tang-lêng Dynasty (東寧王朝), when a large number of soldiers retreating from the Chinese mainland generated a strong demand for staple foods, substantial efforts were made by public authorities to develop irrigation as a means to foster rice cultivation on the island. After the Qing Empire took over the island in 1683, migrants from the mainland invested heavily in irrigation to utilise its agricultural potential. In order to make water available for agriculture during dry seasons, wealthy private developers mobilised large amounts of capital and organised Reclamation Establishments (墾號) to acquire lands and construct irrigation infrastructure. These entities collected fees from water users to support the operation of irrigation systems (Bottrall, 1977; Tsai, 1998; Tung and Pai, 2015).

This private system of irrigation management, however, suffered many limitations. First, the scale and scope of these systems were often constrained by the limited financial capacity of the developers. Second, these small-scale systems usually did not have enough storage capacity to regulate the water flow in canals, and hence could not ensure a reliable water supply. Third, as these irrigation systems were largely profit driven, the high maintenance costs of the irrigation infrastructure were often passed on to farmers through high water fees. Finally, as water was an important resource for both farming and household use, the loosely defined water rights often resulted in violent conflicts among villagers or between villagers and other stakeholders.

Government involvement in irrigation management remained minimal until the beginning of Japanese colonial rule in 1895 (Ka, 1995). Adopting a policy of "Industrial Japan, Agricultural Taiwan", reform measures were implemented to turn the island into a granary for the imperial master. At the beginning of the 20th century, the colonial government nationalised irrigation through the "Rule of Public Ponds and Canals" (公共埤圳規則), which enabled it to set up local-level public entities in different places to govern and manage water resources for agricultural purposes (Abel, 1976; Tung and Pai, 2015). These

were legal public entities with specific duties and authorities, the establishment of which represented a shift of irrigation management from the private to the public domain (Chen, 1997: 406-7).

Figure 2. Chronology of the development of irrigation associations.



Institutionalisation of farmers' participation

In setting up legal public entities, the colonial government confiscated privately owned water sources, irrigation facilities, and the lands on which those facilities were built. The government's actions were met with resistance and public protest, and violent conflicts arose in some locales. To pacify the discontented populace, the colonial government implemented major institutional changes to these legal entities according to a Japanese 'water users association' model (水利組合).[2] In the decades that followed, a series of ordinances were promulgated that converted the public legal entities into water users associations (WUAs).[3]

The governance structure of the WUAs allowed a certain degree of participation of water users, who could elect their representatives to sit on the 'board of regents' (評議會) which ran the WUA. The former owners of the confiscated properties were given memberships on the board as compensation for the loss of their water source. The WUAs presumably exercised collective ownership of the associations' properties; they owned and allocated the water for agricultural purposes and had the power to make managerial decisions regarding the operation of the associations. Under each WUA, a network of water user groups was set up to help manage water allocation and minor system maintenance at the field level. After WUAs were converted to irrigation associations (IAs) and smaller IAs were merged into bigger ones, a network of local IA offices – called working stations (WSs) – was set up to coordinate water allocation and system maintenance at the district level. While a majority of the WUAs had only basic water storage

[2] To control the highly autonomous, scattered irrigation governing systems, the colonial government promulgated a series of laws on arable lands, rivers, forests and water users associations; together, these constituted a comprehensive governing structure to maintain food security (Chen, 2009).

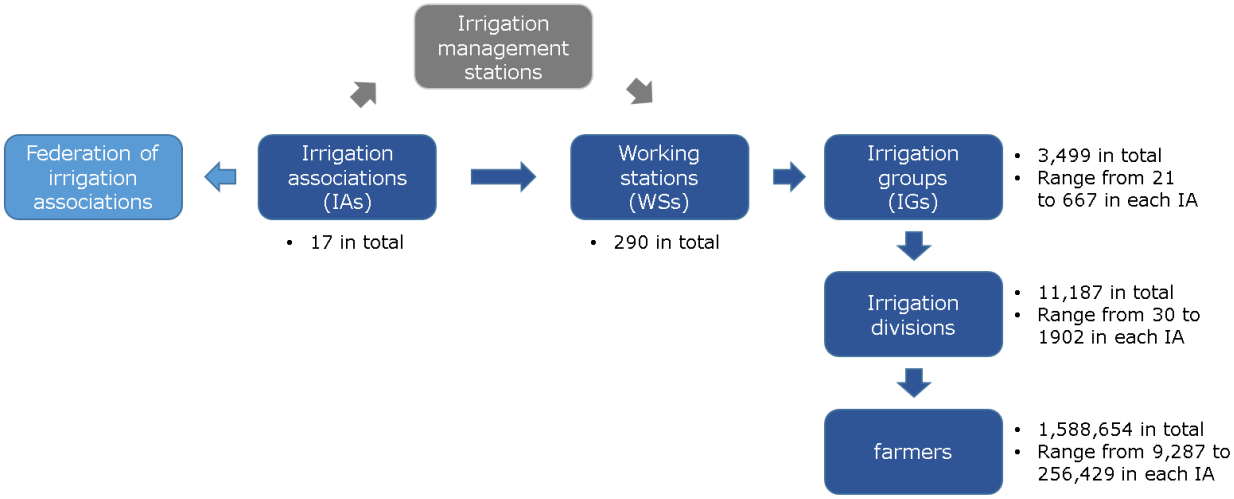
[3] In 1921, the colonial government enacted the Order of Water Users Associations in Taiwan (台灣水利組合令), kickstarting a decade-long process of turning the existing public legal entities into 108 water users associations (WUAs) all over the island. In 1941, the number of the WUAs was cut down to 47, and in 1944 the number was further reduced to 38. The merger of smaller WUAs into bigger ones was meant to facilitate water allocation and to leverage the economies of scale of irrigation infrastructure (see Wu, 2018; Council of Agriculture, 2003).

facilities, some managed large reservoirs and major irrigation systems. These IAs often set up reservoir management offices (RMOs) to manage this large-scale infrastructure (as indicated in Figure 2).

The government maintained a high level of control over the WUAs;[4] for instance, the colonial governor of Taiwan could appoint the chiefs (組合長) of the WUAs, who were required to "consult with", but not take orders from, elected representatives. With the establishment of these public entities, several large-scale infrastructure projects were launched, all funded by the colonial government.[5]

After World War II, the Chinese Nationalist Government (the Kuomintang, or KMT) took over Taiwan and inherited the irrigation infrastructure and institutions from its colonial predecessor. To rebuild the island's economy and strengthen its food security against the threat from Communist China, the KMT implemented a series of reforms, including its famous land reforms.[6] Improving the island's irrigation efficiency was considered to be of major importance to the revitalisation of the island's economy; this important task was assigned to 40 parastatal 'irrigation councils' (水利委員會), which had succeeded the water users associations.

Figure 3. Structure of irrigation associations in Taiwan before 2020.



Source: Council of Agriculture, Executive Yuan (2020)

Note: The number of working stations (WSs), irrigation groups (IGs), irrigation divisions, and farmers shown in the figure are 2019 statistics.

The irrigation councils retained the participatory model with an emphasis on the compulsory membership of water users. Each member was required to pay a water fee; this was not merely a service fee but was, more importantly, a duty that signified farmers' ownership of the IAs. Compulsory

[4] Its strict control over the WUAs allowed the colonial government to adjust the levels of production of the two major crops in Taiwan at the time – paddy rice and sugar cane – so as to maximise their market value (Ka, 2003).

[5] The sizes of cultivated areas and irrigated areas at the beginning of colonial rule were about 350,000 hectares (ha) and 105,000 ha, respectively. By the time colonial rule ended, the size of the cultivated areas and irrigated areas had increased to 860,000 ha and 520,000 ha, respectively (Council of Agriculture, 2003).

[6] The Nationalist Government carried out a series of land reforms in 1949, 1951 and 1953. The first reform reduced and fixed the level of land rents at a maximum of 37.5% of the tenants' harvests. The second reform allowed the tenant farmers who were renting state-owned lands to buy the land at relatively low prices, which were set by the government. The third reform involved expropriating arable land from landlords and reselling it to tenant farmers; the landlords were given shares of state-owned enterprises as compensation (see Apthorpe, 1979).

membership had many advantages – it helped 1) pool farmers' resources for irrigation construction and maintenance, 2) overcome resistance from local farmers in the process of land acquisition for irrigation purpose, and 3) resolve disputes in water allocation in the field. To provide incentives for participation and to empower water users, council members were granted the right to elect their representatives and the organisations' decision-makers. Major decisions were made collectively in an assembly, with some seats being filled by individuals elected through member voting and others by government appointees. The council's chairperson was elected by members of the assembly and was given the authority to, and duty of, managing the operation of the council. Engineers and professional irrigation managers were hired to manage and operate the systems; a network of self-governing irrigation groups, which was formed and run by water users, was given water allocation and system maintenance tasks at the local level.[7]

In the 1950s, Taiwan started its early democratic reforms; these allowed elections for local-level public offices, including city mayors and members of city councils. Riding on this momentum, irrigation councils became irrigation associations (IAs); these were given more power and autonomy, including the power to choose their leaders through popular elections (Chiu et al., 2011).[8] Given that the IAs controlled substantial resources and assets and received heavy government financial subsidies, keeping the IAs accountable politically and administratively was considered a major challenge. As the IAs managed large networks of farmers, of which the influence penetrated deep into rural communities, they were effective tools for the government to impose social control. During colonial times, cadre positions in water user associations were often used as a pawn to solicit the support of local elites for the colonial regime.[9] Ironically, the Nationalist Government found itself in a position similar to that of its colonial predecessor. As an alien regime, an effective way to secure the collaboration and loyalty of the local elite was to develop political patronage through using the resources of the IAs, including cadre positions, construction contracts and monetary benefits (Chiu et al., 2011).

Under each IA, working stations (WSs) were set up in different areas to help manage irrigation O&M at the district level; under the jurisdiction of each WS, a network of irrigation groups (IGs) was set up which was made up of self-governing bodies of water users. The IGs were given a range of responsibilities, from water distribution to participation in irrigation planning and conflict mediation. In rural Taiwan, managing these seemingly trivial irrigation tasks was considered a matter of social status and recognition by the government. Local farmers who had good social standing were often keen to serve as IG leaders.

The IA managers stationed at the WS were able to develop patron-client relationships with local elites (Lam, 1996, 2006; Moore, 1989). Given that the Nationalist Party had tight control over the IAs through appointments and government subsidies, the IA staff at the WSs often found themselves heavily involved in local politics. In many instances, they were the political brokers who cultivated and managed patron-client relationships between the Nationalist Party and local factions. The resources of the IAs were often used by local politicians for political mobilisation purposes and the patron-client relationships that the IAs controlled became an important resource for politicians campaigning in local elections. Those who won local elections with the support of the IAs would return the favour through channelling more resources to the associations. When these local politicians gained access to public office at the national level, they would further solicit resources to strengthen the IAs (Chiu et al., 2011).

[7] The two major sources of funding for irrigation construction and O&M were government subsidies and water fees collected from farmers. In the 1950s and 1960s, a period when the government was making substantial investments in irrigation, government subsidies were the major funding source. A significant portion of the subsidies came from USAID and the Sino-American Joint Commission on Rural Reconstruction (Chiu et al., 2011).

[8] In 1956, the 40 irrigation councils were changed and combined into 26 irrigation associations (IAs); in 1981, the number of IAs was further reduced to 17.

[9] IA cadres were addressed by farmers as Your Honour (大人), which was evidence of the cadres' prestige.

Depoliticisation of the IAs

Beginning in the 1960s, the adverse consequences of the highly politicised system began to surface and the cost of maintaining the system had also attracted substantial public attention. First, the system's marginal benefit of stabilising Taiwan's rural areas had begun to diminish as the Nationalist regime had consolidated its political control. In fact, as the rural population began to decrease due to urbanisation and economic development, the number of votes that the IAs could control and deliver to the Nationalist Party decreased drastically.

Second, with the demise of agricultural production in Taiwan, the value of the irrigation services provided by the IAs decreased substantially. As paddy agriculture was abandoned in many places on the island, the demand for irrigation declined. Since the late 1960s, the acreage of rice fields continued to shrink as domestic rice consumption dropped; moreover, with rapid urbanisation and industrialisation, large areas of agricultural land were rezoned for commercial, industrial and residential purposes.[10] As irrigation lost its importance, the roles and functions of the IAs became less significant.

Third, technological advances such as electric pumps have turned irrigation management into a convenient individual exercise, rendering large-scale collective action unnecessary. By the 1970s, electric pumps had become so inexpensive that many farmers could afford to install them in their fields to pump up groundwater.[11] From the farmers' perspective, groundwater was a better alternative to the often-polluted surface water provided by the IAs. Although the over-appropriation of groundwater could result in such disastrous consequences as land subsidence, the issue did not attract much public attention until the late 1980s.[12]

As the functions of the IAs became more dispensable and the cost of maintaining them continued to increase, reforms became imperative. They were implemented in 1975 to attain two objectives. First, in order to reduce the IAs' role in political patronage, elections of farmer representatives and chairs of the IAs were suspended and, instead, these offices were filled by government appointees. Second, to break up the local patron-client networks and increase administrative efficiency, some IAs were merged; this reduced the total number from 22 to 14 and, in the process, the size of the IA staff was halved.[13]

The reforms, however, encountered setbacks. In the 1977 elections, the ruling Nationalist Party suffered significant losses.[14] The message was clear: the ruling party was unable to maintain effective political control at the local level without the help of the patron-client networks sustained by the IAs and other local organisations. As a remedy, the government halted the depoliticisation process and reinstated elections for IA chairs and farmer representatives.

The ruling Nationalist Party's dilemma remained: on the one hand, the party relied on the IAs for political mobilisation at the local level; on the other hand, maintaining the system was getting increasingly costly as a significant portion of the resources channelled to the IAs was spent on rent-seeking activities. Perhaps more importantly, as the IA leaders gained more political influence through patron-client relationships, they became more autonomous and gained more bargaining power vis-à-vis the Nationalist Party. The risk of their defection to the opposition party became a serious concern.

[10] In 1956, 73% of Taiwan's rural labour force was engaged in agriculture; the number dropped to 54% in 1966. Between 1960 and 1970, the proportion of full-time farming households dropped from 45% to 30% (see Ho, 1979).

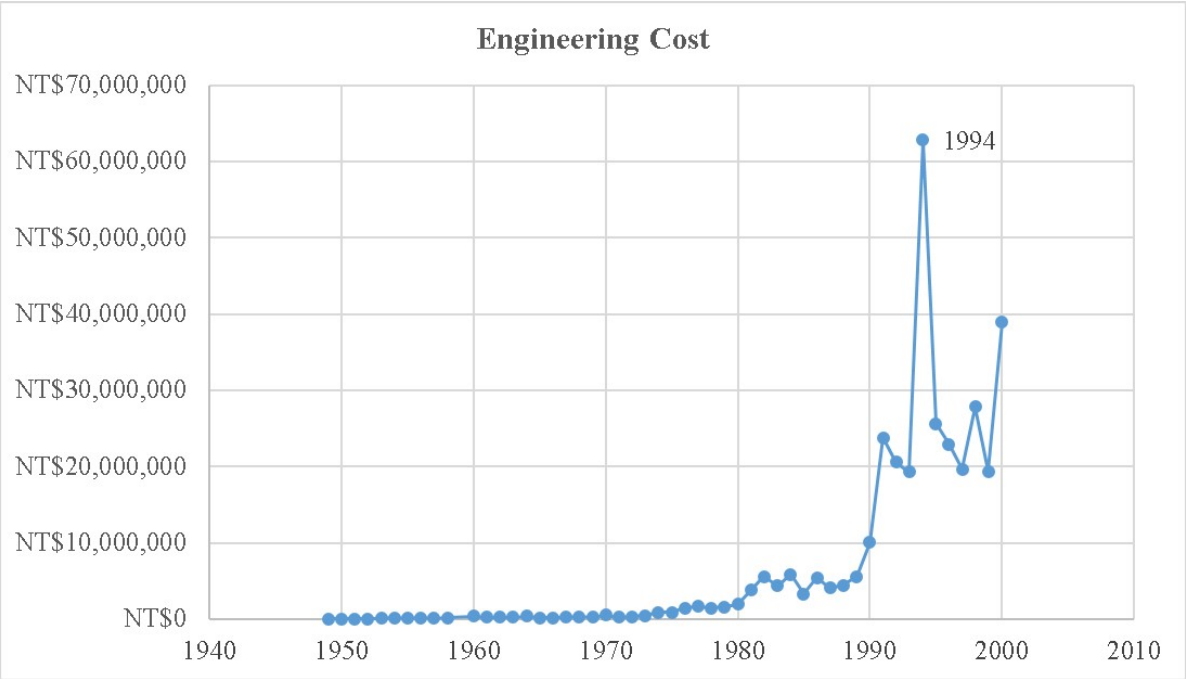
[11] Since 1950, the percentage of the water supply sourced from groundwater has increased annually. By the 1970s, groundwater made up more than 20% of the total water supply (see Peng et al., 2008).

[12] In addition to rice fields, aquafarms that were sensitive to pollutants were also heavy users of groundwater (see Tang and Tang, 2006).

[13] For example, the largest IA, Chianan, downsized drastically from 4203 to 1203 employees in only a few years (Chianan Irrigation Association, 1992).

[14] In that year's mayoral elections, 4 out of 20 KMT-nominated candidates failed, compared to 0 out of 20 in the previous year.

Figure 4. State investment in irrigation associations over the years.



Source: Water Resources, MOEA (2001). Note: NT$ = New Taiwan dollar.

The 1980s witnessed some major changes in Taiwan's political economy, which triggered a series of political and policy reforms. The death of the political strongman Chiang Ching-Kuo was followed by an intense power struggle inside the Nationalist Party, which weakened its authoritarian rule. At the same time, a new middle class had emerged due to economic development; it was more conscious of political rights and social justice, and in the mid-1980s a series of civil protests against social and environmental injustice erupted. Taiwan's complex sociopolitical context made maintaining the IAs and their patron-client relationships a substantial challenge for the ruling party. After the political opposition joined forces to form the Democratic Progressive Party (DPP), the IAs' bargaining power vis-à-vis the Nationalist Party and the government increased significantly.

In response to the increased political uncertainty brought about by democratisation, the Nationalist Party sought to impose its control over the IAs through another attempt to depoliticise the organisations. In 1994, elections of chairs and farmer representatives of the IAs were again suspended and the government also began to pay farmers' water fees. A sunset legislation was passed, with a plan and a timetable for turning the IAs into government agencies in three years.[15] The depoliticisation process came to an abrupt halt in 2000, however, when the opposition DPP won the presidency. Losing control of the government meant that the Nationalist Party could no longer control the appointment of IA chairs and farmer representatives. As a pre-emptive measure, the Nationalist Party, which in 2001 still held the majority in the legislature, scrapped the sunset legislation in order to deprive the new government of its control over IAs. Over the next few years, the IA leaders were able to maintain overall good relations with both political parties. The leadership of the IAs remained largely stable with the same leaders being repeatedly re-elected, suggesting that the political competition and rivalry of the two parties did not seriously affect the operation and internal politics of the IAs. Although a majority of the IA chairs had a

[15] In 1993, the *Act of Irrigation Association Organization* was passed, specifying that the government would fully subsidise farmers' water fees (Chiu et al., 2011).

pro-Nationalist Party background, the associations' influence on local elections had decreased substantially. Even in areas where the agricultural sector – and hence the presence of the IAs – was relatively strong, the results of local elections did not particularly favour the Nationalist Party; on the other hand, even when the DPP controlled the government, there were no attempts to significantly cut IA budgets.

Bureaucratisation as a reform strategy

The IAs attracted little political attention until 2016, when for the first time the DPP gained control of both the government and the legislature. This political change opened a policy window for significant institutional reform of the IAs. A bill was proposed and successfully passed in 2018 which suspended elections for the IAs' chairs and farmer representatives, nationalised the associations' properties, turned the IAs into government agencies, integrated IA staff into the national civil service system, and took back the IAs' water rights.

These drastic reforms were driven by many factors and were supported by a coalition of policy actors of different preferences and backgrounds. The first group of policy actors comprised radical agricultural activists who advocated farmland conservation, farm-water preservation, and the renovation of Taiwan's agricultural system.[16] The emergence of this group was a response to the serious pollution problems of the rural ecosystem, which had been caused by the rapid industrialisation of the previous decades. Beginning in the 1970s, industrialisation in Taiwan began to spill over to the rural areas, where many illegal or extra-legal factories were built on paddy fields. It was estimated that these structures covered as much as 2% of the island's total arable land.[17] The operation of these factories created serious pollution problems, as they often dumped industrial waste on paddy fields and discharged polluted water directly into irrigation waterways. According to an official report, over 900 hectares of arable land was to some degree polluted.[18]

The pollution threats to food safety attracted substantial public attention after a series of food safety scandals between 2004 and 2014.[19] In response to these concerns, the government sought to improve irrigation management by integrating irrigation management agencies at different jurisdictional levels; at the central levels, these included the Council of Agriculture, the Ministry of Economic Affairs, and the Environmental Protection Administration, while municipal and county governments and public legal entities such as the IAs were also included. Given that the IAs were the primary organisations engaged in irrigation management, they were expected to play a key role in enforcing protection programmes against pollution. Unfortunately, as the IAs were not government agencies they did not have the authority to investigate pollution complaints or to impose sanctions. Reform advocates, therefore, argued that turning the IAs into public agencies could empower them to play a more vital role in combating pollution of irrigation water.

The second group of policy actors that pushed for the IA reforms was the environmental groups whose members were dismayed at the IAs' lack of capacity and enthusiasm for supporting eco-friendly agriculture. Over the years, the IAs adopted a rather rigid engineering approach to improving water delivery efficiency: many of the small-scale 'improvement projects' that the IAs conducted were focused on lining water canals with cement to reduce water seepage and improve the flow of water in the

[16] Prominent agricultural activist groups included the Taiwan Rural Front (台灣農業陣線) and the Alliance of Defending Agriculture and Countryside（捍衛農鄉聯盟) (see Chen, 2016).

[17] This totalled 13,859 out of 682,774 hectares (Kong, 2017).

[18] Retrieved from Environmental Protection Administration, Executive Yuan (2016)

[19] Major scandals included cadmium rice in 2004, malachite green fishery in 2006, plasticiser use in food products in 2011, gutter oil incident in 2014, and dioxin or fipronil eggs in 2017.

canals.[20] Canal lining, however, had the side-effect of preventing water from seeping into the soil and stopping weeds from growing,[21] resulting in a loss of biodiversity. In recent years, environmental sustainability, as a pillar of the United Nations Sustainable Development Goals, has attracted widespread public support and policy attention, and the concept of a sustainable society has strongly captured the public imagination. In this regard, the performance of the IAs fell substantially short of the public's expectations.[22]

The IAs had neither incentive to, nor capacity for, promoting eco-friendly agriculture and, as of 2017, organic farming was practised on less than 1% of Taiwan's arable lands (see PRIDE, 2020). Since organic farmers constituted only a very small percentage of water users, they had limited political clout to push the IAs to take a more proactive approach to combating water pollution by chemicals from traditional farming; moreover, environmental conservationists often framed their concern about pollution in terms of conservation of such endangered species as Siberian cranes (*Leucogeranus leucogeranus*) and leopard cats (*Prionailurus bengalensis)*, which the IAs considered outside their purview. As far as the environmentalists were concerned, without meaningful changes to the practices of IAs any attempts to foster a paradigm shift from an efficiency-oriented management system (which focuses on water efficiency) to an ecologically friendly system (which emphasises water footprints and biodiversity) were doomed to fail.

The third group of policy actors who supported institutional reform of IAs was the industry sector, which sought to gain greater access to fresh water for manufacturing. For many decades, more than 70% of freshwater in Taiwan was allocated to the agricultural sector, which contributed less than 2% of the island's GDP; the industry sector, meanwhile, was allocated only about 10% of freshwater but was able to generate more than one-third of the national income (MOEA, 2018). When water was abundant, the skewed distribution was not a problem; in fact, about 80% of the water used for agriculture was appropriated directly from rivers and transferred to farmers' fields, which in turn replenished the groundwater. In recent years, however, the frequency of droughts and water shortages has increased significantly, probably due to climate change; when droughts take place, they pose a serious threat of economic loss to the industrial sector. Members of the sector, therefore, became enthusiastic about revisiting and adjusting the allocation of water among sectors. Central and local governments were also aware of the importance of a stable water supply in attracting investment and sustaining economic growth. A fierce fight for water ensued, which included many famous protests against reallocating water to science parks or petrochemical industries.

Amid the keen competition for water, IAs found themselves in a rather odd position. As farmers' organisations, the onus was on them to maximise water supply for agriculture so as to protect the farmers' interests. In fact, as the owners and managers of much of Taiwan's irrigation infrastructure, they were well-positioned and equipped to appropriate as much water as they desired. For a long time, the assumption had been that the IAs enjoyed a priority right of water appropriation. During water shortages, industries that needed extra water had to pay the IAs, through the mediation of the Ministry of Economic Affairs, to divert part of their water shares to industry. The IAs insisted that sharing their water with industry was not a profit-making transaction, but rather was an act of sacrifice in that farmers had to give up agricultural production in order to be able to spare the precious water for industrial use. The fees the IAs charged, they claimed, were not profit but were only a token compensation for the farmers' sacrifice; in fact, from the IAs' perspective, the fees were enough to cover only the operational cost of using their irrigation infrastructure to deliver the water to the industries.

[20] These projects were often rent-seeking, being used to solicit the political support of local factions, as discussed above.

[21] Canal lining saved farmers the effort of clearing the canals, which had been their major obligation as members of IAs. A further obligation, that of paying water fees, was lifted in 1994.

[22] Another threat to organic agriculture was the spread of pesticide or other chemicals along the waterways.

The assumption that the IAs should enjoy a priority right of water appropriation was under increasing scrutiny.[23] Reform advocates argued that the presumed priority water right, in effect, deprived the IAs of any incentive to improve irrigation management. Perhaps more importantly, as the government was paying the water fees on farmers' behalf and investing heavily in irrigation infrastructure, the IAs were highly financially dependent on the government. This dependence naturally gave rise to an expectation that the IAs should be more accountable to the government and more responsive to social demands. With the IAs' lagging performance and the perceived misuse of water resources, policy makers and members of the public concluded that the current system was failing to ensure the proper accountability of the IAs.

As the demand for institutional change grew, a policy window opened when the DPP. succeeded in gaining control of both government and legislature in 2016. Chen Chi-Chung, a reform advocate, was assigned the challenging task of reforming irrigation institutions. As one might expect, the reform attempt encountered strong resistance from the IAs and their supporters. With no background in irrigation engineering and few connections with the IAs, Chen found it impossible to reform the institutions from within the system. He quickly came to realise that the most viable reform strategy was to follow and improve the earlier efforts to bureaucratise the IAs. By turning the IAs into government agencies, the government would be able to tighten administrative control over their operations. In formulating the reform strategy, its potential adverse impact on co-production was not seriously considered because farmers' participation had already decreased substantially as a result of the demise of agriculture and, moreover, the government's policy of pay the water fees out of public funds had successfully undermined the farmers' sense of ownership of the IAs.

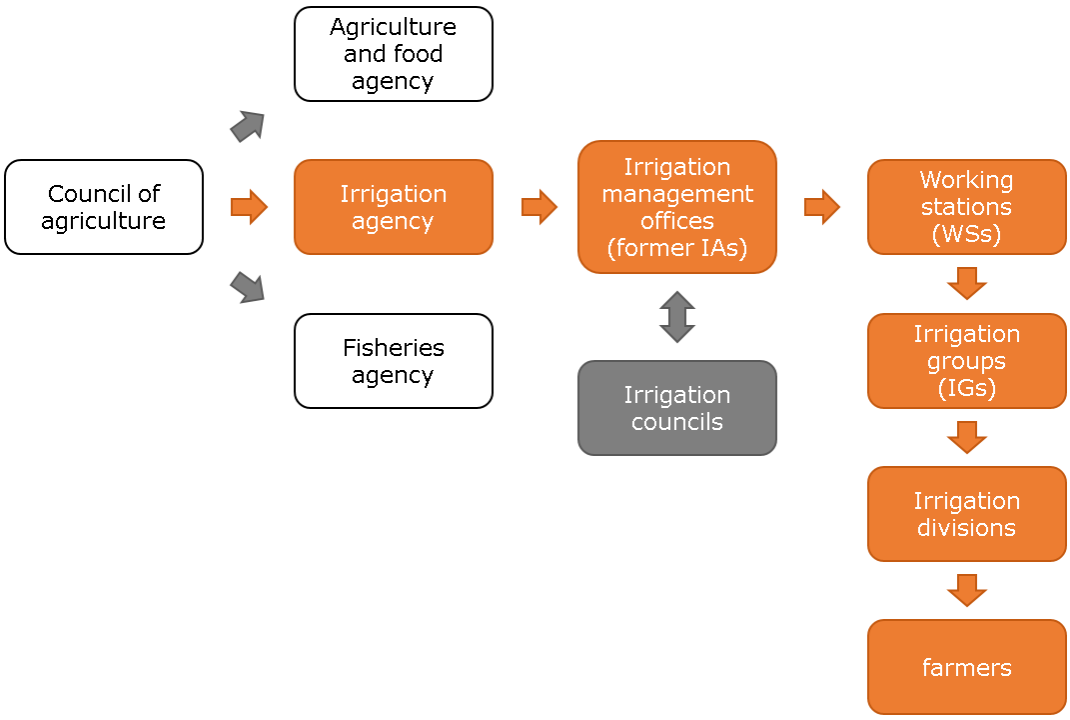
INSTITUTIONAL EVOLUTION AND ADAPTATION

Robustness trade-offs

The evolution and change of the IAs occurred in the course of tinkering with the two imperatives that underlie their design. The first of these concerns the robustness trade-offs on the basis of which irrigation institutions were designed (Anderies et al., 2004; Ostrom, 2009; Walker and Salt, 2006), robustness referring to "the capacity to continue to meet a performance objective in the face of uncertainty and shocks" (Janssen and Anderies, 2007: 44). Before the 1970s, irrigation in Taiwan was developed to serve the objective of supporting agriculture and hence farmers' livelihoods. The performance criterion on which irrigation systems and institutions were designed was water efficiency, often defined in terms of the size of the irrigated area that a particular amount of water could support. The heavy investment in irrigation infrastructure, the meticulous planning of irrigation delivery, and the development of networks of working stations and irrigation groups were all designed to build in robustness to shocks and to the uncertainty associated with water supply fluctuation and water shortages (Bray, 1986; Levine, 1977; Moore, 1989).

[23] According to the *Water Act*, the priority sequence of water use is: first, domestic and public use; second, agricultural use; third, hydropower; and fourth, industrial use. Since most waterways and storage facilities have been built and maintained by specific agencies for specific uses, the agencies that control the higher priority water can demand compensation from lower priority users.

Figure 5. Organisational structure of irrigation governance after reform.



Source: Revised and translated from the website of Council of Agriculture (no date)

Box 1: How IAs reacted to bureaucratisation

Reactions to the bureaucratisation policy varied across and within the IAs. In general, IAs located in more urbanised areas protested strongly against the policy as they perceived it to be a pretext for the government to confiscate their valuable land. In the process of urbanisation, land prices in the urban areas increased as did the IAs' properties. The IAs in and near urban areas were able to generate and accumulate significant wealth through selling or renting out their properties; the generated resources were then used to support their operations as well as irrigation management. The Liugong IA in Taipei City, for example, was the wealthiest IA in Taiwan. Although it managed only a small irrigated area, it generated an annual income of around NT$ 100 million and its accumulated savings reached NT$ 22.3 billion. The Chianan IA, in contrast, was the largest IA in Taiwan, managing an irrigated area of about 7500 hectares but, like other rural IAs, it was unable to reap the benefits of urbanisation and thus was facing financial problems and heavily in debt. To these less-well-off IAs, bureaucratisation was potentially a solution to their dire financial problems and they were therefore less resistant to the policy.

Within an IA, the top political cadres have incentives and attitudes towards the bureaucratisation policy that differ from those of their professional engineer and manager colleagues. Resistance to the policy was strongest amongst the political cadres because it would simply remove them from the system. They had long used their power and resources to develop local networks for political mobilisation and the bureaucratisation policy would depoliticise the irrigation management system and largely deprive them of political influence. The professional staff, on the other hand, were less concerned about the political implications of the policy; many, in fact, welcomed the policy as it promised them packages of benefits and career tracks similar to civil servants. Most ordinary farmer members remained apathetic as long as they were not asked to bear any of the costs and as long as they were assured a stable water supply.

With the changes in Taiwan's political economy, the purpose of irrigation was no longer merely making water available to agriculture. As water resources affected the interests of different policy stakeholders, irrigation management took on a variety of purposes. Irrigation systems and institutions that were built to be robust to water shortages were found to be unequal to the range of new purposes, and it was difficult to retool them to handle the new tasks (Lam and Chiu, 2016); in other words, they were robust to threats of water shortage but fragile to new policy demands (Doyle et al., 2005).

Putting political issues aside, water resources are essential to achieving different social purposes and thus affect the distribution of social interests; an institutional arrangement that allows for the flexible management of competing purposes is thus deemed more suitable (Baumgartner et al., 2009; Jones and Baumgartner, 2005). Specifically, bureaucratising IAs will enable the government to reallocate water resources among sectors and to better integrate irrigation planning into other policy areas such as environmental protection and economic development. Irrigation institutions in Japan and South Korea, which share similar parastatal designs, have long incorporated land development into their design and operation; this has enabled them to use an integrated approach to issues such as flood control, land-use planning, ecological conservation, and rural revival.

Modus operandi of co-production

The second design imperative concerns the modus operandi of co-production, which refers to how the efforts of the government (as the regular producer) and farmers (as the consumer producers) are arranged in a complementary and embedded manner. The core concern of co-production is that the division of work between government and farmers should enable each of them to focus on tasks that can best utilise the resources and expertise at their command and can enable their work to reinforce the other's to generate the most synergy. The modus operandi is reflected in, and supported by, a particular division of labour; which underlies the design of institutions. When the task environment changes, the modus operandi needs to be adjusted through institutional change.

Co-production in the heyday of the IAs hinged upon vibrant communities of farmers who were capable of playing an active role in irrigation operations and maintenance at the local level. When farming was no longer a viable economic activity on which farmers could make a living, and as the rural population shrank and aged, the farmer communities lost their vibrancy as effective co-producers. The demise of agriculture also changed the task requirements for irrigation management. The decreased importance of paddies, the availability of groundwater, and the abandonment of agriculture in many places had all rendered the meticulous management of water allocation in the fields not cost-effective, even irrelevant. In fact, in dealing with the new challenges facing irrigation management, including pollution and cross-sectoral competition for water, farmers began to have little to contribute.

The adaptation and adjustment of the modus operandi of co-production started in the early 1980s. Instead of requiring farmers to self-manage water allocation in the field, water guards were hired to work on behalf of farmers. While the IGs presumably remained farmers' self-governing entities, their actual operation was often managed by a small number of more active farmers, with strong support and steering from the WSs. The government's policy of paying farmers' water fees had further eroded their sense of ownership of the IGs (Lam and Chiu, 2016).

In parallel to beefing up WS support for the IGs, conscious efforts were made to develop irrigation technologies that would automate water allocation and delivery, including automatic sprinklers and water gates; extensive work was also done on improving canal linings and the physical condition of irrigation infrastructure. All these efforts were meant to replace farmers' input with professional management and infrastructure, and as this asymmetry in the division of labour increasingly took hold, the replacement of farmers' contribution by government input was deemed feasible.

Commitment to co-production

Effective co-production is built on strong commitments from both government and local communities. As scholars have long argued, co-production is not a simple process of pooling the efforts of the regular producer (government) and the consumer producers (farmers); instead, the government's marginal productivity is a function of the farmers' efforts, and vice versa. The joint productivity function involved in co-production creates both opportunities and constraints. While effective management of co-production can bring about gains in efficiency, interdependence can also create perverse incentives for collaboration; credible commitment from both parties is therefore fundamental. Unfortunately, there is an inherent difference between the interests and focus of government and that of local communities; the government has a broader constituency with a focus on the overall well-being of society, while local communities tend to focus on more parochial interests. Any co-production initiatives must therefore deal with the tension between engagement and autonomy (Goodwin, 2019).

In the early days of the Nationalist regime, the IAs served the simple yet essential mission of ensuring food security in support of a smooth regime transition. As that mission was instrumental to the state's survival, the regime was fully committed to the IAs. The Nationalist regime was also well aware of the potential use of the social networks of local rural communities which, if leveraged properly, would be essential to materialising agricultural potential and enhancing social control. From the perspective of farmers and local communities, co-production would allow them to preserve their autonomy, protect their interests, and access government resources.

As the IAs gradually evolved into patron-client mechanisms for the Nationalist regime to mobilise political support, the nature of the state's commitment changed. It was no longer based on the IAs' functional contribution, but rather on the regime's political calculus. The Nationalist regime would remain committed to the co-production mode of irrigation management only as long as doing so would give them a competitive advantage politically. The ebb and flow in the development and evolution of the IAs reflects the government's struggle with different considerations in its search for appropriate institutional arrangements for irrigation governance. The search ended with the government's eventual withdrawal of commitment to co-production.

In contrast to South Korea where irrigation parastatals were converted to state-owned enterprises, and Japan where self-governance of irrigation associations was largely retained, institutional reforms of Taiwan's IAs have been a series of attempts towards bureaucratisation. The institutional choice of bureaucratisation was probably based on the government's calculation that, although engagement with farmers and rural communities was desirable, water resources were simply too important to be controlled, if not held ransom, by parochial associations; it had, moreover, invested substantially in irrigation over the previous several decades. Bureaucratising the associations could allow the government both to better leverage the resources for attaining its many policy priorities and to avoid rent-seeking activities. It was therefore the most desirable option.

CONCLUSION

From a comparative perspective, many places around the world are facing the problem of irrigation resources being pressured by rapid economic development and urbanisation. Competing demands from other sectors, pollution, individualised irrigation practices made possible by technologies, and declining political importance are all driving forces for institutional reform. How would parastatal water institutions with a focus on co-production respond to these substantial challenges?

By examining the evolution and change of Taiwan's parastatal irrigation associations – which were once considered the holy grail of co-production and self-governance in irrigation management – we have shown how the process of institutional change was shaped by the structure and dynamics of the changing political economy and undergirded by two design imperatives: robustness trade-offs and the modus

operandi of co-production. The parastatal institutions of the IAs were designed to maximise robustness to water shortages and fluctuating water supplies. The meticulous organisation of farmers' collective action in the field through networks of irrigation groups, together with the well-structured grids of canals and ditches, was meant to maximise water efficiency and hence expand irrigated areas. These institutions served the IAs' purposes as long as it was confined to agricultural production; however, when the changing political economy imposed new missions and hence new performance criteria, it was difficult to retool the institutions and infrastructure to cope with the more complex tasks.

Effective co-production hinges upon high degrees of complementarity and embeddedness between the efforts of government (as the regular co-producer) and communities of farmers (as consumer producers). The demise of agriculture and the rapid aging of the rural population adversely affected the capacity of farming communities to function as effective consumer producers. Adjustments to the modus operandi have been made over the past few decades to cope with the increasingly asymmetric relationship between government and farmers; the general direction was to replace farmers' decreasing contributions with more government support and better irrigation infrastructure. When the process of substitution was pushed to the extreme, IGs became no more than vehicles through which the government engaged the farmers, often in a nominal manner. As far as the government was concerned, the consideration of the robustness trade-offs and the search for an appropriate modus operandi of co-production had all pointed to the conclusion that drastic institutional reform of IAs was urgently needed. A policy window opened when the ruling DPP gained control of both the presidency and the legislature.

In pondering how to reform the IAs, the government was determined to tighten water source control, which was considered to be at the core of such major policy issues as economic development, pollution control and sustainability. With the heavy investment in irrigation made by the government over the years, it would only be natural for it to put these resources under direct scrutiny. The institutional choice also showed the impact of the path-dependent dynamics. The Nationalist Government's initial decision to embed the parastatal irrigation associations into local patron-client relations as a means of soliciting the support of local elites for the regime had set them on a path towards politicisation of the IAs; political calculus became an integral consideration in the institutional design of these entities. As the purpose of irrigation efficiency faded away after industrialisation, the political influence of the IAs remained. The government looked at such influence as a threat to its dominance, a perception which may explain its lack of hesitation in going to the extreme of scrapping the parastatals, a very different reform path from those adopted by South Korea and Japan.

REFERENCES

Abel, M.E. 1976. Irrigation systems in Taiwan: Management of a decentralized public enterprise. *Water Resources Research* 12(3): 341-348.

Addison, J.; Stoeckl, N.; Larson, S.; Jarvis, D. and Esparon, M. 2019. The ability of community based natural resource management to contribute to development as freedom and the role of access. *World Development* 120: 91-104.

Anderies, J.M.; Janssen, M.A. and Ostrom, E. 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society* 9(1): 18.

Andersen, O.J. 2008. A bottom-up perspective on innovations: Mobilizing knowledge and social capital through innovative processes of bricolage. *Administration & Society* 40(1): 54-78.

Apthorpe, R. 1979. The burden of land reform in Taiwan: An Asian model land reform re-analysed. *World Development* 7(4-5): 519-530.

Baumgartner, F.R.; Berry, J.M.; Hojnacki, M.; Leech, B.L. and Kimball, D.C. 2009. *Lobbying and policy change: Who wins, who loses, and why*. Chicago: University of Chicago Press.

Bottrall, A.F. 1977. Evolution of irrigation associations in Taiwan. *Agricultural Administration* 4(4): 245-250.

Bray, F. 1986. *The rice economies: Technology and development in Asian societies*. Oxford, UK.: Blackwell.

Cartel, M.; Boxenbaum, E. and Aggeri, F. 2014. Experimentation and bricolage on institutions: Understanding the selection of new arrangements. AIMS, Rennes, France. <hal-01089472>

Chen, H.T. 2009. *The evolution of the irrigation management in Chianan Plain*. Tainan: Tainan County Government (in Chinese). 陳鴻圖, 2009,《嘉南平原水利事業的變遷》, 台南: 台南縣政府.

Chen, R.H. 2016. In the name of the farmer: A historical review of agrarian movements in postwar Taiwan, *Router: A Journal of Cultural Studies* 22: 75-122. (in Chinese) 陳瑞樺, 2016, 以農之名：台灣戰後農運的歷史考察,《文化研究》, 22: 75-122.

Chen, Z.X. 1997. *Taiwan: An economic and social geography, Volume 2.* Taipei: SMC Publishing Inc. (in Chinese). 陳正祥, 1997,《台灣地誌（中冊）》, 台北: 南天.

Chianan Irrigation Association. 1992. *The 70 years History of Chianan Irrigation Association.* Tainan: Chianan Irrigation Association (in Chinese). 嘉南農田水利會, 1992,《嘉南農田水利會七十年史》, 台南: 嘉南農田水利會.

Chiu, C.Y.; Tang C.P. and Huang, C.H. 2011. Institutional choice of local governance and transition politics: An analysis of institutional adaptation of irrigation associations in Taiwan. *Journal of Social Sciences and Philosophy* 23(1): 93-126 (in Chinese).

Cleaver, F. 2005. The inequality of social capital and the reproduction of chronic poverty. *World Development* 33(6): 893-906.

Cleaver, F. 2017. *Development through bricolage: Rethinking institutions for natural resource management*. London: Routledge.

Council of Agriculture. 2003. *History of irrigation in Taiwan*. Taipei: Council of Agriculture, Executive Yuan, Republic of China (in Chinese).

Council of Agriculture. 2020. *Annual Statistics Yearbook for 2019.* https://agrstat.coa.gov.tw/sdweb/public/book/Book.aspx (accessed 26 May 2021) (in Chinese).

Council of Agriculture, no date. https://www.coa.gov.tw/ws.php?id=8715 (accessed 26 May 2021)(in Chinese).

Doyle, J.; Alderson, D.L.; Li, L.; Low, S.; Roughan, M.; Shalunov, S.; Tanaka, R. and Willinger, W. 2005. The "robust yet fragile" nature of the Internet. *Proceedings of the National Academy of Sciences* 102(41): 11497-11502.

Environmental Protection Administration, Executive Yuan. 2016. The Environmental Protection Agency actively conducts farmland surveys and protects farmland together with the environmental groups. *Environmental News Zone*. 5 June 2016. https://enews.epa.gov.tw/Page/894720A1EB490390/87484e8b-7fb7-46ed-9ca0-226ba91756d6 (accessed 26 May 2021) (in Chinese).

Goodwin, G. 2019. The problem and promise of co-production: Politics, history, and autonomy. *World Development* 122: 501-513.

Ho, S.P. 1979. Decentralized industrialization and rural development: Evidence from Taiwan. *Economic Development and Cultural Change* 28(1): 77-96.

Janssen, M.A. and Anderies, J.M. 2007. Robustness trade-offs in social-ecological systems. *International Journal of the Commons* 1(1): 43-65.

Jones, B.D. and Baumgartner, F.R. 2005. *The politics of attention: How government prioritizes problems*. Chicago: University of Chicago Press.

Ka, C. 1995. *Japanese colonialism in Taiwan: Land tenure, development, and dependency, 1895-1945*. Taipei: Westview Press.

Ka, C. 2003. *Conflicts of rice and sugar cane: Development and dependency of Taiwan under Japanese colonialism*. New Taipei: Socio Publishing (in Chinese). 柯志明, 2003, 《米糖相剋–日本殖民主義下臺灣的發展與從屬》, 新北: 群學

Kong, D.L. 2017. Recover lost farmland! Only 570,000 cubic meters of farmland production remains. *News & Market.* 4 September 2017. https://www.newsmarket.com.tw/blog/99937/ (accessed 26 May 2021) (in Chinese).

Lam, W.F. 1996. Institutional design of public agencies and co-production: A study of irrigation associations in Taiwan. *World Development* 24(6): 1039-1054.

Lam, W.F. 2001. Coping with change: A study of local irrigation institutions in Taiwan. *World Development* 29(9): 1569-1592.

Lam, W.F. 2006. Foundations of a robust social-ecological system: Irrigation institutions in Taiwan. *Journal of Institutional Economics* 2(2): 1-24.

Lam, W.F. and Chiu, C.Y. 2016. Institutional nesting and robustness of self-governance: The adaptation of irrigation systems in Taiwan. *International Journal of the Commons* 10(2): 953-981.

Lansing, J.S. 1987. Balinese "water temples" and the management of irrigation. *American Anthropologist* 89(2): 326-341.

Levine, G. 1977. Management components in irrigation system design and operation. *Agricultural Administration* 4: 37-48.

Meinzen-Dick, R. 2007. Beyond panaceas in water institutions. *Proceedings of the National Academy of Science* 104(39): 15200-15205.

MOEA (Ministry of Economic Affairs). 2018. *Water Statistics*. www.wra.gov.tw/News.aspx?n=2953&sms=9084&_CSN=277 (accessed April 29, 2021)(in Chinese).

Moore, M.P. 1989. The fruits and fallacies of neoliberalism: The case of irrigation policy. *World Development* 17(11): 1733-1750.

Ostrom, E. 1998. A behavioral approach to the rational choice theory of collective action. *American Political Science Review* 92(1): 1-22.

Ostrom, E. 2005. *Understanding institutional diversity*. Princeton, NJ: Princeton University Press.

Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325: 419-425.

Peng, T.R.; Chen, C.T.A.; Wang, C.H.; Zhang, J. and Lin, Y.J. 2008. Assessment of terrestrial factors controlling the submarine groundwater discharge in water shortage and highly deformed island of Taiwan, western Pacific Ocean. *Journal of Oceanography* 64(2): 323-337.

PRIDE (Policy Research Indicators Database). 2020. *Graphical view of the world: The organic trend prevails around the World*. https://bit.ly/3ulQl9j (accessed 26 May 2021) (in Chinese).

Sakthivadivel, R.; Aloysius, N. and Matsuno, Y. 2001. *Assessment of performance and impact of irrigation and water resources systems in Taiwan and Sri Lanka*. Vol. 31. IWMI.

Schlager, E. and Cox, M. 2018. The IAD framework and the SES framework: An introduction and assessment of the Ostrom Workshop frameworks. In Weible, C.M. and Sabatier, P.A. (Eds), *Theories of the policy process*, pp. 215-252, New York, NY: Westview Press.

Shivakoti, G.; Vermillion, D.; Lam, W.F.; Ostrom, E.; Pradhan, U. and Yoder, R. 2005. *Asian irrigation in transition: Responding to challenges*. New Delhi: Sage.

Tang, C.P. and Tang, S.Y. 2006. Democratization and capacity building for environmental governance: Managing land subsidence in Taiwan. *Environment and Planning A* 38(6): 1131-1147.

Tsai, C.C. 1998. The analysis of "time and space "on Taiwan water exploitation from Ming to Ching Dynasty (1624-1894). *The Journal of Social Studies Education Research* 3: 25-95 (in Chinese).

Tung, Y.T. and Pai, T.Y. 2015. Water management for agriculture, energy, and social security in Taiwan. *CLEAN – Soil, Air, Water* 43(5): 627-632.

Walker, B. and Salt, D. 2006. *Resilience thinking: Sustaining ecosystem and people in a changing world*. Washington, DC: Island Press.

Water Resources, MOEA (Ministry of Economic Affairs). 2001. *Annual Report*. https://twinfo.ncl.edu.tw/tiqry/hypage.cgi?HYPAGE=search/merge_pdf.hpg&type=s&dtd_id=11&sysid=T0508371 (accessed 26 May 2021) (in Chinese).

Wu, C.R. 2018. The dilemma and further development of legal system of public incorporation for irrigation association. MSc thesis. National Chengchi University, Taipei, Taiwan (in Chinese).