‘Two Hands, Multiple Fingerprints’:

Understanding the Development of Water Markets in China

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ABSTRACT

Since several countries have used formal and informal regulatory and institutional mechanisms to deal with water competition, they have become pivotal to our understanding of the role of water markets in water management. In *'Two Hands, Multiple Fingerprints': Understanding the Development of Water Markets in China*, I examine the emergence, diffusion, and diversity of water markets in China. In this dissertation, through an historical analysis of three case studies across northern and north-western China, I argue that the water supply infrastructure and water markets have developed alongside one another, thus culminating in a "two-hands" (government and market) approach to water governance. Drawing on an original transactions data set for the period from 2000 to 2019, I extend the analysis of the "two hands" approach to water governance by (1) identifying the different configurations of water markets, and (2) looking at how they have developed across space and time. I argue that, in multiple ways, which are based on critical junctures in Chinese politics, the central government influences patterns of water-rights trading. In addition, Chinese–Australian development projects have exerted an external influence over China's water rights and market reforms.

This dissertation contributes to theories of institutional choice in two domains – the relation of institutions to different types of infrastructures, and the role of hybrids and the potential for configurations to discern different pathways. Its findings show patterns of institutional development in Chinese markets that move beyond a dichotomous relationship between state and market. This dissertation also extends the policy transfer and diffusion literature by analyzing the rise, fall, and revival of tradable water rights policy through the lens of individual actors and bilateral development cooperation. It highlights the political role of individual actors along three functional dimensions – (1) the part played by the former minister of water resources, Wang Shucheng (1998–2007), in transforming market ideas into policy; (2) the role of senior Chinese officials engaged in best-practice

learning from Australia (2005–2007) in helping to draw up a national framework for water entitlements and allocations in China; and (3) the activities of scientists in designing an online trading platform in the Shiyang Basin based on lessons learned from Victoria, Australia. Finally, the dissertation highlights the importance of the structure of the international system as a driving force behind the bilateral development cooperation. The Water Entitlements and Trading Project (WET) and the Australia China Environment Development Partnership (ACEDP) occurred when Australia pursued a policy of accommodation with China at a time when the international consensus was to integrate China into global institutions.

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ACRONYMS

ACEDP	Australia–China Environment Development Partnership
ASEAN	Association of Southeast Asian Nations
AusAid	Australian Agency for International Development
AWP	Australian Water Partnership
BJ	Beijing
CAS	Chinese Academy of Science
CHES	Chinese Hydraulic Engineering Society
CCP	Chinese Communist Party
CHES	Chinese Hydraulic Engineering Society
CIS	coupled infrastructure system
CLTS	community-led total sanitation
CNKI	China Academic Journals full-text database
CPC	Communist Party of China
CPR	common-pool resources
CSIRO	Commonwealth Scientific and Industrial Research Organization
csQCA	crisp-set qualitative comparative analysis
CWEX	China Water Exchange
DAFF	Department of Agriculture, Fisheries and Forestry
DAWR	Department of Agriculture and Water Resources
DCCEE	Department of Climate Change and Energy Efficiency
DDA	Dutch Delta approach
DFAT	Department of Foreign Affairs and Trade
DRC	Development and Reform Commission
FDI	foreign direct investment
fsQCA	fuzzy-set qualitative comparative analysis
GDP	gross domestic product
HH	Hohhot
HSR	high-speed rail
IAD	institutional analysis and development
ICE WaRM	International Centre for Excellence in Water Resource Management
ICLEI	International Council for Local Environmental Initiatives
ID	irrigation district
ISO	International Organization for Standardization
IWRM	integrated water resources management
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
MEP	Ministry of Environmental Protection

MOFCOM	Ministry of Commerce
MoU	memorandum of understanding
MWR	Ministry of Water Resources
mu	measure of land (micrometre)
NDRC	National Development and Reform Commission
NSW	New South Wales
OECD	Organisation for Economic Co-operation and Development
PNAS	Proceedings of the National Academy of Sciences
NWC	National Water Commission
PRC	People’s Republic of China
QCA	qualitative comparative analysis
RDA	regionally decentralized authoritarian
RMB	renminbi (China’s official currency)
SES	social-ecological systems
SEWPAC	Sustainability, Environment, Water, Population and Communities
SFA	State Forestry Administration
SNWDP	South-to-North Water Diversion Project
SoGE	School of Geography and the Environment (Oxford)
SPR	source protection region
SSEE	Smith School of Enterprise and the Environment
TY	Taiyuan
UCCL	Universities’ China Committee in London
WeGo	World Smart Sustainable Cities Organization
WET	water entitlements and trading
WMRA	water market readiness assessment
WUA	water user association
YRCC	Yellow River Conservancy Commission

1. INTRODUCTION

1.1 MOTIVATION

While the People's Republic of China (PRC) under Chairman Mao Zedong (1943–76) began in 1949 by standing up (站起来) on the one hand, and becoming rich (先富起来) under Deng Xiaoping (1978–89) on the other, the world now faces a strong China (富强国家) under President Xi Jinping (2013–).

A distinct feature of China's system of governance is that it is a political meritocracy (Nathan 2003) and, since imperial times, has used examinations as a means of selecting officials by merit. Moreover, the Chinese Communist Party (CCP) has constructed a set of performance incentives to ensure that officials at all levels and throughout its bureaucratic system are promoted on the basis of economic growth and the provision of public goods. Nathan (2003) attributes the resilience of the CCP to its increased use of a meritocracy in the promotion of its political leaders, as opposed to relying on factional considerations. Landry et al. (2018), however, suggest that the political returns for economic performance on the career prospects of Communist Party secretaries and government executives decline as they climb the administrative ladder. After controlling for political connections, these authors found consistent evidence of a positive correlation between economic performance, measured as fiscal revenue and GDP, and the promotion of politicians at the county level, although not at the prefecture and provincial levels.

Another distinct feature of China's system of governance, as Xu (2011) describes it, is that it combines political centralization with economic and administrative decentralization – in other words, it operates a regionally decentralized authoritarian (RDA) system. When in the 1980s China decided to adopt an opening-up strategy, its leadership embraced the market like a "bird in a cage", with the cage representing the state's centrally planning capacity. The market, represented by the bird, was free to develop up to certain limits, and the centrally planned economy adjusted in response to changing circumstances (Coase and Wang 2012).

In terms of government capacity to foster development, the RDA system relies on two mechanisms, regional competition and regional experimentation (Xu 2011). China's local government is more deeply involved in business development than the local governments of other developing countries (Bardhan 2020). As a result, subnational governments compete not only to achieve the policy targets set by the central government, such as local stability, but also for business, which includes attracting FDI. In addition, improving the provision of public goods is an important source of local government legitimacy (Dickson et al. 2016). Thus, subnational governments initiate trial-and-error projects and policy reform experiments with a view to improving local governance and for the purposes of career promotion. As a consequence, China's development trajectory has led to regional socio-economic and environmental problems. In this regard, Eaton and Kostka (2014) argue that local leaders have a short time horizon, and the frequent turnover of cadres may undermine the implementation of ambitious environmental regulations and targets.

Now, in the Xi era, through its Ideological Responsibility System (意识形态责任制) (Chen 2018), the CCP is back to rebuilding the political loyalty of politicians and bureaucrats to the party and central authority. From this standpoint, the relationship between party and state is similar to that of the bird/cage metaphor in which the party is the cage. Not only does the party control appointments in both public and state enterprises, but it also has the agency to direct the state to translate party ideology into policy (Brown 2020). Another critical element is the party's embeddedness in the private sector, a phenomenon that Chen and Rithmire (2020) describe as "the rise of the investor state". As Chen and Rithmire (2020) show, the CCP has deployed state investment instruments to pursue strategic goals, such as facilitating industrial upgrading, maintaining financial stability, and monitoring and influencing business actors.

According to *The Economist* magazine, "the idea is for state-owned companies to get more market discipline and private enterprises to get more party discipline, the better to achieve China's great collective mission" (Economist 2020). The blending of public and private, market and planning is such that observers have begun to note that the Xi era “marks a new paradigm in China’s development trajectory” (Blanchette 2020). From a global perspective, China’s hybrid political economy gives us an important opportunity to gain new insights into forms of governance in a multi-level one-party state with a large domestic market. In particular, for a number of reasons, China is an important country to study in the context of water market development.

The impact of China’s national conditions on the institutional design of water markets is an important consideration. At the core of the literature on institutional arrangements for governing natural resources lies a shift from focusing on governments, markets, and self-governance alternatives to new user interest in a combination of governments, market tools, and self-governance (Lemos and Agrawal 2006; van Laerhoven, Schoon and Villamayor-Tomas 2020; Villamayor-Tomas et al. 2019). Recent decades have witnessed a shift in discussions about water markets from the concept of free-market environmentalism and cap-and-trade allocation to an emphasis on the institutions that surround markets (Garrick and Svensson 2018). The case of China, in turn, has the potential to further our knowledge about the conditions that influence the emergence, design, and practice of water markets in the context of a political regime that is the opposite of a liberal democracy.

To begin with, since 2000, China’s response to the intense competition over water use has been to establish a national-scale water entitlement and trading system. However, given that trading in water rights flourishes in some places in China but not in others, its development has followed neither free-market reallocation nor the traditional administrative means of water management (Wang 2014). A water market is a mechanism for adjusting the initial allocation of water rights among different government entities and resource users (industries and farmers) (Wang 2018: 180).

Accordingly, water is a shared public property owned by the state and users only have the right to its use. The government decides on the initial allocation of water rights at three distinct but interconnected levels – the river basin level (water use/consumption quota), abstractor level (diversion permission), and at the level of terminal users within public water supply systems (Jia et al. 2016). The 2002 Water Law of China provides the framework for the integrated management of water resources, including the establishment of water rights.

According to this framework, a basin allocation plan is used to distribute water to different provinces in an inter-jurisdictional basin. Provincial plans then allocate the prefectures' share, and prefectural plans distribute water among the counties. The water allotment of a region operates a bulk water entitlement, which is used to supply multiple water users within either an irrigation district or as part of an urban water supply system (Shen and Speed 2009). In 2020, a volume of 670 billion m^3 was capped, divided, and allocated to 31 provinces and cities across China. If regions or users save some of their water quota, they can sell it in the market. According to the provincial measures on the administration of water-rights trading that the Ministry of Water Resources (MWR) issued in April 2016, diverse water-rights trading arrangements exist in China's politically centralized system: regional water-rights trading (between local governments at or above county level), water abstraction rights trading (from water abstraction permit holders, but excluding urban public water supply enterprises), and water-rights trading between irrigators (water user organizations or individual users of irrigation water with clearly defined water rights) (MWR 2016).

More importantly, for its thirteenth five-year plan for water reform (2016–2020), the central government promoted its 'two hands' approach (两手发力) to water governance, which involved the state and market joining forces to improve water reallocation (MWR 2016). The government undertook to construct and manage the water conservancy facilities, including the provision of large infrastructures for storage and inter-basin transfers. The government was also expected to provide the conditions under which to liberalize further the operational water market and to shift the politics from direct administrative control to macro control and market supervision (Wang 2014). In this regard, Jiang et al. (2020) studied China's water policy development over the period 1998 to 2018. They found that "experiments in water rights and water trading have continued alongside renewed growth in water supply infrastructure and continued state control of water rights and allocation" (Jiang et al. 2020: 7). Furthermore, they suggest that "this may take many diverse forms according to the characteristics of particular political-economies" (Jiang et al. 2020: 7). Yet, there is very little empirical research into how the roles of state and market work out in practice in China.

As such, China presents an opportunity to study the applicability of the two-hands approach to water governance and its variations within China. Indeed, one of China's leading public policy scholars, Yahua Wang, recently argued that scholars pay insufficient attention to factors associated with "Chinese characteristics", and urged them to analyse differences in water markets in various countries to reveal the impact of the macro institutional choices (Wang, Shu and Wu 2017: 93–5). Other scholars have described China's water market as having "Chinese characteristics". For example, more than a decade ago, Speed (2009a: 279) noted that "government-facilitated water transfers – water trading 'with Chinese characteristics' – appear more in keeping with the country's culture and political system, and have been successful in achieving their objectives." The numerous and diverse water-rights trading arrangements point to the need for a study that can characterize the institutional configurations of Chinese water markets. Such a study would improve our knowledge of the impact of external factors (like central government) on the adoption of marketization, as well as provide insights into how an interplay of factors (such as farmer organizations, local government and enterprise) might contribute to the development of water markets. Thus, a focus on water markets in China could enhance the general literature on the combinations of institutions involved in environmental governance (Lemos and Agrawal 2006, 2009; Meinzen-Dick 2007).

At the same time, the scholarly focus on "Chinese characteristics" obscures the fact that Chinese policy-makers and non-governmental actors have looked beyond their country's borders to find solutions to problems of water scarcity and quality. One country in the twenty-first century – Australia – stands out as having vibrant water markets alongside tight government controls. To the best of my knowledge, there have been three bilateral exchange programmes related to water rights and markets between China and Australia – the water entitlements and trading (WET) project phases 1 and 2 (2005–2007); the Australia China Environment Development Partnership (ACEDP) (2007–2012); and the water-rights trading exchanges (2018–2019). Yet, the nature and impacts of these exchange programmes between China and Australia on water rights and markets remain unknown.

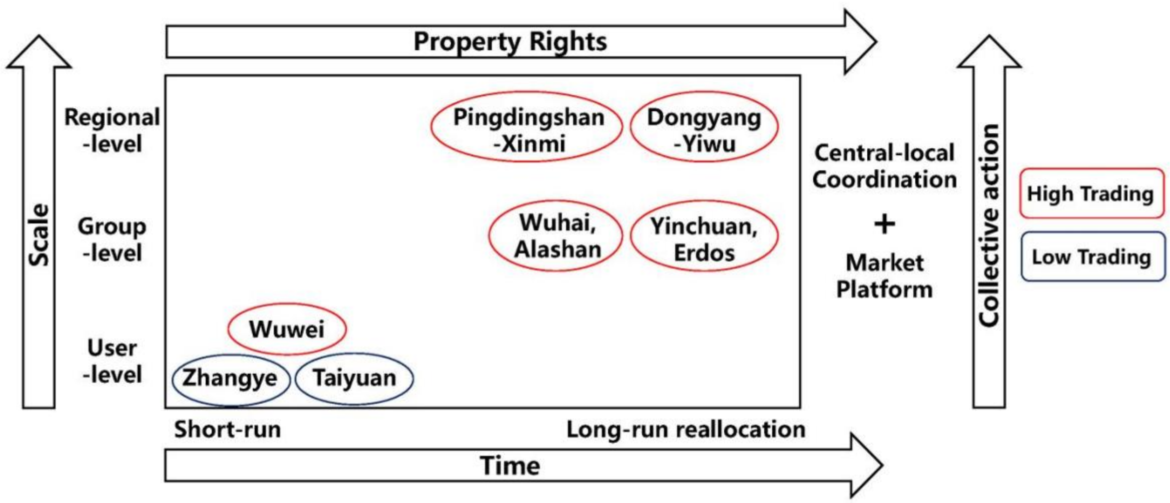
In summary, the interplay between central government, the market, and features of local governance that contribute to water-rights trading patterns on the one hand, and to the interaction between international and domestic factors in the diffusion of tradable water rights policy within China on the other, provides the core rationale for this dissertation.

1.2 RESEARCH FRAMING

How, then, should we understand variations in the water markets and their changes over time in contemporary China?

In this dissertation, I examine the puzzling variation and diversity of water markets in China through the lens of institutional diversity. As Ostrom (2005: 3) recognized, institutions are the "prescriptions that humans use to organize all forms of repetitive and structured interactions". Scholars point out that there is no single solution to water problems, but that one should instead recognize that institutional arrangements can take diverse forms to solve water problems at multiple scales (Meinzen-Dick 2007; Ostrom 2007). In essence, the term "institutional diversity" means that institutions are configurational in the types of rules they use in different settings (Ostrom 2010: 651–2). McGinnis (2011) notes multi-level, multi-type, multi-sectoral, and multi-functional units of governance in the context of diversity. According to McGinnis (2011), multi-level units involve local, national, regional, and global governance units. Multi-type governance involves general-purpose nested jurisdictions (as in traditional federalism) and specialized, cross-jurisdictional political units (such as special districts). Multi-sectoral units of governance mean public, private, voluntary, community-based, and hybrid kinds of organizations. Finally, multi-functional governance incorporates specialized units for provision (selection of goals), production (or co-production), financing (taxes, donors), coordination, monitoring, sanctioning, and dispute resolution.

Figure 1. **Property rights and coordination mechanisms related to Chinese water markets across time and space**



Note: Adapted from Meinzen-Dick (2014).

Thus, because markets are not monolithic, but operate in diverse human and biophysical contexts dependent on a variety of governance mechanisms, China's water markets provide an ideal setting in which to understand institutional diversity. By "institutional diversity", I mean the combination of market, government and community elements characteristic of China's water markets (Table 1).

In this thesis, I bring together the theoretical insights of historical institutionalism, infrastructural systems/theory, and policy transfer/diffusion studies in an attempt to theorize the conditions under which, over time and space, water markets are configured in terms of property rights, governance arrangements, and infrastructure. Drawing on semi-structured interviews, historical archives, and qualitative and quantitative measures on water-rights trading, I rely on a combination of case-study and comparative analysis. In doing so, I explain how domestic variations can influence the configurations spatially and how policy transfer and diffusion processes can do so internationally.

Chapter 4 consists of an analysis of the emergence and evolution of water markets across three river basins in north-western China. To understand how and why water rights systems and markets have evolved in Heihe, Shiyang and Yellow Rivers since 1949, the historical accounts of the decision-making cycles of infrastructural investments and institutional reform are examined by combining the concepts of path dependency and coupled infrastructure systems (CISs). This longitudinal research sheds light on how formative moments in Chinese politics affect the configurations of water markets.

The concept of a coupled infrastructure system (CIS) stresses how interactions among different types of infrastructural components affect the robustness and resilience of a defined CIS (Anderies, Janssen and Ostrom 2004; Anderies and Janssen 2013; Anderies, Janssen and Schlager 2016). Although much of the development of the CIS concept was focused on smaller-scale social-ecological systems (SES), including irrigation ones (McCord et al. 2017; Yu et al. 2015), more recent studies of sustainability challenge larger systems, including adaptations to water risk in cities (Tellman et al. 2018), coastal regions (Bonté et al. 2019), marine reserves (del Mar Mancha-Cisneros et al. 2018) and highways (Janssen et al. 2019). The insights that these studies generate call for a shift away from favouring institutional arrangements to explain resource outcomes and towards incorporating the role of technology, biophysical variables, and interdependencies. In this dissertation, there are two reasons why water markets are analysed from a CIS perspective. First, the CIS framework is suitable for this enquiry because water markets are made up of more than just institutions, and the CIS framework provides an analytical tool with which to understand water markets as configurations of institutional, physical, natural, and social infrastructure.

Second, looking at the development of water markets from a long-term perspective fits into scholarly calls to use the CIS framework to highlight the evolution of infrastructural investments and to generate an understanding of their dynamics over time (Anderies, Janssen and Schlager 2016: 511). In that it emphasizes formative moments and institutional reproduction mechanisms, path dependency is an important aspect of CIS because infrastructural investments can generate increasing returns that veer toward lock-in.

The focus of historical institutionalism is primarily on how institutions emerge and are embedded in concrete temporal processes (Thelen 1999). Scholars have often used the concept of path dependency to analyse how the historical path of institutional choices affects future options to reform water institutions (Garrick 2015; Heinmiller 2009; Marshall, 2013; Marshall and Alexandra 2016). Path dependency refers to "the causal relevance of preceding stages in a temporal sequence", implying that "what happened at an earlier point in time will affect the possible outcomes of a sequence of events occurring at a later point in time" (Pierson 2000: 252). The concept of path dependency contains one key insight concerning the cost of exit and the increasing returns processes. In other words, the status quo bias characteristics of political systems and the increasing returns associated with taking the same path down the line reinforces the difficulties of moving off an established trajectory. Moreover, the high cost of reversing a development trajectory is attributable to institutional arrangements and individual and organizational adaptations to previous arrangements. While actors might reflect on the potential benefits of institutional change, social adaptation to institutions "increases the cost of exit from existing arrangements" (Pierson 2000: 492). Path dependency emphasizes that choices made during formative moments in the past determine future institutional trajectories. Policy stability is punctuated by formative moments when "new conditions disrupt or overwhelm the specific mechanisms that previously reproduced the existing behavior" (Sjöstedt 2015: 2).

Chapter 5, which consists of a comparative analysis of the institutional design of water markets and of their diversity over the past twenty years, contains an evaluation of trading patterns in water rights within a CIS framework. Water markets are classified as coupled infrastructure systems in which different classes of infrastructure (such as natural infrastructure in the form of levels of water scarcity; hard infrastructure in the form of reservoirs and storage capacity; and soft infrastructure in the form of types of water rights, types of pricing, and roles of the local state and community) interact with the central government to shape patterns of trading in water rights. Going beyond the dichotomy of private versus public property regimes, I follow Meinzen-Dick's (2014) approach of separating property rights from the various coordinating institutions that govern water use and the exchange of property rights – whether they be the state, the community, or the market.

I draw on Meinzen-Dick (2014) to understand types of water rights and their dependence on the state and on farm-level organizations in China. The vertical axis in Figure 1 illustrates the level of water-rights trading, which ranges from transfers between farmers and communities to inter-sectoral and inter-jurisdictional trading. The arrow on the upper horizontal axis indicates that private property rights suit temporary trading among farmers. As the time dimension proceeds along the arrow, property rights change from being private to state-controlled. This means that inter-sectoral/inter-jurisdictional trading to secure the permanent or long-term reallocation of entitlements fares better under state-ownership and state control. The vertical axis on the right side of the figure indicates that water markets rely on central–local coordination and types of market platforms. As such, I engage with scholarship on the state's role in facilitating collective action (Mansbridge 2014; Villamayor-Tomas et al. 2019) to theorize the mechanisms that the central government deploys to shape patterns of water-rights trading. In doing so, I show how the central government interacts with the market and local institutional arrangements to implement pilot projects, infrastructural construction, and the reformation of water rights.

In Chapter 6, I focus on how interactions between domestic factors and Chinese–Australian development projects affect the adoption of tradable water rights policy in different provinces of China. I use the concepts of policy transfer and diffusion, which stress the processes of policy spreading (Minkman, Van Buuren and Bekkers 2018) and the factors "that cause a policy to spread from one government to another" (Shipan and Volden 2008: 841). In so doing, I extend and deepen the policy transfer and diffusion literature by analyzing the rise, fall, and revival patterns of tradable water rights policy through the lenses of powerful individuals, time (Dolowitz 2020), and bilateral development cooperation (Stone, Porto de Oliviera and Pal 2020).

In summary, in this dissertation I argue that the empirical patterns of institutional development identified in the Chinese water markets move beyond the binaries between markets and states, thus supporting the application of institutional diversity theory (Ostrom 2005, 2010). Longitudinal research and the comparative analysis of water markets in China are useful insofar as (1) they support the performance evaluation of water markets in the future, and (2) provide guidelines for other countries when designing water markets.

Table 1. **Elements of the institutional configurations associated with water markets in China**

Arrangements	**Element(s)**	**Description**
Central state	Top leader attributes and strategies	Decision-makers can tap into scientific and legitimate authority to (a) frame water-rights trading-policy by linking local practices of trading to national guidelines/policy frameworks; and (b) by establishing international partnerships to foster knowledge sharing.
	Pilot programmes	Provision of funding and/or co-implementing pilot programmes related to water rights registration and water rights transfer models.
	CWEX-platform	Centrally coordinated broker of local transfers that provide transaction consultation, technical evaluation, information release, intermediary services and public services (CWEX 2020).
Local state at or above county level	Local state participation	Local governments at regional, provincial, prefecture, and county level are water rights holders and possess the authority to (a) sell/buy surplus water within the total water use control quota, and (b) further allocate water rights to end users. The local government's water administrative department is responsible for the supervision and management of water rights transactions within its administrative area. This means, for example, that a local government is involved in implementing water-saving measures to finalize a long-term forward contract between a transferee and transferor. Moreover, the national water administration and river basin agencies exercise the authority to approve cross-basin water-rights trading (MWR 2016).
	Local water market platform	Two types of water market platforms exist at the local level in China: (a) water banks capable of water stocking; and (b) bulletin boards. Several provinces have established trading platforms, including the Inner Mongolia Autonomous

		Region Water Right Purchase, Storage and Transfer Centre (December 2013); Henan Water Right Purchase, Storage and Transfer Centre (April 2017); Guangdong Environmental Rights Exchange (June 2010); Ningxia Hui Autonomous Region Water-Rights Trading Platform (November 2017). The platforms in Inner Mongolia, Henan and Guangdong have the financial means to purchase, store and transfer water rights. Other platforms mainly provide trading information and intermediary services. These platforms are regulated by water administrative departments or, as in Guangdong, by industry authorities and the local people's government (Tian and Gu 2019). A few local platforms operate jointly with the CWEX platform.
Market	Price determination	Free market price refers to flexible price bargaining between a seller and a buyer. By contrast, fixed price refers to prices that a water agency determines. Bottom or capped price, in turn, refers to a benchmark price that the government sets but that allows for bargaining (Liu, Peng and Zhang 2018).
Community	Participation	Farmers can engage in the exchange process through price bargaining and determine the terms of the contract within the irrigation area if the water administrative authority has clarified the rights of irrigation water users through, for example, issuing a water rights certificate. Approval from the authorities is only required if the contract exceeds one year, in which case it must be reported to the irrigation district management unit or county-level equivalent in advance.
	Type of property right	Private property refers to the allocation of entitlements to households and water user associations. Collective property refers to group decision-making entities such as irrigation districts and enterprises that hold entitlements (Wang, Wan and Biswas 2017)

1.3 CORE RESEARCH QUESTIONS AND AIMS

Given the background above, what explains the emergence, diffusion, and diversity of water markets in China from a CIS perspective? The aim of the research for this DPhil is to answer three separate but interconnected sub-questions:

1) What factors shaped the design and evolution of the system of water rights and of water markets along the Shiyang, Heihe and Yellow rivers in north-western China?

2) How does the interplay of the central government, the market and local governance influence patterns of water-rights trading in China?

3) How do international policy transfers and domestic forces interact to shape the local adoption of water markets in China?

1.4 NOTES ON THESIS FORMAT

The structure of this dissertation is as follows. Chapter 2 is devoted solely to a review of the literature; Chapter 3 covers data sources and research methods. Chapters 4, 5 and 6 contain the empirical material, and Chapter 7 is an attempt to address the overall question of the thesis. I conclude the dissertation by explaining its core contributions, delineating the limitations of the research, and suggesting future directions into which these initial findings might expand.

This dissertation takes the form of the "paper" route along which the presented scholarly work in Chapters 4 to 6 has been published or submitted to the following peer-reviewed journals:

Svensson, J., Garrick, D. and Jia, S. (2019). Coupled infrastructure systems: comparing the development of water rights and water markets in Heihe, Shiyang and Yellow rivers. *Water International*, 44 (8), pp. 834–53. https://doi.org/10.1080/02508060.2019.1669110. (Chapter 4)

Svensson, J., Wang, Y., Garrick, D. and Dai, X. (2021). How does hybrid environmental governance work? Examining water rights trading in China (2000–2019). *Journal of Environmental Management*, Volume 288. https://doi.org/10.1016/j.jenvman.2021.112333. (Chapter 5)

Svensson, J., Zheng, H. and Garrick, D. (submitted). China/Australia cooperation and the rise, fall and revival of tradable water rights policy in China, 1998–2019. *Geoforum*. (Chapter 6)

The supplemental appendix provides the co-author declaration forms. The text, figures, and tables in each chapter (4–6) are the same as published or presented in the submitted version to the journals. All references have been compiled into a single list at the end of the thesis. Supplementary information to support the methods adopted in the chapters is available in the appendix at the end of the thesis.

2. LITERATURE REVIEW

In this review, which is an attempt to synthesize current understandings of water markets, I have two aims, namely to summarize the empirical findings of the literature, and to introduce the relevant variables and interactions that are examined in the three chapters of the dissertation. After defining water markets, both formally and informally, I then move on to describe the major trends in previous studies from the viewpoints of both path dependency and property rights. Since water markets do not arise from nowhere, their institutional legacies form an important part of their political economy. The theoretical relationship I outline between reforming water rights and initiating water markets suggests that water markets are as much about politics as about economics. To date, the importance of infrastructure and the central government's shifting role in managing water resources are yet to be properly integrated into the literature on China's water markets, which is essential in setting a priority for future research. Section 2.3 contains a summary of the findings of the various empirical studies of water markets. However, most of these focus almost exclusively on the institutions per se, albeit with increasing sophistication, but are restricted to democracies and fail to consider adequately the interplay between institutions and infrastructure. Moreover, studies on water markets in China have seldom concentrated explicitly on the impact of China's national conditions. Section 2.4 is therefore devoted to situating China's water markets within the water commons literature. Finally, Section 2.5, consists of a review of the policy diffusion and transfer literature on environmental policy, through which I identify the time dimension, and cooperation in the fields of foreign policy and development as at the leading edge of our knowledge in the field. I suggest that the rise, fall, and revival of tradable water-rights policy in China are useful avenues through which to understand the power of individuals, time, and cooperation in bilateral development.

2.1 WHAT IS A WATER MARKET?

Water markets are the allocation institutions that facilitate the voluntary, compensated reallocation of tradable water rights in which willing buyers and sellers respond to price signals that convey the scarcity value of water (Garrick and Svensson 2018: 4). Importantly, the legal reforms underpinning formal water markets enable public property rights to be used in such a way as, under a range of conditions, some water-use rights can be divided, transferred, privately managed or traded (Wheeler and Xu 2021: 3). For at least forty years, formal water markets have been developed in countries as varied as Australia, Chile, China, Spain, and the USA to address the water scarcity challenge, with mixed success and some regions, like Canada, abandoning the approach altogether (Easter and Huang 2014). Furthermore, informal water markets can also be established, which involve transactions that lack legal status or occur in the absence of regulation. Informal water markets come in multiple forms, including private tubewells and informal swapping of water, as has occurred in Angola (Cain 2018), India (Srinivasan, Gorelick and Goulder 2010; Venkatachalam 2015), Kenya (Whittington et al. 1989), Pakistan (Razzaq et al. 2019) and Nepal (Raina, Gurung and Suwal 2020).

As O'Donnell and Garrick (2019) pointed out, in practice, a water market can operate without legally defined tradable rights, and market formality can be framed as a spectrum rather than a binary, thereby implying that water can be traded between a buyer and a seller on the market without making any allowance for a profit markup. Moreover, they observe that the distinction between agricultural and urban water markets is becoming less relevant with growing water scarcity and mounting urban water demands. However, water markets do not emerge in a vacuum, but evolve in different stages across many countries.

2.2 PATH DEPENDENCY AND REFORMING WATER RIGHTS

To start with, there are several theories of institutional change. There are a handful of scholars focusing on collective-choice theories of institutional change. These scholars view institutions as an outcome of a centralized, collective-choice process in which actors, such as individuals, organizations, the community or the state engage in activities such as lobbying, bargaining, voting or competing to change rules for their own benefit (Kingston and Caballero 2009: 155). In this vein, Ostrom (2005) treats institutional change as a process by which individuals engage in cost-benefit analysis of an institutional change (Ostrom 2005: 254). If a 'minimum coalition' necessary to effect change is achieved, then institutional change can occur. Similarly, Mahoney and Thelen's (2010) logic of institutional change emphasize the power-distributional process of institutions by which problems of rule interpretation and enforcement open up space for actors to implement existing rules in new ways (Mahoney and Thelen 2010: 4). More specifically, their theory focuses on the concepts of displacement, layering, drift, and conversion. Displacement is defined as the removal of existing rules and the introduction of new ones. Layering is defined as the introduction of new rules on top of or alongside existing ones. Drift, on the other hand, is defined as the changed impact of existing rules due to shifts in the environment. Finally, conversion is defined as the changed enactment of existing rules due to their strategic redeployment (Mahoney and Thelen 2010: 16).

Also, institutional change exhibits the logic of path dependence even though this concept is commonly used to explain institutional stability. Path dependency is the notion that history matters to the choices and evolution of institutions. Heinmiller (2009) notes that research on collective action has paid little attention to either the historical institutional context in which collective action occurs, or to the constraining effects of path dependency. In the context of water, path dependency means that it becomes difficult to undertake institutional change when investments and adaptations to early resource management institutions provide positive feedback to the actors subject to them. According to Heinmiller (2009), this positive feedback is prevalent in the water appointment institutions of the rivers of Colorado, Murray–Darling and Saskatchewan. In all three cases, Heinmiller (2009: 135) identified four sources of path dependency – vested interests at multiple governance levels, network effects (hydrological and institutional connections between jurisdictions and between water users within a jurisdiction), the sunk costs of investments in the physical infrastructure, and the contractual nature of water entitlements. Combined, these factors have made water appointment institutions path dependent and constrained conservation efforts.

Furthermore, path dependency, along with its effect on institutional change, is evident in the water-rights assignments (Krutilla and Krause 2010). Libecap (2011) argues that appropriate rights structures, and the public irrigation districts that had in the past emerged in the western United States to facilitate agriculture, constrain water markets today because modifying or replacing property rights comes at a considerable cost. The central point, according to Libecap, is that this "institutional path dependence illustrates how past arrangements to meet conditions of the time constrain contemporary economic opportunities" (Libecap 2011: 66).

Hanemann and Young (2020) argue that arrangements to manage water need to be redesigned if water marketing is to become the norm. Although initially sharing a similar system of riparian water rights and arid conditions, the water-rights reforms undertaken in the western USA and Australia in the nineteenth century produced different institutional trajectories. In the western USA, riparian and appropriate rights are not self-enforcing and have distorted water marketing, but in Australia, the common law property right to water was abandoned and replaced with a statuary right that legislation or the administration could modify. This, in turn, shifted the conflict resolution arena from courts to parliaments and government agencies, which reduced barriers to trading water.

Hanemann and Young (2020) also identified several factors distinctive to Australia compared with the US west: (1) water rights in Australia are nationalized; (2) state governments in Australia closely and actively control the irrigation institutions; and (3) the Australian national government is willing to intervene in state and local water management in the face of environmental crises. In short, the water market in Australia accommodates both short-term flexibility and long-term water reallocations, achieved mainly through funds the national government provides for buying water back from irrigators for the environment. However, the progress of the reform has been slow and costly due to institutional reproduction mechanisms and hence path dependency.

For instance, Marshall and Alexandra (2016) found that irrigator-sector organizations in Australia's Murray–Darling Basin managed to divert attention away from buy-backs and towards water-saving infrastructure projects. They also identified other sources of path dependence – information asymmetry/institutional complexity (the longer and deeper involvement of irrigation groups in water policy creates informational advantages); mental models (traditional engineering approaches became locked in with public policy discourse); and a shortage of skills among irrigators required to undertake complex reforms.

In a parallel research development, scholars have examined the state/market dichotomy in water paradigms. On the one side, studies have turned their attention to the politics of state-led water management. The state hydraulic paradigm, as Bakker (2014: 472) notes, is "the reconceptualization of water as a sinew of development as states actively sought to extend control over and develop water resources, focusing on subsidized supply-side, large-scale, state-run hydraulic infrastructure projects for a range of (at times conflicting) purposes." Focusing on China, McCormack (2001: 26) states that "the Western mechanistic view of nature as refracted through the Marxist-Communist bureaucratic state – happens to be rooted in the oldest traditions of the Chinese hydraulic state." He further argues that the Chinese government favours the "modern" paradigm of water engineering and that the paradigm shift will be more difficult in China than it has been elsewhere in the world.

More than a decade later, the contributors to a special issue of *Water Alternatives* asked, "are we witnessing a widespread (re)turn to big infrastructure projects for water management?" (Crow-Miller, Webber and Molle 2017: 195). They held that the endurance of big infrastructure projects globally, including big dams and inter-basin transfers, is couched strategically in discourses on green development and sustainability. Their findings suggest that scholars need "to pay greater attention to both the historical contingencies and financial connections that have shaped the water infrastructure projects of today" (Crow-Miller, Webber and Molle 2017: 203). A study by Crow-Miller, Webber and Rogers (2017) in the special issue analysed how the doubling down on big water infrastructure came about by describing the evolution of China's approach to water management. Their findings to some extent mirror those of McCormack (2001), in which a techno-political regime, made up of infrastructures and other technologies, ideologies, and networks of institutions reflects past choices about controlling nature. But, as Crow-Miller, Webber and Rogers (2017) suggest, this techno-political regime has since 1978 also developed in new directions and now enrols domestic and international state and non-state actors.

Then again, scholars have criticized the state hydraulic paradigm and called for new ones to replace it. One response has been to promote market environmentalism, defined as "a doctrine premised on the synergies between environmental conservation and protection, economic growth, market economies, and neoliberal governance" (Bakker 2014: 475). Bakker also stresses the importance of reassessing the literature on market environmentalism in the water sector, and more specifically on the privatization of resource ownership and management, the commercialization of resource management organizations, the environmental evaluation and pricing of resources, the marketization of trading and exchange mechanisms, and the liberalization of governance. It is suggested that market environmentalism has only partially displaced traditional state involvement in water management and many aspects of the hydrological cycle in countries are still government owned, managed, and regulated. It is further suggested that market environmentalism is not synonymous with privatization. Rather, market environmentalism involves an array of processes that may, among other things, include the creation of market-based mechanisms. However, while implementation of trading and exchange mechanisms may involve tensions that are difficult to resolve in practice, Bakker (2014) argues that a return to state-led water management is unlikely.

Finally, scholars who focus on hybrid forms of governance in the context of water management are now moving away from the distinction between the state hydraulic paradigm and market environmentalism (Pahl-Wostl 2019; Pahl-Wostl et al. 2011). With regards to property rights, different actors (individuals, groups, and the state) can hold overlapping rights to and responsibilities for water resources, forming what Schlager and Ostrom (1992) describe as a bundle of rights, which implies rights to access and withdrawals (use rights), as well as rights to management, exclusion, and alienation (decision-making rights). Wang (2018), who pinpoints pluralism in water rights, argues that the private property rights of end users, namely the right to use water and in some jurisdictions to trade it, are conditioned by collective property rights held by water withdrawing groups and state ownership of water on behalf of the Chinese people. He further develops a hierarchical framework within which to describe the structure of China's water rights. It involves implementing a mixture of administrative and market methods at different levels in the hierarchical governance structure. A decision-making entity in the hierarchical governance structure is defined at four levels – central decision-making entities; local decision-making entities; group decision-making entities; and users (farmers). Decision-making entities are governmental agencies at the top of the hierarchy, while water rights for users at the bottom levels are generally informal and unclearly defined. The central argument is that market mechanisms are gradually introduced for cost effectiveness. Wang (2018) also stresses that there are stronger reasons to introduce market mechanisms at the bottom of the hierarchical framework than at the top because a lot of the lower-level decision-making entities are highly heterogeneous and expensive to administer.

To summarize, despite increasing attention paid to hybrid governance systems in China (Jiang et al. 2020; Wang 2018), little has been done to examine how the adoption of water rights and associated market mechanisms came about in China's state-led water management system. Although a considerable amount has been written on water-rights reform (Hu and Wang 2000; Wang, Wan and Biswas 2017; Xiao 2004; Yubo 2001), and on big infrastructure projects for water management (Crow-Miller, Webber and Rogers 2017; McCormack 2001), not nearly enough has been done to link water-rights reforms to infrastructural decisions and the central government's shifting role in the management of water resources. Nonetheless, through this dissertation, which I have based on an historical analysis, I attempt to fill this knowledge gap. I emphasize the formative moments with respect to property rights and path dependency, and trace the institutional choices associated with capping water diversions, the initial formal allocation of water rights, and trading rules pertaining to water policy and politics in the People's Republic of China before 1998, between 1998 and 2009, and after 2009.

2.3 EMPIRICAL FINDINGS ON WATER MARKETS

In recent years, scholars have expanded their research into the institutional foundations of water markets. Building on Bakker (2007), Grafton et al. (2016) offer insights into the theory as opposed to evidence of water markets. They highlight that (a) it is possible to privatize the entitlements without actually marketing the water; (b) that it is possible to have water markets without "appropriation by accumulation"; and (c) that water-market depend on "the surrounding institutional and social setting" (Grafton et al. 2016: 915). Moreover, they developed an integrated framework through which to identify the strengths and weaknesses of five water markets – Australia's Murray–Darling Basin, the western United States, Chile, South Africa, and China. They also highlighted eight criteria through which to assess and compare the institutional foundations of the selected water markets (Grafton et al. 2011: 221). This integrated framework offers a systematic approach to studying water markets beyond market preconditions such as administrative capacity, definition, and recognition of water rights. Rather, they consider mechanisms for resolving conflicts and horizontal coordination at a given level of governance and vertical coordination between different levels of governance. Integrated water markets also recognize the capacity for institutional adaptation, defined as the ability to "adjust to unexpected shocks, incorporate new and revised information, and respond in a timely manner to changes in societal preferences over how water is managed and used" (Grafton et al. 2011: 228).

Even more specifically, Garrick, Hernández-Mora and O'Donnell (2018) analysed the institutional mechanisms used to facilitate coordination and conflict resolution in three countries with experience of water markets. They used process tracing techniques to compare the involvements of national and state governments in the water markets of Spain (the most centralized example), the USA (the most decentralized) and Australia (the mixed approach). Their findings suggest that the institutions involved in coordinating activities can take multiple forms, and that "effective markets go hand in hand with effective governance and strong institutions, whether formal, informal or some blend of the two" (Garrick, Hernández-Mora and O'Donnell 2018: 1605).

Wheeler and Xu (2021) have undertaken a recent global review of the water market literature in which they identify 465 studies within the social sciences on surface water and groundwater markets over the period from 1970 to 2019. They summarize the regional distribution of water-market studies as follows – Australia (36 per cent); United States (28 per cent); China (7 per cent); Spain (4 per cent); United Kingdom (1 per cent), Middle East and North Africa (4 per cent); Canada (2 per cent), and others (8 per cent). Moreover, they apply a water market readiness assessment (WMRA) framework to twenty regions across six continents to determine a country's "readiness" for the implementation of formal water markets. The WMRA envisions three institutional steps:

1. An assessment of hydrological and institutional needs. This first step defines the total resource pool available for consumptive use and hydrological factors of use, and evaluates the current institutional, legislative, planning, and regulatory capacity to facilitate water trade, including setting caps and regulations on use.
2. A market evaluation. The second step develops clear and consistent trading rules and assesses benefits and costs of market-based reallocation, including number of individuals who can trade, homogeneity of water use, adaptation benefits, cost of water reform, ongoing trade transactions and assessment of externalities.

3. Continuous review and assessment of future needs. The third step is a monitoring and enforcement exercise that seeks to ensure the compliance and development of trade-enabling mechanisms, including reducing transaction costs, scanning for externalities, developing new market products and, if needed, implementing new legislative changes and planning requirements.

Table 2 shows how factors and institutions associated with water market readiness have developed across different case-study areas. In Europe, America and Oceania, several water market characteristics are missing, especially in France, Italy, the United Kingdom, Chile, and Diamond Valley in the USA. These include the unbundling of rights; transferable rights; understanding trade impacts; the existence of a cap (though England and Chile have made some progress in this area); monitoring and enforcing water extraction; trustworthy water registers; and trade and market information (Wheeler 2021: 239). Although France has strong institutions and a considerable amount of hydrological information on hand, property-right reforms, such as unbundling water rights from the land, coupled with a very low social acceptability of water markets, have hampered the use of the latter as a reallocation mechanism (de Bonviller and de Bonviller 2021: 154). Moreover, water markets in Italy are also situated in Step 1 of the WMRA framework. The Po River basin district in northern Italy has unbundled the water rights from the land, but the development of water markets has remained stagnant due to a fear of third-party impacts (Dionisio Perez-Blanco 2021: 169).

Table 2. Overview of WMRA framework in Oceania, Asia, Europe and America

Key fundamental market assessors	A	B	C	D	E	F	G	H	I	J
Property rights/institutions										
Water legislation	✓	✔	✔	✓	✔	✔	✔	✓	✓	✓
Unbundled rights	✓	✔	x	✓	x	x	✔	x	x	✓
Rights transferable	x	✔	✔	✔	x	x	x	✓	x	✓
Rights enforceable	✓	✔	✓	✓	✓	✔	✔	✓	✔	✓
Constraints between connected systems	✓	✓	x	✔	✔	x	x	x	✔	✓
Hydrology										
Documented hydrology system	✓	✔	✓	✔	✔	✔	✔	✔	✔	✓
Understanding of connected systems	✓	✔	✓	✔	✓	✔	✔	✔	✔	✓
Future impacts modelled	✔	✔	✓	✓	✓	✔	✔	✔	✔	✓
Trade impacts understood	x	✓	x	x	x	x	x	✔	✔	x
Resource constraints understood	✓	✔	✓	✓	✔	✔	✔	✔	✔	✓
Resource constraints enforced	x	✔	✓	x	x	✔	x	✓	x	✓
Externalities/Governance										
Strong governance impartiality	x	✔	✓	✓	✔	✔	✔	✓	✔	✓
Existence of externalities understood	x	✓	x	x	✔	✔	✓	✓	✔	x
Water-use monitored	x	✔	✓	x	✓	✔	x	x	x	✓
Water-use enforced	x	✔	✓	x	✓	✔	x	x	x	✓
System type										
Suitability of water sources for trade	x	✔	✔	✔	✔	✔	x	✓	✔	✓
Transfer infrastructure availability/suitability	✓	✔	✓	✓	✔	✔	✔	✓	✔	✓
Regulation requirements for trade	x	✔	✓	x	x	✔	x	✓	x	✓
Adjustment										
Gains from trade	x	✔	✔	✓	x	✔	x	✓	✔	✓
Political acceptability of trade	x	✔	✓	✓	x	x	x	✓	✔	✓
Entitlement registers and accounting										
Trustworthy systems	x	✔	x	✔	✔	✔	x	✓	x	✓
Trade and market information availability	✓	✔	x	x	x	x	x	x	x	✓
Trade step reached:	2	2–3	2	1–2	1	1	1	2	1–2	2–3

Note: A = Australia (Northern MDB); B = Australia (Southern MDB); C = Chile; D = China (Zhangye); E = France (Poitevin); F = France (Neste); G = Italy; H = UK; I = USA (Diamond valley); J = USA(Idaho). x indicates further reform required for that issue in the particular regional example; ✔ indicates that there is good evidence supporting that particular part of the assessment; while a smaller ✓ indicates that there is positive but limited evidence, and thus room for improvement.

Source: Adapted from Wheeler (2021).

The water markets in both the UK and Chile, by contrast, have achieved Stage 2. Bark and Smith (2021) applied the WMRA framework to the Upper Ouse and Bedford Ouse catchments in eastern England, and found a dynamic and informal water market based on land trades. In addition, their study suggests that England has many conditions conducive to the development of water markets, including strong water legislation and environmental protection. Nonetheless, they argue that there is a critical need for trusted decision-making tools with which to strengthen the future development of a formal water market (Bark and Smith 2021: 187). While Chile has a long tradition of managing water resources with water rights, Donoso et al. (2021) found that trading is only prevalent where there is a high demand for water in valleys with a flexible water distribution infrastructure and where water user associations (WUAs) assist. These results mirror the findings of Hearne and Easter (1997) in four valleys in Chile, which suggest that low transaction costs and frequent trades in valleys are attributed to a modern infrastructure and well-developed WUAs. Nevertheless, Donoso et al. (2021) identify the possible barriers to water markets as being (1) a lack of information on water rights and the water-rights market; (2) the insufficient regularization of customary water rights; (3) the failure of water rights and water use enforcement; and (4) no modelling of externalities.

When Gilson and Garrick (2021) applied the WRMA framework to the Columbia Basin, they placed the Diamond Valley on Steps 1–2 of the trading framework, and Idaho on Steps 2–3. Since their results pointed to an unevenness of local institutional capacity both within and across state boundaries, they argued that enabling conditions should be pursued and coordinated at basin, state and local levels. More specifically, they drew attention to the cultural context in the early stages of water-market development: “certain geographies may need to expand the scope of their assessment beyond externalities to adequately and proactively prepare for socio-cultural barriers, such as push-back from farmers who perceive transactions as threatening to their cultural heritage” (Gilson and Garrick 2021: 218).

Focusing on Australia, Wheeler and Garrick (2020) compared the water markets of the southern and northern sections of the Murray–Darling Basin (MDB), and looked into why they have been more successful in the southern part (Steps 2–3) than in the northern one (Step 2). Their findings show that (1) property rights and market design matter and must be fit for the context; (2) up-to-date information, a complete set of water-market registers, a strong monitoring ability, compliance enforcement, and large numbers of participants keep the transaction costs low; and (3) that while the water-market products are homogeneous, the water traders are heterogeneous (Wheeler and Garrick 2020: 148–9). They also give several reasons for the gap between the southern and northern parts of the MDB:

1. The southern MDB is much more hydrologically connected than its northern counterpart.
2. There are more ‘unregulated’ water entitlements in the north than south.
3. There is far greater reliance on groundwater for irrigation in the northern MDB than in the southern one (on average, 17 per cent and 10 per cent respectively), plus the use of on-farm irrigation storage (32 per cent versus 3 per cent respectively).
4. The opportunity cost of water is far higher in the southern MDB (on average 2.6 times higher in annual irrigation water charges paid $/ML) than the northern MDB.
5. There are many more irrigators in the southern than northern MDB.
6. Southern irrigation businesses tend to be smaller (on average 84 hectares in the southern as opposed to 124 in the northern basin).
7. The southern MDB has strong monitoring (up to 84 per cent of water use is monitored) and compliance, while the northern MDB has the opposite (up to 75 per cent of water use is not monitored, along with very poor compliance enforcement/checking by state water authorities).

8. The southern MDB is much more industry diverse, while the northern one is dominated by one industry – cotton.

Notably, Wheeler (2021) also stressed that China is the only country in either Africa or Asia to have progressed past Step 1 and to have established property rights and strong independent water institutions, although it is necessary to acknowledge that the assessment is based only on the Heihe River Basin, around Zhangye City in Northwestern China. Scholars regard the institutional reform in the Heihe River as a typical example of establishing a tradable water-rights system in China's rural areas. Even more than a decade ago, Zhang (2007) noted that the experimental water markets in Heihe were not working because inadequate monitoring was allowing farmers to extract more than their entitled amount of water, which reduced their need to buy it on the market. Since then, there have been several studies on the theory and practice of water markets in China. Zuo et al. (2021), who applied the WRMA framework to the Heihe River, concluded that "without an exchange platform and irrigation infrastructure to facilitate trade at the individual level efficiently and effectively, formal water trade between farmers is not likely to result in substantial benefits, and hence is not widely adopted" (Zuo et al. 2021: 74). Likewise, as Sun et al. (2016) noted, the low level of trading activity along the Heihe River has brought little by way of benefits, for which several barriers are responsible. These included the high cost of implementation given the large number of small-scale farmers, and a lack of consistency in applying measures to hold water users accountable.

In contrast to the Heihe River, since 2008, a primary water market has emerged among irrigators in the Shiyang Basin, in Gansu province. Xu et al. (2016) utilized a structural method to assess the water market in Xiying district in the Shiyang Basin in north-western China, and their findings highlight the importance of (1) the initial allocation of water rights; (2) a prior or proportional definition of rights; (3) the presence of a water supply and monitoring infrastructures; and (4) the active participation of water user associations. For example, they found that most water sellers are located upstream of the irrigation canals and the WUAs they use to buy water are located downstream. Furthermore, they highlight several barriers, including insufficient incentives for water-saving and trading; high transaction costs; an inefficient irrigation schedule; and corruption.

With the focus on scale, a study by Wang (2012) simulates water markets through the lens of their transaction costs in different areas of the Yellow River. In general, he finds that it is potentially much easier to trade water between the agricultural sector and the industrial sector than it is within the agricultural sector because the industrial sector is less sensitive to transaction costs. Within this vein, Wang, Shu and Wu (2017) provide a comprehensive literature review of water markets and outline guidelines for China. One point they make is that theoretical research and policy practice tend to over-emphasize the role of the market and pay too little attention to China's national conditions. Wang, Shu and Wu (2017) then go on to ask the following questions. What national conditions in China constrain the development of a water-rights market? How should one best develop water-rights trading under such national conditions? How can one coordinate between various water rights entities? How can sub-regional governments effectively supervise water-rights trading under the different geographical and socio-cultural conditions that exist on so many small-scale agricultural farms? And, finally, how close is the match between the reforms of the water price, water rights and the water market? Moore (2015), who has examined the links between China's national conditions and the design of water markets, identifies three distinct features that constrain water markets. These are the legacy of administrative control over water; the existence of a distinctive agricultural structure and the salience of peasant political interests; and central–local tensions and conflicts.

Lewis and Zheng (2019) also highlight the challenge of effectively monitoring and enforcing water rights when the amount of available water is being shared among such a very high number of farmers with small plots of land. Considering these challenges, Jiang (2018: 218) notes that there is an ongoing debate in China about whether it is better to operate the water markets at an individual farmer level, or at the level of WUAs or irrigation districts; and on whether China should adopt a decentralized or centralized approach to administering water rights. She furthermore argues that water markets are being significantly undermined by the attempts of the jurisdictions and bureaucratic units responsible for administering water rights to coordinate their activities, thus highlighting the importance of recentralizing at provincial/river-basin levels to promote progress towards trading within broader scopes.

Finally, Liu, Peng and Zhang (2018) examine the resilience of ten water markets from the eastern, central, and north-western parts of China. While bearing in mind the conditions of market environmentalism, their focus is more specifically on the ownership of water entitlements, market intermediaries, water pricing, and spot/forward trade categories. They found that no necessary conditions contribute to resilience, and that there "exist multiple paths that a resilient water market can follow and develop" (Liu, Peng and Zhang 2018: 1). Although they mention using a simplified operationalization of the resilience concept (Liu, Peng and Zhang 2018: 13), their analysis is characterized by a notable absence of biophysical characteristics, and a failure to integrate the role of infrastructure into the argument. To summarize, while institutional conditions, like assigning water-use rights to individual users for market-based allocation, have generally been strengthened in China (Wheeler 2021), an understanding of how enabling conditions vary within the country as well as across scale is important for driving the literature forward.

2.4 RELEVANT INSIGHTS FROM THE WATER COMMONS LITERATURE

Institutional analysis is at the centre of collective action research. In the past, Hardin (1968) saw the state and market as the two governance options that could prevent a tragedy of the commons. This led to rising empirical evidence that governance by government or governance by markets are not the only solutions to natural resource management. In *Governing the Commons*, Ostrom (1990) showed, through her comparison of many case studies, that under certain conditions resource users are able to govern common-pool resources (CPRs) sustainably. She developed a set of eight design principles to describe the features of rule clusters associated with successful collective action in CPR governance. More recently, Cox and Villamayor-Tomas (2010) undertook a meta study in which they analysed the design principles of 91 studies and found them to be well supported. However, when Araral (2014) reassessed Ostrom's work, he identified several concerns to examine further. First, he argued that Ostrom's critique of Hardin is valid for small-scale locally governed commons, but Hardin's pessimism is justified for regional and global ones. Second, Araral (2014) argued that the five case studies that Ostrom referred to as successfully governed CPRs are not entirely correct. These five cases can be seen as privatized systems in which exclusion is feasible. Moreover, he also found that the eight cases that Ostrom decided were institutional failures were in fact open-access goods from which exclusion of the resource system and unit is difficult and where consumption is rivalrous. He, therefore, called for a rethinking of Ostrom's critique of private property rights and markets in the commons. Against this background, in this dissertation, I respond to two trends in the study of the governance of common-pool resources.

First, scholars have begun to look at combinations of design principles, rather than to examine them independently (Baggio et al. 2016; Cox 2011). The study by Baggio et al. (2016) extended the work of Cox and Villamayor-Tomas (2010) to assess the co-occurrence of design principles through the lens of a coupled infrastructure system (CIS). Having conducted a qualitative comparative analysis of 69 cases, they found that no single design principle is necessary for success, but that success depends on the natural and hard-made infrastructure. For instance, clearly defined social boundaries are important when the natural infrastructure is highly mobile (as with tuna fish), while monitoring is more important when the natural infrastructure is more static (as in forests or water contained within an irrigation system). Schlager (2016) noted that more work is needed to examine different combinations of design principles and how they are linked to diverse CPR settings. In China, a comprehensive study on collective action by Wang, Chen and Araral (2016) called for a configurational approach to the study of Ostrom's design principles. Based on a survey of 1,870 irrigation households, they found that labour migration has a statistically significant adverse effect on collective irrigation participation. Although migration partly explains the massive drop in the use of collective canal irrigation systems, several factors, including leadership, social capital, sense of community, economic heterogeneity, and dependence on resources mediate the effects. Consistent with the broader literature on the commons, they confirmed that "the complex interactions among the factors remain to be studied to deepen the understanding of complex institutional arrangements in diverse socio-ecological settings" (Wang, Chen and Araral 2016: 91).

Second, the institutional tripod of government, markets, and communities has also received increasing analytical attention (van Laerhoven, Schoon and Villamayor-Tomas 2020). A study by Wang, Zhang and Kang (2019) examined the connection between external political factors at the macro level and self-organization at the micro-level. They applied Ostrom's design principles and found that improving them increased the probability of success in nine WUA cases. External resource interventions were measured as financial support, infrastructure property control, and workplace provision to WUAs, while leadership interventions were measured according to whether the WUA leader was a village cadre or grassroots official of the CCP. While the evidence generally supports Ostrom's design principles on all outcome dimensions, resource and leadership interventions from the macro-level lead to an unclear boundary between power and responsibility over making rules, as well as conflicts with local power structures (for example, the village committee), thus causing inefficient rule enforcement mechanisms and lower outcomes.

Moreover, Wang, Eisenack and Tan (2019 examined diverse rural renewal patterns in China based on data from 27 cases. They identified eight archetypes, which consisted of one unsustainable, two semi-sustainable, and five sustainable rural renewals. Their findings suggested that the governance system should be aligned with the attributes of rural land resources, actors' characteristics, and the properties of interactions. They also found that a governance system with decentralized features contributes to sustainable rural renewal and to a long-term perspective on rural renewal, and that both long-term incentives and a horizon of revenue disposition contribute to rural sustainability. Also focusing on rural China, Su, Araral and Wang (2020) systematically examined the effects of trading land-use rights on irrigation collective action in the irrigation commons in the light of large-scale rural labour outmigration. They found that trading land-use rights has a positive effect on the collective action of the commons and can slow down and mitigate the negative effects of labour outmigration. They conclude that the reforms in farmland property rights are helping to create a new class of farmers and new modes of ownership.

Absent from the above literature review is any analysis of the determinants of water markets in terms of both breadth of comparison and depth of individual cases, plus any descriptions of their characteristics. Consequently, through this dissertation, I hope to be able to contribute to the broader ongoing theoretical environmental governance debates on the institutional tripod of government, markets, and communities, and generally explain the spatial and temporal dynamics of water-rights trading. I do so in three major ways – (1) by assessing the role of the central government and its varied channels in shaping water markets, including pilot programmes and the CWEX platform; (2) by explaining how the assignment of property rights is fit for its context and linked to types of water market platforms (water bank versus bulletin board); and (3) by examining the interplay of institutions and types of hydraulic infrastructure (including inter-basin transfers, storage capacity, and/or irrigation efficiency investments) in water markets. Broadly speaking, the three areas offer potential guides to future studies on how exclusion and boundary rules that define access to Chinese water markets can work to prevent a tragedy of the commons.

2.5 POLICY DIFFUSION AND TRANSFER LITERATURE REVIEW

Research on policy transfer and policy diffusion has received significant analytical attention in different academic fields in recent years. On the one hand, international relations theory confronts the reality of explaining how and why a policy or programme shifts and spreads over multiple territories.

On the other hand, development studies scholars attempt to understand how, and under what circumstances, international organizations support best-practice policy borrowing among governments (Jordana 2021: xiii). In a nutshell, policy diffusion refers to a process that “cause[s] a policy to spread from one government to another” (Shipan and Volden 2008: 841). Policy transfer, in turn, is defined as a process by which “knowledge about policies, administrative arrangements, institutions and ideas in one political setting (past or present) is used in the development of policies, administrative arrangements, institutions and ideas in another political setting” (Marsh and Shaman 2009: 270). In short, both approaches aim to explain the movement of political objects in time and space (Porto de Oliviera 2021: 6).

Marsh and Shaman (2009) contend that the two approaches complement each other but differ in various ways. Diffusion theory focuses on structure, while the literature on policy transfer tends to focus on agency. In this context, diffusion research is interested in mechanisms or combinations of mechanisms that affect policy spreading. Regarding methodological approaches, diffusion studies use quantitative methods and rely on large-N studies to generalize “the reasons for, and the results of, the process”. Policy transfer studies, in turn, tend to use qualitative analysis to focus on “a detailed analysis of the transfer of a policy” in small-N settings (Marsh and Shaman 2009: 273–5).

Despite differences, a typology of mechanisms consisting of learning, emulation, competition, and coercion has become dominant (Kuhlmann 2021: 43). To date, studies of policy transfer and diffusion in China have embraced mechanism-based approaches (Huang and Kim 2019; Wu and Zhang 2016; Zhang and Zhu 2019a, 2019b; Zhu 2014, 2017; Zhu and Zhang 2016). Learning refers to a process in which knowledge or experiences elsewhere are used to inform policy-making. Emulation refers to a process in which a government copies the policies adopted by other governments. Competition refers to economic interactions between units that may lead to spillover effects across jurisdictions, thereby affecting the benefits and costs of adopting a policy. Coercion refers to a power asymmetry in which one unit puts pressure on another to adopt a certain policy. In addition, these four mechanisms are sometimes conceptualized as horizontal (between units) and vertical (from a higher unit to a lower unit) (Kuhlmann 2021: 46). A critique from Kuhlmann (2021) holds that studies often neglect the causal processes underlying the different mechanisms, and that these studies lack conceptual clarity when it comes to distinguishing one mechanism from another. She further suggests that scholars need to pay attention to actor constellations, stages of policy processes, and promoters (such as for example “policy entrepreneurs” (Kingdon 1984), “epistemic communities” (Haas 1992), or “policy ambassadors” (Porto de Oliviera 2020).

Environmental policy remains an important field of policy transfer and diffusion. In detail, Pacheco-Vega (2021: 387) broadly defines it as “the sets of tools, techniques, programs, instruments, plans and ideas associated with the governance of ecosystems and their interactions with society.” Pacheco-Vega (2021) also provides a review of policy transfer in the environmental sector using four issue areas, namely water, waste, climate, and energy. He notes that although water and waste received significant attention in the late 1990s and early 2000s, it has stagnated because of the central concern of climate and energy-related issues. Nevertheless, he holds that water policy has regained attention in the light of a global shift towards the privatization of public services. A point made by Pacheco-Vega (2021) is that, due to the high degree of environmental variability, there are uncertainties associated with transferring environmental policies.

In one example, Michaels and de Loë (2010), who show how water management institutions were transferred into Canadian states from Australia and the USA, cite bio-physical factors as critical to lesson-drawing. Swainson and de Loë (2011), who took this research further, looked into what factors shaped the transferability of the water allocation system in NSW, Australia. They argued that the NSW environmental water allocation systems were “developed in a specific hydrologic context” and that biophysical contexts “influence fit and the transfer of policies for water management” (Swainson and de Loë 2011: 67). De Loë et al. (2016) also identified the importance of biophysical attributes in transferability. In a study of policy transfer among 19 source protection regions (SPRs) established under a common legislative framework in the province of Ontario, they noted that the survey participants who knew which SPRs had similar contexts “preferred to contact colleagues from these SPRs directly rather than to review information these people had posted online” (de Loë et al. 2016: 45). They also found that policy transfer was most useful in the initial phase of policy development. In the early phase, they noted that “participants were able to gain ideas from what other SPRs were doing and to consider how to apply similar approaches to their context. As the policy process progressed, participants indicated that they were less likely to look for ideas or examples from other places” (de Loë et al. 2016: 45). Also, the presence of the *Clean Water Act* in Ontario facilitated the policy transfer.

While water policy has received increasing attention in the literature on policy transfer in recent years, it remains focused on (a) the transfer of water-management models, such as integrated water resources management (IWRM) in different cases and regions (Hasan, Evers and Zwarteveen 2020; Hermans 2010; Malano, Bryant and Turral 1999; Minkman and van Buuren 2019); (b) the spread of global ideas to river-basin organizations (Mukhtarov and Gerlak 2013); (c) IWRM (Allouche 2016); and (d) community-led total sanitation (CLTS) (Zuin et al. 2019). However, to the best of my knowledge, no studies on policy transfer and diffusion have addressed the question of how the idea of tradable water rights policy took root and spread in China. In this study of the rise, fall and, revival of tradable water-rights policy in China over the last two decades (1998–2019), I strive to extend and deepen the policy transfer and diffusion literature in two major areas – (1) the dimension of time (Dolowitz 2020; Dolowitz, Plugaru and Saurugger 2020); and (2) foreign policy and development cooperation (Stone, Porto de Oliviera and Pal 2020), which are considered to be among the current frontiers of knowledge in the area (Porto de Oliviera 2021: 11).

Pacheco-Vega (2021) has stressed that political leadership is a key factor in successful policy transfer. When it comes to deciding which policies are transferred and how, the amount of impact that different actors (which include non-state and international organizations) can make and how much scope they have for manoeuvre will obviously differ. The objective is to consider whether the transfer process is, as Pacheco-Vega (2021: 397) suggests, “demand-driven (another country is interested in the policies that a country is operating) or supply-driven (where a county is systematically interested and actively engages in the process of promoting and exporting a particular idea, instrument, program or plan”. Despite the considerable number of studies produced on the role of policy entrepreneurs and policy advocates, little has been done to link the concept of time to the role of actors in the policy process (Porto de Oliviera 2021).

A notable exception is a study by Dolowitz (2020), who recommends using the concepts of time, timing, and tempo to improve our understanding of time in policy transfer. Time is the flow of history, the chronological period that shapes past, present and future decisions. Timing is the relationship between time and opportunity, and tempo is the rhythm of the efforts that agents make to speed up or slow down the transfer and policy processes. By applying the concept of time to the actor’s role, it becomes possible to trace the ideational dimension of tradable water-rights policy in China, and thus to gain a better understanding of the power of individuals during the adoption and abandonment phases. Also, integrated into the analysis is an additional but overlooked setting – namely the three bilateral development cooperation programmes associated with the cooperation between China and Australia with respect to water rights and water markets.

International development cooperation, as encapsulated in the work of the World Bank and other multilateral development agencies, has not been ignored in the policy transfer and diffusion literature. However, only recently has this literature started to shift its attention away from the OECD nations to a wider group of countries, including those in the South (Stone, Porto de Oliviera and Pal 2020). Indeed, water policies often feature in Australia’s foreign policy affairs (DFAT 2017), and bilateral aid agencies, such as the Australian International Development Assistance Agency (AusAID) and the Australian Water Partnership (AWP) are involved in activities to promote best practices and policy innovations abroad. Therefore, understanding the dynamics of policy transfers introduced through the bilateral development programmes between China and Australia casts light on the different power relations that are embedded in these programmes and, therefore, on Australia's positioning in Asia in relation to the re-emergence of China as a major power in the region.

3. METHODOLOGY

3.1 METHODS

In this dissertation, I examine three different, but interrelated, institutional components of water markets – (1) their emergence, co-evolution and infrastructure in three river basins in north-western China; (2) spatial divergences in them and their underlying patterns of governance; (3) and the effects of policy transfers on their institutional design and on changes driven by the Chinese–Australian development projects.

In an attempt to construct an interconnected and consistent analysis of the evolution, design, and performance of water-rights trading in China, in this section I apply a mixed-method approach to the three research chapters. Broadly, this entails providing a conceptual and methodological foundation for the initial steps taken towards acquiring a deeper understanding of the promises, paradoxes, and practices of water markets in China. By *promises* I mean the theoretical potential of water markets to address water scarcity and conflict. The *paradoxes* refer to the institutional diversity of water-rights trading arrangements in the politically centralized institutional context of China, as well as to the critical but hidden role of infrastructure. The term also casts light on China's exchanges with democratic Australia and on how their bilateral programmes affect the development of China's water market. The term *practices* is used to refer to the insights gained and contributions derived from the dissertation.

Methodologically, I have relied on a combination of historical institutional analysis, comparative analysis, and policy transfer analysis to examine the emergence, diffusion, and diversity of water markets. This mix of methods was enabled by the production of an original data set consisting of 29 cases involving 385 trading transactions between sellers and buyers across China. A significant part of the dissertation is based on fieldwork, which consisted of fifteen months of continuous data collection and five trips to China for field visits and official meetings. The combination of quantitative data derived from 29 cases, archival evidence from policy documents and regulations, focus-group discussions, semi-structured interviews, and letters from key people involved in the policy transfers, enabled me to triangulate my research findings over time and space, and to relate them to systematic case-study analysis.

The comparisons in Chapter 4 between the Heihe River, Shiyang River and Yellow River initiatives comply with the logic of John Stuart Mill's "most similar systems" design. This methodological choice yields insights into (1) the link between water-rights reform and initiating water markets, and (2) the interplay between institutional reform and infrastructural decisions. As such, Chapter 4, drawing on government-related documents, published research, focus groups and semi-structured interviews, represents an attempt to implement process tracing as an analytical strategy through which to trace the evolution of the policymaking processes and the resulting path-dependency of the reforms adopted in the three cases in question.

In Chapter 5, a combination of fsQCA and qualitative case-study analysis are used to examine the breadth and depth of water markets. The original data set provided the core material for conducting the fsQCA and for identifying coherent archetypes. To complement the underlying patterns borne out by the fsQCA analysis, the qualitative case-study analysis was employed to interpret the trends and to deepen the examination of indicative cases, thus demonstrating how local governments and other institutional arrangements influence trading patterns. Finally, in Chapter 6, drawing on a semi-structured interview questionnaire and bilateral programme reports between China and Australia, process tracing was used to trace the interactions between the sender and receiver and to evaluate their impact.

Also described here are the mixed methods approaches used in the dissertation, including the procedures to conduct field research, the data collection, and the analytical techniques employed to analyse the empirical data. The methods, data sources, and fieldwork conducted for the three chapters are summarized in Tables 3 and 4 and discussed in greater detail below.

Table 3. Summary of mixed-methods components

Component	Theory	Method	Analytical tool	Data source
Design and evolution of property rights systems	Historical institutionalism (Pierson 2000; Pietz 2015) and coupled infrastructure systems (Anderies, Janssen and Schlager 2016; McCord et al. 2017; Tellman et al. 2018)	Qualitative case study design (snowball sample)	Semi-structured interview questionnaire and focus groups Content analysis	-Semi-structured interviews n=5, -Focus groups n=6, -Government-related documents n=10, -Academic articles n=35
Spatial and temporal distribution of water-rights trading; patterns of central government, market and local governance dynamics	Institutional diversity (Ostrom 2005, 2010) and coupled infrastructure systems (Anderies, Janssen and Schlager 2016; Baggio et al. 2016)	QCA methods (snowball sample)	Fuzzy set qualitative comparative analysis (fsQCA) – spatial and temporal mapping of water-rights trading Qualitative case study analysis of selected cases – Focus group questionnaire and content analysis	-Original transaction-data set n=385 transactions in 29 water-scarce cities, -Focus group interviews n=6, -Government-related documents n=11, -Academic articles n=18, -Media reports=10
The Australia to China and subnational aspects of policy transfer	Framework on policy transfer, policy diffusion (Minkman, van Buuren and Bekkers 2018) and the dimension of time (Dolowitz 2020)	Qualitative case study design, -Purposive sampling of ten informants, -Snowball sampling of five informants	Semi-structured interview questionnaire Process tracing and content analysis of government-related documents	-Semi-structured interviews n=15, -Government-related documents n=13

Table 4. Summary of the field work periods

Duration	Data Generated	Collaborators	Fellowship funding
June to October 2017	Historical choices of China's water market development and infrastructure investments	Institute of Geographical Sciences and Natural Resources Research (CAS)	Royal Geographical Society Hong Kong research grant
March to April 2018; 1 September 2018 to 3 November 2019	A total of 29 water-scarce cities trading water rights were analyzed from 2000 to 2019.	Tsinghua University and North China University of Water Conservancy and Electric Power	Royal Geographical Society Geographical Club award; Chinese government scholarship
October to December 2019	Collected perspectives from former officials, consultants and scientists involved in the development and implementation of three bilateral projects between China and Australia.	Dongguan University of Technology	Universities' China Committee in London (UCCL) scholarship

Research components and data sources

The data for the dissertation come from multiple data sources, including archival evidence of policy documents and regulations, focus groups, semi-structured interviews, letters from key people involved in policy transfers, and an original data set of trading transactions between sellers and buyers in China. Data for the three case studies in Chapter 4 were largely collected from government-related documents and literature reviews, complemented by focus groups and semi-structured interviews. The original data set of 385 trading transactions provided the core material for Chapter 5. Chapter 6 relied on a semi-structured interview questionnaire and bilateral programme reports between China and Australia to trace the interactions between the sender and receiver and the impact of those interactions.

Government-related document and peer-reviewed journal document inventory

An historical perspective is employed to connect the evolution of water allocation reforms to present-day patterns of water-rights trading in China. Studying the past entails the collection of multiple data sources and, thus, an integration of historical processes and descriptive evidence. Accordingly, the data in the dissertation were collected from a range of legal, policy and planning documents formerly endorsed by the Chinese government. All 24 of these official documents address the policy, strategic, planning and legal aspects of developing market-based mechanisms for allocating water resources in China, and they are cited and reviewed in Chapters 4, 5 and 6. In addition, other documents, such as media reports and articles in academic journals, were also reviewed.

Peer-reviewed journal articles were identified through a systematic content search of the CNKI database by using the three keywords "water rights", "water market" and "tradable water right" in Chinese. Consequently, the thesis is built on a comprehensive systematic review of Chinese and international water markets (Wang, Shu and Wu 2017). The data for the case studies in Chapter 5 in particular were collected from this literature review. They were also based on a special 2018 issue (no. 19) of the journal, *China Water Resources* (中国水利), in which the nationwide experiences of a water-rights pilot scheme conducted between 2014 and 2017 were reviewed, and in which information was provided on how various individual cases were calibrated. In Chapter 4, Shen's (2014) three distinct water-policy time periods are evoked to explain the evolution of water allocation reforms in contemporary China since 1949. In Chapter 6, a study by Jiang et al. (2020) is used to divide the history of Chinese tradable water-rights policy into three periods, each of which reflects a point in the Chinese state's engagement with the sub-national aspects of Australia's policy transfer.

Semi-structured interviews and focus groups

The data for the three case studies in Chapter 4 were primarily collected from the literature and document review. However, given the implementation gap in China's environmental policies, they would be unreliable if they relied solely on government-related documents. Therefore, domestic and international research publications related to water rights and markets were also reviewed. A series of six focus groups were undertaken and, between June and September 2017, with a view to understanding property rights reform from the perspectives of different individuals within the government and society, five individual semi-structured interviews were conducted with provincial and prefecture officials in the river basin organizations and irrigation districts, and well as with members of water-user associations (WUAs). A snowballing method was used to identify potential interviewees; in addition, a research collaborator and interview partner established contacts before the field trip and directed me to people who were relevant to the study.

The main reason I needed to rely on a partner to conduct fieldwork was because it was difficult to gain access to government officials and other stakeholders and to encourage them to express themselves. I completed site visits to the Shiyang, Heihe, and Yellow rivers and spent approximately fifteen days in the Ningxia and Gansu provinces. The interviews took place in Beijing, Zhengzhou (Henan province), Yinchuan (Ningxia), Helan county (Ningxia), Zhangye city (Gansu), Gaotai county (Gansu), and Liangzhou county (Gansu). The average size of an interviewed groups was three people. In total, 23 participants were interviewed across both focus-group and individual interviews – see Appendix for full list of interviews.

The data for Chapter 5 were collected through focus-group discussions and semi-structured interviews with multiple government representatives at county, prefecture, city, provincial and central government levels. To ascertain what conditions enabled water-rights trading, I carried out several rounds of field research between the spring of 2018 and the autumn of 2019. Either via focus groups or through face-to-face interactions, I discussed selected cases with water-market officials in Inner Mongolia (Hohhot), Shanxi (Taiyuan, Yuncheng), Henan (Zhengzhou), Gansu (Wuwei), and Hebei (Cheng'an). I conducted separate field visits for each type of trading, namely within irrigation districts (Cheng'an, Taiyuan, Wuwei), between companies and irrigation districts (Hohhot, Yuncheng), and between regions (Zhengzhou). While approximately twenty-seven individuals attended the six focus groups, only one or two government leaders would willingly express their opinions at each meeting through face-to-face interactions — see Appendix for the focus group questionnaire.

The interviewees were again identified through the use of snowball techniques and relying on one of the research collaborator's contacts in the Ministry of Water Resources (MWR). Also, semi-structured interviews were held with the two MWR representatives in favour of nationwide trading. The calibration of the causal conditions underlying price discovery, water rights and physical infrastructure were developed in an iterative process that relied on semi-structured interviews with two MWR officials. The aim was to gather data from several sources on each transaction between a buyer and a seller, a data triangulation that supposedly enhanced the validity of the readings of the various cases in hand (Bryman 2004: 1142). The focus groups and semi-structured interviews were used to complement the results of the fsQCA and to ensure that the analysis of water markets in China was comparative.

In Chapter 6, which is based on empirical data, I analyse and explain the adoption during the period between 1998 and 2019 of tradeable water-rights policy in China and the impact of the Chinese–Australian development projects. In addition to documentary sources, the data were collected through semi-structured interviews with government officials, consultants, and water-resource specialists with a view to understanding, from the perspective of the individuals concerned, the interactions and the outcomes of interactions between senders and receivers. In total, I interviewed three Australian officials, five Australian consultants, one British consultant, one Australian company manager, one former high-level Chinese official, and four Chinese consultants and researchers in water-market projects in China — see Appendix for the semi-structured interview questionnaire. Seminal reports of bilateral programmes between Australia and China and the list of stakeholders in those reports were used to recruit respondents. I then asked them to suggest new ones, which resulting in snowball sampling for about one-third of the respondents.

Accessibility and the need for a variety of opinions guided the selection of participants. What bound them together was their expertise and experience of water rights and markets in China. The first series of interviews took place in the autumn of 2019 before the outbreak of COVID-19. Three Chinese respondents were interviewed in Beijing and then a further nine in 2019 and 2020 through remote face-to-face conversations using Skype software. Moreover, three of the respondents wished to answer the questions by filling in a semi-structured interview questionnaire. Finally, to enhance the validity of the data, a written summary was created of each interview. This enabled the interviewee to review the interview findings, resulting in the clarifications of statements or correction of information if needed.

Multiple sources of statistical data

A purposive sampling strategy was pursued for case selection according to their typicality and diversity criteria (Gerring 2008: 9). First, all the selected cities in the sample faced water scarcity and had adopted market-based transfers at the rural–urban interface. In fact, Lijphart (1971: 687) had followed similar criteria for comparable cases. Second, the selection of cities was based on feasibility of access to reliable information in China, and variation in market attributes, institutional arrangements, and infrastructural traits associated with water-rights trading. Moreover, Lijphart (1971) suggests that comparative analyses should strive to "develop theoretical generalizations in areas where no theory exists yet" (Lijphart 1971: 692). Following Lijphart's suggestion, the objective was to characterize the cases by focusing on the configurations of governance attributes that shape water-market development in water-scarce cities, where water-market development is captured by trading activity.

From the 34 provincial-level administrative units in China, I collected data on 29 water-scarce cities in 11 provinces – Gansu (n= 2), Guangdong (n= 2), Guizhou (n= 2), Hebei (n= 1), Henan (n= 5), Inner Mongolia (n= 5), Jiangxi (n= 1), Ningxia (n= 3), Shanxi (n= 2), Xinjiang (n= 1) and Zhejiang (n= 5). The cases in the sample consist of 23 prefecture-level cities and 6 county-level cities from the northern, eastern, central, southern, and western parts of China. Two county-level cities (Dongyang and Yiwu) trade with each other, and four county-level cities (Cixi, Dengfeng, Xinzheng, and Xinmi) trade with three prefecture-level cities (Shaoxing, Nanyang, and Pingdingshan).

More specifically, the data came from multiple sources: 280 out of 385 transactions were collected from China's national water-rights trading platform, China Water Rights Exchange Co. Ltd, and 84 transactions from a study by the Yellow River Conservancy Commission (YRCC 2008) in Ningxia and Inner Mongolia. Also, sixteen transactions were identified from scholarly articles (Bao et al. 2017; Han, Zhao and Wang 2010; Jiang 2017; Liu, Peng and Zhang 2018; Wang 2018; Xu et al. 2016) and five from news reports (Chinanews 2003; DDCPC 2017; Jxnews 2015; People's Daily 2014; Sinanews 2017).

As of August 2019, China's leading data provider, EPS China Data, had 71 databases containing Chinese statistical and census records. It was the primary data source used in this study to construct variables and to convert the original scored-based data set to fuzzy-set membership values. Data on hydrology, including surface and groundwater resources and water quotas, came from provincial and municipal water bulletins. Data on the storage capacity of completed reservoirs came from the China Water Conservancy Database. Information on the percentage of the total volume of water traded through water brokers came from the websites of both the China Water Rights Exchange Co. Ltd, and the Inner Mongolia Autonomous Region Water Rights Collection and Transfer Centre. Information on urban populations came from the China City Database, and that on the per capita annual income of urban and rural households came from the China Labor Economy Database. The raw data matrix and an in-depth justification for the calibrations of each case are provided in the case descriptions in the Appendix.

3.2 ANALYTIC APPROACHES

In Chapter 4, the coupled infrastructure system (CIS) framework is applied as a data analytical tool with which to reconstruct the decision-making processes associated with infrastructural investments and institutional reform. The time frame of the study stretches from 1949 to the present. Drawing on historical accounts, archival sources, documentary evidence, and interviews on water rights and markets, the aim of the qualitative analysis of the data is to identify critical moments in time and the decisions linked to those events. It seems appropriate to combine the content analysis with case-study research because the case studies are intended to elucidate how CIS elements influenced the formation of water rights and trading systems in the three river basins in north-western China. This approach is in line with qualitative research that uses multiple sources of evidence to enable the triangulation of data and thus to increase the reliability and validity of the findings (Creswell 2007: 43–5). For example, the review of China's tenth, eleventh, and twelfth five-year plans highlights the state-led infrastructure narrative on the one hand, while the review of academic papers, key policy documents, and relevant laws over the same period highlights the policy evolution of water rights and markets on the other. These different data sources reveal how investments in water infrastructure and national policies associated with water rights and markets have become interrelated and reinforced over time through the decisions that were made.

In Chapter 5, I employ fsQCA and qualitative case-study analysis to qualify and contextualize the trends. As Michael Cox noted, QCA allows the researcher to place more emphasis on the effects of interaction and the conditions of causal necessity and sufficiency than does the normal statistical technique (Cox 2015: 6). Given the medium-N data set at hand here – 29 water-scarce cities – and the focus on the patterns of governance that shape water-market development, this research is best understood in terms of set relations rather than through a regression-oriented statistical approach. For the foregoing reasons, in this dissertation, I adopt a QCA approach towards assessing institutional diversity systematically and identifying coherent archetypes.

I employ an analytical tool known as a fuzzy-set qualitative comparative analysis (fsQCA) to an original transaction data set consisting of 385 transactions across nearly thirty cities in China. Ragin (2009) undertook analyses of necessary and sufficient conditions using the fsQCA software 2.0 to show whether and how trading occurs. According to Basurto (2013: 578),

> a condition is both necessary and sufficient if it is the only cause that produces an outcome and it is singular (i.e. not a combination of conditions). A condition is sufficient but not necessary if it can produce the outcome but is not the only condition with this capability. A condition is necessary but not sufficient if it is capable of producing an outcome in combination with other conditions and appears in all such combinations.

The fsQCA analysis was implemented in two steps.

First, an analysis of necessary conditions was conducted. Following Schneider and Wagemann (2012), a consistency threshold of 0.9 and a coverage threshold of 0.30 was adopted for necessary conditions. Table 3 in the Appendix provides consistency and coverage scores for the presence and absence of ten conditions. Second, a sufficiency analysis of seven causal conditions was conducted that focused on governance and infrastructure arrangements. Ragin (2008) recommended that a threshold above 0.8 is required for a causal condition to be sufficient. The fsQCA software provides three standard analysis options – the complex solution, the parsimonious solution, and the intermediate solution. I followed the intermediate approach because, according to Ingrams (2018: 432), it "makes fewer simplifying assumptions than the parsimonious solution" and unlike the complex solution it "allows logical minimization by using theoretical and empirical knowledge". As Ragin (2008: 171) explains, "the intermediate solution … is optimal because it incorporates only easy counterfactuals, eschewing the difficult ones that have been incorporated into the most parsimonious solution. The intermediate solution thus strikes a balance between complexity and parsimony."

The software program for the intermediate solution conducts counterfactual analyses based on information about causal conditions supplied by the researcher. Among the three options, "present", "absent" or "present or absent", I selected "present or absent" for each condition. This was an appropriate choice given that I did not want to input into the software the assumed direction of influence of each condition on the outcome (trading). It should be noted that the solution coverage, consistency scores and pathways of the intermediate solution were similar to those that the complex solution produced (0.80, 0.92). This demonstrates that (1) a combination of pilot programmes and market platforms tied to the central government lead to the most trading in water rights at the local level; and (2) establishing water markets and investing in infrastructure are not mutually exclusive regardless of the type of trading. These results were borne out by the fsQCA. Next, the pathways were further interpreted using qualitative case-study analysis to deepen the examination of indicative cases. Drawing on focus groups (HH180403; TY181129; and WW190729) and documentary evidence (Dai et al. 2017; Shanxi News Network 2018; Shanxi Provincial Department of Water Resources 2018; and Zheng et al. 2017), I make two further arguments. First, the cases of Shiyang Basin and Taiyuan, Shanxi province, illustrate how farmer associations, markets, and local governments are forcing the hybridization of governance. Second, property rights are being adapted to local trading practices (temporal versus permanent) in China's one-party state, and this requires further research.

In Chapter 6, the reliance is on an analytical framework built from the policy transfer studies literature. This framework provides a useful analytical tool with which to understand the adoption of tradable water rights policy by highlighting (1) the role of domestic actors in the design and implementation of water markets; and (2) how Australian development projects fit into patterns of diffusion within China. Both perspectives are important because the current literature focuses exclusively on learning, emulation, and competition to explain how policies emerge and spread to other units. Against this background, the selection of factors was theoretically guided and focused on agency and time. However, the theoretical framework cannot isolate the other factors that influence the spread of policy adoption.

Nevertheless, it should be noted that tradable water-rights policy is a highly technical subject that has attracted little attention from the public in China's closed political system. Furthermore, the MWR neither split nor merged during the period under study. From 1998 to 2018, the following three ministers – Wang Shucheng (1998–2007); Chen Lei (2007–2018); and E Jingping (March 2018–present) (Chinavitae 2020) – presided over it. Chapter 6 follows a sequential analysis approach, based on three interconnected steps. First, the abstract factors in the framework were translated into interview questions. Second, process tracing was employed to trace the interactions between the sender and receiver and the impact of the interactions for each of the three periods 1998–2007, 2007–2013 and 2013–present. In this light, process tracing is a suitable qualitative tool with which to trace causal mechanisms and link causes to outcomes (Beach 2017). In doing so, I used the timeline of Jiang et al. (2020) that lists the sequence of policy events related to water markets and tradable water right policy from 1998 to 2018. I then linked domestic decision-making cycles to three Chinese–Australian development projects across the time periods to explore which causal processes triggered or failed to trigger the adoption of tradable water right policy at the local level in China. Third, the data were extracted and results interpreted by triangulating perspectives and perceptions among different interviews combined with reviewing programme reports, policy documents, and written letters. In presenting the results, I quote extensively from interviews and letters to enhance transparency.

3.3 ETHICS

Because informants and collaborators can be exposed to harm, their safety came first before any other research criteria. Before commencing any data collection, I underwent two ethics review processes (SoGE 17A-125), with research approval obtained from the University of Oxford's Central University Research Ethics Committee. All selected participants were, following Kvale and Brinkmann (2009: 70) and Silverman (2005: 258), informed about the purpose of the research, the procedures involved in it, any potential harm, risk or discomfort it may entail, as well as questions of confidentiality and the nature of participation and withdrawal. In conducting the research, I tried hard to be as sensitive as possible to Chinese cultural norms. The ethical aspects of the design were written down in both English and Mandarin and given to the participants with a view to minimizing any misunderstandings that might arise between the researcher and the subjects and to enhance the transparency of the research process (see Appendix). Most of the research participants signed the consent form, though a few gave oral consent instead. Thus, above all else, I attached great importance to my informants' informed consent and confidentiality. I coded all the interviews used in the dissertation to protect the confidentiality of the interview subjects (see Appendix).

In conducting research in China, it is necessary to think about how to gain research access and how to maintain conceptual equivalence when translating interview instruments or documents from one language and context to another (Liang and Lu 2006). Although the fieldwork is essential if we are to trace the extent to which water rights are being traded among farmers, let alone details about their status and trends, institutional bureaucracy and secrecy surrounding data below county level limit its use. This presented a practical challenge to both me and my collaborators – hence the gap in our knowledge about the association between local collective action and water-rights trading. According to Shih (2015), when researching authoritarian regimes it is advisable to adopt a multi-method approach and to use data from a range of different sources. Consequently, I employed various methods of data collection, including semi-structured interviews and focus groups with various people, as well as documentary analyses. Instead of relying on county-level surveys, I made full use of data sets collected from publicly available sources such as the China Water Rights Exchange Co. Ltd, and acquired material on trading transactions and hydrological data from provincial and municipal statistical bulletins. In addition, interpersonal contacts, guanxi (关系), and visiting different trading schemes at the municipal level in China, played a key part in enabling me to gain access to useful contacts, which was helped considerably by a multi-partner collaboration with Tsinghua University, the Institute of Geographic Sciences and Natural Resources Research, Dongguan University of Technology, and the North China University of Water Conservancy and Electric Power. My co-authors played an essential role in helping to maintain an equivalence in the meanings of words and expressions in the interview tools developed in Chinese. Consultations with my co-authors were also necessary for designing the study and structuring conversations in the field settings.

However, it can be hard to draw a line between the fieldworker and people in the field when researching in China (Heimer and Stig Thøgersen 2006: 263). In particular, the setting in which one conducts interviews may affect their quality (Shih 2015). Sometimes, a mutual friend might arrange an interview with an informant in a café or restaurant, which could occasionally make it difficult to maintain the appropriate balance between researchers and their informants in terms of intimacy and distance. Yet, at the same time, people complain that researchers from Europe and North America never share their research with the people in the host country (Hertel, Singer and Lee Van Cott 2009). To counter this accusation, however, I have arranged to share the final data set, which contains no human subject data, with Tsinghua University in China.

3.4 LIMITATIONS

There are limitations associated with this research. To begin with, it is assumed that the trading of water rights among farmers and water-user associations (WUAs) is far more prevalent than officially acknowledged and recorded.

Moreover, the fsQCA methodology has distinct limitations that need to be recognized. For example, it would have been desirable to have included cities that did not engage in trading their water. However, while the list of water-scarce cities provided in the Appendix offers a valuable overview of cities in China that trade their water rights, it is important to note that I only used one measurement of water scarcity, which limits my ability to evaluate and consider different supply and demand drivers of water-rights trading. Follow-up studies can address this limitation by using multiple scarcity measurements to consider China's various hydrological and geographical features. Regrettably, length restrictions and time constraints have prevented me from addressing this here.

Furthermore, I have failed to provide an inventory of water reallocation projects for Beijing, which is mainly due to the secrecy surrounding data pertaining to the multiple reallocation projects around the Jingjinji region, also known as the Beijing–Tianjin–Hebei region. In addition, these reallocation projects are thought to be governed by administrative decisions. Yet, as a global political city, Beijing could fill significant knowledge gaps about coercive and/or cooperative interactions among governments and resource users involved in multiple water reallocation projects.

Another limitation concerns the data used in Chapter 6 in relation to policy transfers from Australia to China. Although I conducted interviews in China in October and December 2019 with representatives from research institutions and central ministries involved with designing and implementing water markets. However, the author was unable to interview local governments due to the outbreak of COVID-19.

4. COUPLED INFRASTRUCTURE SYSTEMS: COMPARING THE DEVELOPMENT OF WATER RIGHTS AND WATER MARKETS IN HEIHE, SHIYANG AND YELLOW RIVERS

4.1 ABSTRACT

By applying a CIS perspective to three case studies in north-western China, in this chapter we explain how and why water markets and water-rights systems have changed since 1949. The evolution of water-rights systems has been shaped by periods during which water-supply projects have proliferated and other periods when the emphasis has been more on regulatory and institutional measures to manage water resources. We argue that a water-supply infrastructure and water markets have been developed not in sequence but parallel with one another. The development of water diversion projects and nationwide market-oriented water allocation reform programmes will continue to co-evolve in the future as part of the complex CIS.

4.2 INTRODUCTION

China's various social ecological systems (which include its fisheries, wetlands, forests, and rivers) have undergone rapid transformation on a scale and at a speed that is unprecedented in human history. With the country's urbanization and industrialization increasingly extending from the coastal regions to the western hinterland, the pressure to divert water from agriculture to industry is likely to increase (Wang et al. 2015). The competing demands of agriculture, cities, industry, and the environment have elevated water to the top of China's policy agenda, which has culminated in the so-called "three red line policy", which is "the strictest system of water resource management" in the country. A national water-use cap of 670 billion m^3 for 2020 has been divided and distributed at nested hydrological scales across China. Using the national water-use cap as a criterion, in 2014 China's Ministry of Water Resources (MWR) selected seven provincial areas in which to establish pilot markets for trading water rights. As a result of rapid economic development and changes in water availability, large-scale common-pool resources (CPR), already riven by consumption rivalry and difficult decisions about which rivers between northern and north-western China to exclude, face an increased level of uncertainty. The Heihe, Shiyang and Yellow river basins in Gansu and Ningxia provinces are at the leading edge of China's water-resource challenge, and pressures for water-rights reform are mounting. The need for trade-offs between economic development and protecting ecosystems underlies many of the tensions linking water allocation with social conflict. Both Gansu and Ningxia provinces have been targeted to achieve a breakthrough in water-rights reform and trading with a view to providing guidance for national expansion.

A water allocation system consists of an "institutional tripod" (Meinzen-Dick 2007) that combines varying degrees of state, market and community-based management (Garrick 2015; Meinzen-Dick 2007). Contrary to the categorization of state, private and common property, water usage entitlements in China are state owned but with a mixture of both public and private rights to it (Ma, Zhu and Wang 2012). As Nickum (2010: 540) points out, "there has been a continuous dialectic between state, collective and private (including foreign) ownership and plan-directed and market-directed approaches to the economy, including water policy." Within China's hierarchical water system, tradable water-use rights are conditioned by state ownership of the water but local administration by water users. Water is allocated at three distinct but interconnected levels – the river basin one (water use/consumption quota), the abstractor one (diversion permission) and at the level of terminal users within public water supply systems (Jia et al. 2016). The allocation plans for water resources follow a vertical institutional arrangement for sharing water resources between different jurisdictions within a river basin. In theory, the systems for allocating water rights in China share a similar overall administrative framework, but how the allocation plans define water entitlements varies considerably in practice (Shen and Speed 2009).

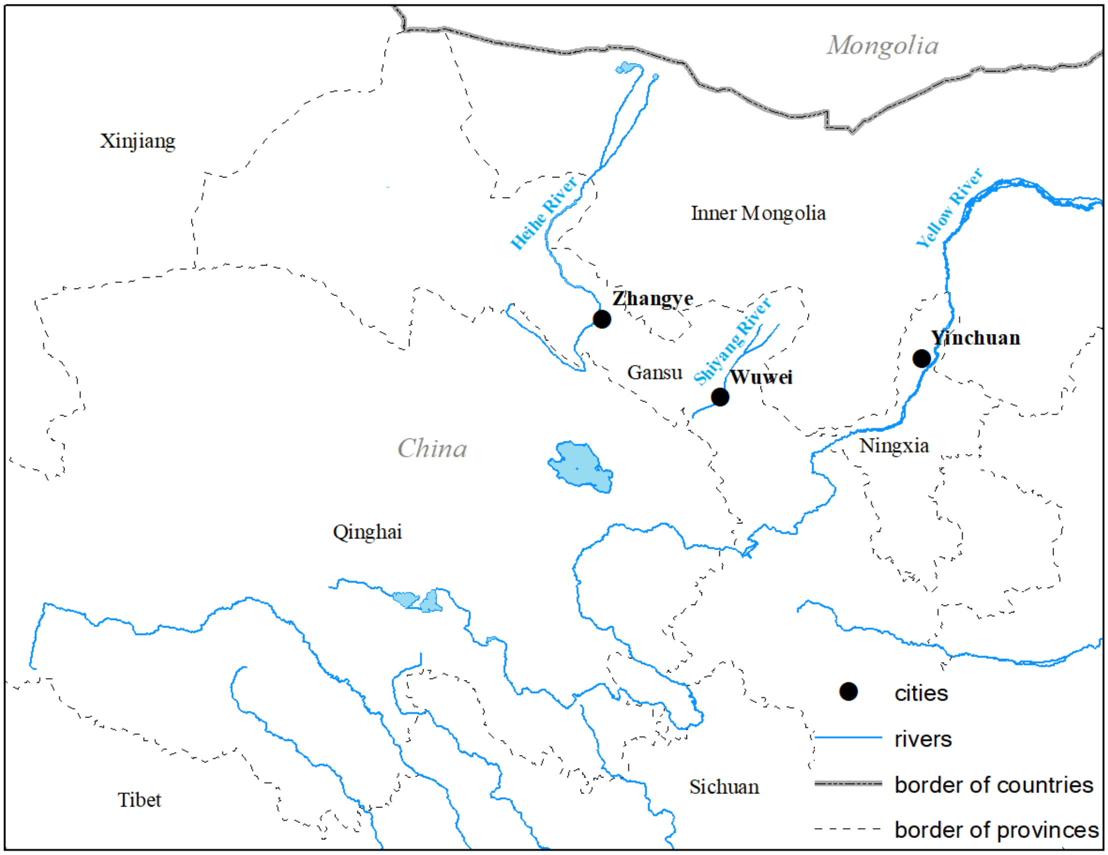
Scholars have emphasized the importance of ensuring that water markets have strong regulatory institutions and community roles through which to deal effectively and equitably with water scarcity in countries as diverse as Australia, Chile, Spain and the United States (Easter and Huang 2014; Garrick, Hernández-Mora and O'Donnell 2018; Grafton et al. 2011; Maestu 2013; Wheeler et al. 2017). Although these studies offer valuable insights into natural resource governance, the focus on institutional arrangements may overlook an array of other factors that are important for the development of water rights and water markets. Overall, the global experience of water transactions is much more varied than is generally acknowledged in terms of market formality and underlying conditions. Accordingly, interactions among biophysical, economic, infrastructural and institutional processes play critical roles in structuring the formation of water markets. Compared with cases such as Australia, Chile, Spain and the United States, China is regarded as an immature water market in the literature (Jiang 2018; Moore 2015) and this study highlights the transformational process. Broadly speaking, the existing literature has examined the legal framework of water rights and trading (Jiang 2018; Speed 2009a); the development of the water allocation regime in the Yellow River Basin (Xia and Pahl-Wostl 2012); performance of public water rights allocation (Zheng et al. 2012); and comparisons between China's water-rights systems and markets and those of Australia (Lewis and Zheng 2019; Speed 2009b) and India (Jia et al. 2016). Furthermore, Yahua Wang has developed a water-rights hierarchy framework that highlights the structural changes in China's wate-rights structure from the period of formation of China's planned economy to the present (Wang 2018). There is a recognition that institutions matter in the literature, but there is no explicit focus on the interplay of infrastructure and institutions concerning how and why markets emerged.

The CIS framework, in which human-made institutions (rules in use) are one class of infrastructure that interacts with physical human-made (technology) and natural infrastructures to produce resource outcomes, is again applied here. And again, the CIS framework is being used as an analytical and conceptual lens through which to examine the design and evolution of three water-rights systems and markets in north-western China. Our contribution is to demonstrate how the elements of the CIS – physical-human made, soft and natural infrastructures – have influenced the formation of water rights and trading systems in three river basins in north-western China. The insights, yielded by this approach further the broader literature on water markets by demonstrating the sequence of infrastructure investments and institutional reform over time. Water markets are explicitly recognized from a configurational perspective rather than understood as competing alternatives to supply-side measures. Here, the data from archival research and fieldwork are combined to address the following question. How have elements of the coupled-infrastructure system shaped the design and evolution of the water-rights system and water markets in three river basins in north-western China?

4.3 OBJECTIVES, CASE-SELECTION AND METHODS

Juxtaposing the Heihe and Shiyang rivers in Gansu province with the Yellow River in Ningxia province offers one the opportunity to make a "most similar systems" comparison, which in turn yields insights into how an interplay of infrastructural decisions and institutional reforms are associated with the formation of water rights and trading mechanisms. A most-similar system design was used to select the three cases. Shiyang Basin, Zhangye city in Heihe Basin and Ningxia province in Yellow River (Figure 2) share a number of similarities, including semi-arid conditions, a historical major allocation of water to the irrigation sector, over exploitation, and the development of water markets as a support to water allocation reforms. Following the periods considered by Shen (2014), the evolution of the water-rights systems in China is divided into three phases – before 1998, between 1998 and 2009, and post-2009. Primary data are based on extensive analysis of Chinese governmental reports and archive documents, including specific laws and regulations, policy documents and research publications related to water rights and markets. In addition, the materials were supplemented by semi-structured interviews with Chinese academics and officials between July and September 2017. A total of six group-based and five individual semi-structured interviews were conducted in Beijing, Zhengzhou (Henan), Yinchuan (Ningxia), Helan county (Ningxia), Zhangye city (Gansu), Gaotai county (Gansu), and Liangzhou county (Gansu), with provincial and prefecture officials, river basin organization staff, irrigation district staff and WUAs (Appendix). Two of the authors also completed site visits to the three river basins. The identification of the interviewees relied on snowballing procedure. Prior to the fieldwork in the two provinces, one of the authors contacted people relevant to the study, who in turn directed us onwards to other people. The number and range of interviewees were determined by the need for diverse variation in opinions on allocation of water entitlements, and the feasibility of access to information. Due to cultural sensitivity and language limitations, the lead author conducted group interviews rather than individual interviews. The average size of the interviewed groups was 3 people and in total 23 participants were interviewed across both group and individual interviews. Given the historical approach to explain the development of water rights and associated market mechanisms, the sources of data were analysed by using content analysis and process-tracing of the sequence of reforms and changes. Furthermore, triangulation was employed in the data collection and analysis to ensure accuracy of findings. Sample questions are listed in the Appendix.

Figure 2. Map of North-western China

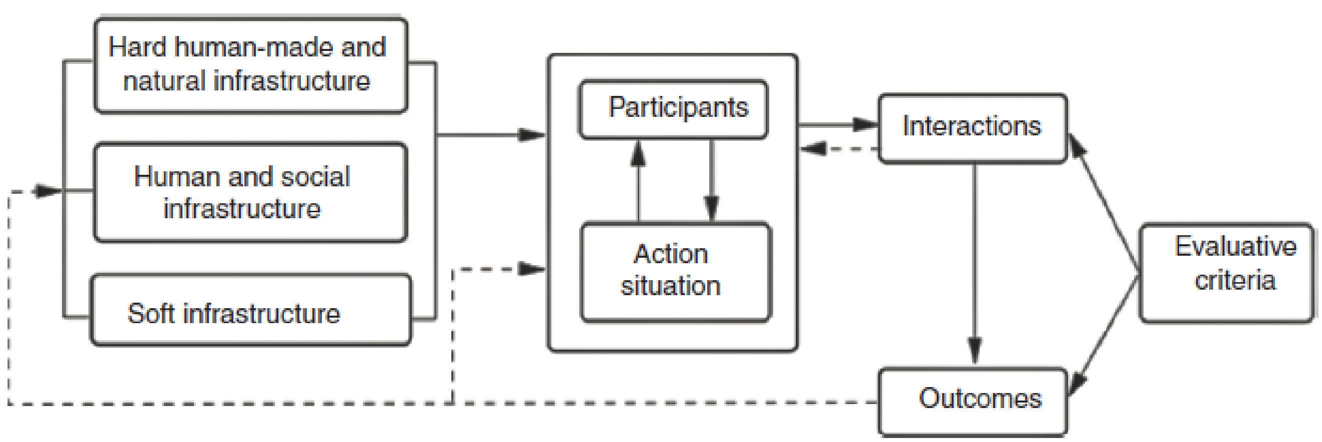


4.4 CONCEPTUAL FRAMEWORK

The institutional analysis and development (IAD) framework is the one most commonly used for analysing collective action problems in common-pool resources. It is a helpful framework within which to examine how rules influence patterns, interactions and outcomes, and to assess the effect of biophysical attributes, community attributes and rule-in-use systems on outcomes. Within an IAD framework, one can broadly group the factors that affect the incentives of individuals to engage in collective action into three categories – biophysical conditions, the attributes of the community, and rules-in-use. The interaction of the variables in these three categories form the structure of the action situation, and within the action situation, individuals interact to produce outcomes. Over time, IAD has been expanded into a framework for examining the robustness and resilience of social-ecological systems (SES). More recently, scholarship building withing the IAD framework has been extended to account for biophysical complexity and technological development more carefully through the CIS framework (Figure 3). Hard and natural infrastructure replace the biophysical conditions from the IAD framework, and human and social infrastructure replace attributes of community, whereas soft-infrastructure replaced rules-in-use (Anderies, Schoon and Schlager 2016). The CIS framework is conceptualized as a way of examining the interactions among five classes of infrastructure – (1) human (knowledge), (2) social (social relations), (3) natural (ecosystems), (4) soft (institutions) and (5) hard (built) infrastructure. The CIS framework has been applied to diverse settings ranging from adaptation to water risk in urban systems to water delivery in irrigation systems. In expanding the focus beyond institutions, McCord et al. (2017) found that healthy physical human-made and biophysical infrastructures in irrigation systems in Kenya allowed the management committee to impose fewer sanctions without detracting from water-delivery outcomes. Prior work has also demonstrated that managing environmental resources through soft and hard infrastructures is associated with trade-offs in robustness and vulnerability over time (Tellman et al. 2018; Yu et al. 2015).

In this study, water markets are conceptualized as CIS. The application of the CIS to them is useful because water markets are not free. Although an array of factors affect the types and patterns of water-rights trading, the primary goal is to focus on how soft (institutions) and hard (built) infrastructures mediate the natural infrastructure (rivers) over time to create water markets. Thus, other elements of the CIS framework are not explicitly addressed in this chapter, including "participants", "action situation", "interactions", "outcomes", and "evaluative criteria", although they are a subject for future research. Instead, the framework emphasizes the importance of path dependence. According to this logic, historical institutional choices made at formative moments matter because the paths embarked on can be difficult to reverse because they generate benefits (Pierson 2000). In terms of path dependence, decisions regarding infrastructure and institutional reform determine the future trajectories of water management for the Heihe, Shiyang and Yellow rivers. According to the literature, scarcity of water is often cited as a key factor that motivates water markets (Easter et al. 1998). For example, water markets emerged informally in water scarcity situations in Spain (Breviglieri, Osório and Puppim de Oliveira 2018). In terms of natural infrastructure, the water markets in California, Chile, and the Murray–Darling Basin were all characterized by low precipitation during their irrigation periods (Endo et al. 2018). Moreover, a formal water market requires at least three institutional choices (soft infrastructures), such as a quantity cap that is placed on the market, allocation of water entitlements, and trading rules that can limit the negative impacts of trading (Easter and Huang 2014; Grafton et al. 2011). In Chile, the water law was changed in 1981, and water markets emerged when water rights were separated from landownership (Bauer 2004). The importance of physical human-made infrastructure is also critical for water markets. California, Chile and the Murray–Darling Basin all have highly varying river flows, and these regions require reservoirs in which to store the water before the irrigation period starts. In addition, Spain has a mature infrastructure and interregional connectivity through water infrastructure (Breviglieri, Osório and Puppim de Oliveira 2018).

Figure 3. Coupled Infrastructure System



4.5 THE EVOLUTION OF A WATER-RIGHTS SYSTEM AND MARKET DEVELOPMENT IN NORTH-WESTERN CHINA

Before 1998

This era dated from the founding of the PRC in 1949 to the time when the State Council revised the Yellow River allocation plan in 1998. Following Jia and Zhang (2011), this period can further be subdivided into three sub-periods based on the focus of water conservancy projects – 1949–1977; 1978–1988; and 1988–1998.

In the early days of the founding of the PRC, the State Council made it clear that water resources were public. In November 1949, the Water Resources Department pointed out in a summary report (Ma and Han 2009) that:

> all rivers and lakes are national resources and are common to the public and should be managed by the water administrative organs at all levels of the Ministry of Water Resources. Any water conservancy business must first apply to the water authorities to obtain the right to use the water and the right to benefits.

An emphasis on engineering projects characterized the 1949–1977 period and the Yellow, Heihe and Shiyang river basins experienced massive dam constructions and a marked expansion of irrigated land. Rights to public property were de facto open access systems because there were no formal water allocation plans to establish a connection between river basin volume and regional water use (Wang, Wan and Biswas 2017). Prior to China's introduction of a planned economy, water allocation agreements had existed since ancient times. As far back as the days of the Western Han Dynasty, a time-based water allocation model linked to the natural hydrological cycle had operated in the Shiyang River Basin. The provision mainly established the water intake time for different counties to balance upstream and downstream water use. However, with the continuous construction of water conservancy projects, such as reservoirs and wells, the water cycle of the river basin gradually changed from the natural to an artificial model. To alleviate the situation, the Gansu Provincial Party Committee adjusted the agreement in 1962, stipulating that Wuwei city in Liangzhou county discharge water to downstream Minqin county twice a year, but the water protocol failed to be enforced (WET 2006). After the 1970s, the surface and underground runoff had undergone fundamental changes. Indeed, runoff decreased from 129 million m^3 in the 1960s to 47.1 million m^3 in the 1970s and 1980s (Huo et al. 2007). In the Heihe River Basin, rapid socio-economic development also led to dramatic shifts in water allocation between upstream and downstream users.

Under the reform and opening-up period, which started in 1978, China experienced a trend towards fiscal and administrative decentralization, with one consequence of the reforms being the increased autonomy of local officials. During the period between 1978 and 1987, water policy in China experienced a gradual shift from traditional water allocation to agriculture to an emphasis on industrial and urban development. As a result of increasing water demands, water conflicts gradually emerged. For example, in 1949, China's water consumption was only 103.1 billion m^3 but by 1980 it had risen to 443.7 billion m^3 (Jia and Zhang 2000). Between 1949 and 1985, the utilization ratio of surface water in the Heihe River Basin increased 19 times; the irrigation area expanded by 89.5 per cent, and the desert area increased by 4 per cent to 11 per cent (Deng and Zhao 2015). River discharge to the lower reaches reduced, and as a result, the West Juyan Lake and the East Juyan Lake dried up in 1961 and 1992 respectively (Hu et al. 2015). Meanwhile, conflicts in the mid-1980s at both provincial and municipal levels over water allocation in the Yellow River Basin led the central government to implement China's first formal institutional arrangement for water allocation – the 1987 Yellow River Water Allocation Plan. The YRCC allocated a total of 37 km^3 to the provinces by setting aside 21 km^3 for sediment transportation and other ecological water uses. However, the circumvention of water allocation regulations at the local level persisted (Pietz 2015).

In 1988, China established a water abstraction permit system with the 1988 Water Law. Accordingly, Article 34 stipulated that "anyone who uses water provided by a water-supply project shall pay a water fee to the supplying unit in accordance with the relevant provisions" (MOFCOM 1988). Furthermore, according to Article 32, the state shall

> put into practice a licence system for drawing water directly from subterranean streams, rivers or lakes. However, it shall not be necessary to apply for a licence if water is drawn for household use or for livestock and poultry to drink, or if a small amount of water is drawn for other purposes.

Moreover, the law split the responsibility over water among a multitude of authorities by "adopting a system which combines unified administration with administration at various levels and by various departments" (Article 9) (MOFCOM 1988). This was followed by related legislation, including implementation methods for a water abstraction permit system (1993), a law on the prevention and control of water pollution (1996) and another on flood control (1997). The 1993 regulation on the water withdrawal permit system was widely applied across China and established a connection between river basin volume and individual water use (Shen 2014). At the same time, transfers of water withdrawal permits were forbidden.

Rapid economic growth in the 1980s and 1990s, which was accompanied by a growing demand for water, a scarcity of available resources, and an increase in pollution and flooding, presented challenges to the managers of water resources. In response to the increasing scarcity of water in the Shiyang River Basin, in 1990 the Gansu provincial government ratified a water allocation plan based on "allocating water according to quantity". However, because it was never implemented because of insufficient funds and unclear lines of responsibility, the users reverted to the water allocation agreement of 1962 (WET 2006). In the 1990s, a combination of dry years and a failure to enforce allocation limits at provincial and local levels precipitated the closure of the Yellow River Basin (Pietz 2015). The arrival of "hard limit" in the basin reflected the historical and continuing tension between centrally formulated policy objectives and local economic interests. Such was the impact of dams and reservoirs that the average annual water and sediment discharges from the Yellow River to the sea in the ten years from 1990 to 1999 were 13.2 km^3/y and 389.9 million t/y, only 28.7 and 29.5 per cent of those in the 1950s (Wang et al. 2006). In 1997, the Yellow River experienced the longest dry up of its main channel since 1972 (Shen 2014). The central government responded by revising the allocation plan in 1998 and by strengthening the YRCC's role in water management. An allocation scheme was adjusted every year by imposing provincial quotas in proportion to the expected water availability for the year. The stricter institutional framework for water allocation in the Yellow River became a model for water allocation in other river basins in China, including the Heihe (2000) and the Shiyang (2007) (Shen and Speed 2009). Subsequently, the State Council set up the Heihe River Basin Authority under the YRCC to lead the project on uniform water management and allocation in the Heihe River Basin. With regard to property rights systems, before 1998, China's water conservancy was primarily focused on physical-human-made infrastructure to support national economic development.

1998–2009

In the same year, Wang Shucheng, the minister of water resources, delivered an important speech to the Chinese Hydraulic Engineering Society (CHES) about "realizing the transformation from engineering water conservancy to resources water conservancy" (Jia and Zhang 2011). During his term as minister of water resources (1998–2007), Wang Shucheng introduced notions about water rights and markets and facilitated policy discussions in China (BJ170802-1; ZZ170711). Moreover, in the 1990s, the Ejina oasis downstream of the Heihe River shrank because of increased water diversion in the middle of the basin. Thus, faced with basin closure, the State Council of China decided to reallocate irrigation water to increase the discharge of water downstream to restore the ecology of the region (ZZ170711). With the implementation in 2000 of a water reallocation scheme for different probability years, Zhangye City, which is located midstream, was asked to discharge 950 million m^3 to downstream areas in normal years when the upstream reaches 1580 million m^3 (Lu et al. 2015). At that time, the Chinese government started to explore market-based mechanisms for water allocation. In 2000, Dongyang and Yiwu, two cities in Zhejiang province, agreed to inter-jurisdictional water transfers and thereby broke China's old administrative water allocation system. The agreement was controversial because, as a form of de facto property rights, it did not have legal standing (Jiang 2018). Furthermore, in 2001, the Gansu provincial government established the Shiyang River Basin Authority to service the Shiyang River Basin. Notably, the tenth five-year plan marked a 362.5 billion yuan investment in water conservancy infrastructure, equivalent to the total amount of national water conservancy fixed assets investment from 1949 to 2000 (NDRC and MWR 2007). With respect to infrastructure projects, the diversion channel of the Jingdian project formally began diverting 100 million m^3 water from the Yellow River to the Hongyashan reservoir in Minqin (Huo et al. 2007).

During this period, the 2002 Water Law, a revised version of the 1988 one, incorporated water rights and Wang Shucheng's proposed water conservation strategy (BJ170802-1; ZZ170711). In fact, it provided a comprehensive framework for integrated water management and included provisions for the ownership, abstraction rights, planning, allocation and economic use of water resources, and for the settlement of disputes. In Article 45, the law stipulated that "plans for water allocation shall be formulated on a watershed basis in accordance with the watershed", and that (NPC 2002)

> the water administration departments of the local people's governments at or above the county level or the watershed authorities shall, according to the approved water allocation plans and the annual forecast of the amount of incoming water, formulate the annual water allocation and diversion plans and implement the unified water diversion.

Thus, the 2002 Water Law combined the jurisdictional and basin-management components of water resources. Aside from constructing the South-to-North Water Diversion Project in 2002, the MWR selected Zhangye as the first pilot city to apply market-oriented mechanisms in water allocation based on the theory of water rights and water markets. Another model of water reallocation was conducted in Ningxia province. Since agriculture accounted for more than 90 per cent of the total water use and new industrial enterprises were restricted by scarce water supplies, Ningxia province submitted a pilot project in 2003 to the YRCC on behalf of the MWR to approve water reallocation between agriculture and industry. This was followed in 2006 by a water permit regulation that provided details on granting and managing withdrawal permits. The regulation was built on previous provisions and allowed a permit holder who saves water to transfer it "with compensation" (Article 27) (Liu and Speed 2009).

China's eleventh five-year plan (2006–2010) required the establishment of a water rights allocation and transfer system and associated compensation mechanisms. During this period, a water entitlement and trading project was carried out jointly by the MWR, China and the Australian Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), arising from a memorandum of understanding in 2003 (WET 2006). A national water rights system was designed and focused on water right at three levels – regional water rights (the allocation of water rights between provinces, prefectures and counties); permit-level water rights (rights to abstract water from a source); and certificate-level rights (rights to a share of water within an irrigation district). In the meantime, the investment scale of water conservancy construction reached a new high. During the eleventh five-year plan period, the completed water conservancy construction investment for the whole country exceeded 700 billion yuan (NDRC and MWR 2012).

However, a lack of control over discharge and limited implementation of regulations led the government in 2009 to create a new soft infrastructure in the form of the "strictest water resources management strategy" (Shen 2014). A framework within which to promote a strict system for managing China's water resources was established, which contained red lines – the first to control total water use, the second to control total pollution discharge into water bodies, and a third water-use efficiency one to promote water productivity. These targets were subdivided and distributed to 31 regions in China for a number of benchmark years to 2030 (Liu et al. 2013). In sum, from 1998 onwards, China has been experiencing a gradual blending of the physical human-made and soft infrastructures with which to manage its water resources.

Post-2009

In addition to implementing stringent measures with which to manage the country's water resources, the twelfth five-year plan (2011–2015) marked another new high by investing two trillion yuan in the water conservancy infrastructure (NDRC and MWR 2016). Furthermore, under President Xi Jinping's leadership, China's central government has prioritized allowing the market to play a decisive role in the allocation of natural resource, characterized by a 'two-handed force' (两手发力) in which one hand is the state (政府) and the other hand is the market (市场) (International Online Eco-China Channel 2017). In 2013, a volume of 670 billion m^3 was pinpointed for capping the water use of the whole of China by 2020 to be divided between and allocated to all 31 regions across the country. In 2016, the management of the arrangements was divided into three parts – water trading between local governments at the county level; water withdrawal rights; and the trading of water-use rights between irrigators. In the same period, the MWR and Beijing municipal government jointly established the China Water Exchange (CWEX), a national company for buying and selling water-access entitlements. By July 2019, regional governments and sectors had traded 2.77 billion m^3 of water through the exchange services provided by this company (CWEX 2019). In the next section, the discussion moves to three cases of water-rights piloting that have occurred during the course of the development of a water market.

Temporary agricultural water trading: Zhangye city, Gansu province, Heihe River

The MWR's 2002 plan to build "a water saving society" in the city of Zhangye contained three elements – government investment in an irrigation infrastructure; the creation of water-metering facilities; and the establishment of water-use rights with tradable water quotas (Zhang 2007). Scarcity and ecological degradation in the downstream area were cited as key justifications for market-oriented reforms in the Heihe River Basin (BJ170802-1; ZY170724). A non-formal system of water-rights trading had existed before the 2002 water reform (Wang 2018: 184). WUAs were established and became the organizational units for water allocation and trading at the terminal level. Trading water rights was placed within a wider set of initiatives, ranging from basin-level planning to basin-level water diversion projects. From 2000 to 2006, an inter-basin project transferred 5.29 billion m^3 to the lower Heihe River (Liu et al. 2013). Water-use rights are granted to the individual farmers of several irrigation districts in Zhangye's six counties (Ganzhou, Linze, Gaotai, Shandan, Minle and Sunan Yugur) in the form of water certificates, which are based on the water-rights area and on crop irrigation quotas (Zhang 2007; ZY170724). Farmers are entitled to buy water tickets on an annual basis through the WUA from the administrators of the irrigation district during a particular irrigation period. Farmers are issued with water certificates to show their permanent entitlement to water use, as well as with temporary tradable tickets, which are linked to their actual water consumption (Zhang 2007). The amount of water noted on the water ticket should not exceed the allocated water-use right noted on the farmer's water certificate (BJ170802-1). Based on the initial allocation, different water users can sell their surplus water to other users annually. The highest permitted trading price is three times that of the basic water price set by the government (BJ170802-1; Deng et al. 2017). In the Lutuo town irrigation district of Gaotai county, the water-rights certificate is issued along with an electronic card with which farmers prepay for the groundwater they want. The total area is 120,000 mu (80 km^2) and six farmers share one groundwater pump, to which a combined electric and water meter is fitted. The farmers elect the manager of the pump. As of 2017, the irrigation quota per mu is 814 m^3, and the water fee per mu is 12 RMB. After a comprehensive water price reform in 2014, the price of water increased from 0.0049 RMB/m^3 to 0.1 RMB/m^3. Moreover, if farmers exceed their allocated quota by 10–30 per cent, they have to pay 0.2 RMB/m^3 for the excess. If it is 30–50 per cent or more than

50 per cent above the allocated quota, the farmer has to pay 0.3 RMB/m^3 and 0.4 RMB/m^3 respectively (GT170725).

A second element of the CIS is its natural infrastructure in the form of melted snow from the mountains that provide natural water storage. Because there is not much change in the annual volume of water, the river flow is subject to very little uncertainty (Wang 2018). Although the elements of various infrastructures to establish water-rights trading in Zhangye city have been in place for 16 years, there is little evidence of an active water market. A recent study of the Heihe River area by Sun et al. (2016) found that the ineffectiveness of issuing water certificates to enable trading arose from the high administrative cost of implementation and the small sizes of the farms. Other scholars ascribed it to the lack of benefits from trading and the absence of industries (BJ170802-1). As one scholar concluded, "the agricultural water use cannot provide a high output value per cubic meter of water. Therefore, the water transaction in agriculture use can hardly provide an attractive price to induce water saving" (Deng et al. 2017: 38).

Inter-sectoral water permit transfers: Ningxia province, Yellow River

The Ningxia experience of trading water rights in the Yellow River area illustrates that the enablement of trading requires a conjunction of different infrastructures. When development, industrial demand and limited water supplies converge, it becomes increasingly difficult administratively to reconcile the supply and demand differences between different water users (Wang, Wan and Biswas 2017). To meet industrial water demand without exceeding the provincial water consumption objective of four billion m^3, investments in water saving technologies and in conservation projects for the irrigation districts are required to promote the efficiency of agricultural water use. By 2015, 52 firms were investing in irrigation districts to transfer 494 million m^3 of water entitlements to their industries (Sun et al. 2017; Ningxia Water Resources Department 2017). The implementation of water transfer projects in Ningxia province was driven by the low water-use efficiency in agriculture and the high demand for water by industry (YC170717-1; ZZ170710). The close links between the physical (large irrigation districts and energy industries) and natural (surface water) infrastructures in the upper part of the Yellow River have facilitated the management and movement of water. In this context, Ningxia's Water Resources Department is legally responsible for planning, designing, constructing and managing all the water transfer projects in the area (Ningxia Water Resources Department 2017). It also stipulates the components of the water-transfer fees paid by the industrial sector, which include the costs of constructing, conserving, operating and maintaining its services, as well as compensating agriculture and the environment. The department also specifies what quantities of water can be transferred without adversely affecting the agriculture sector. Enterprises and the irrigation district's bureau of administration, but not farmers or WUAs, are called upon to participate in the water transfer projects. An individual farmer's access to water is regulated through the water-withdrawal permits that the WUAs issue to them. Each enterprise is responsible for paying its own share to the Ningxia water bureau, which coordinates the relationship between the firm and the administrative bureau of the irrigation district in question (Ningxia Water Resources Department 2017). Enterprises hold withdrawal rights to all benefits derived from their water withdrawal permits. Water withdrawal rights are intake rights, which means that the owner of the rights uses them to acquire water physically at the intake point, but not the water from sellers (Sun et al. 2017). When an agreement is reached, the water withdrawal permit is adjusted to the irrigation district, and a new water abstraction permit is issued to the purchaser. The water rights transfer is set for 15 to 25 years, and every five years the YRCC checks and approves the water withdrawal permit (ZZ170710).

In contrast to the Heihe River and Shiyang River areas, Ningxia province has allocated quotas to counties and, in a few cases, as in Wuzhong city, issued water right certificates at the terminal water-user level. Interview informants stated that Ningxia adopted a step-by-step approach to registering tradable water rights certificates because the runoff in the basin varied significantly in volume in different years and Ningxia has no reservoir in which to store water (YC170717-2). In interviews, several officials indicated that there is always a risk associated with establishing water rights at the farm level if the allocation later has to be reduced (YC170717-2). From a CIS perspective, a trading platform has been established in Wuzhong city and the Ningxia government has invested in several irrigation modernization projects, including an automatic monitoring and information processing system (Wei 2018). Moreover, different kinds of trading occurred in Ningxia after the release of the 2016 provisional measures on the administration of water-rights trading (MWR 2016). In 2016, an irrigation district in Zhongwei county agreed to sell a total of 32.85 million m^3 to Power Beijing Ltd for 0.93 RMB/m^3 on the CWEX platform in Beijing for 15 years. Moreover, as of 2017, two villages in Helan county made two water supply transactions, with Hetan (河滩) paying Tonggui (通贵) 100,000 RMB in 2015 and 60,000 in 2017 for water entitlements, relying on WUAs as the unit for transactions (HL170718). In Helan county, there have also been water supply transactions between two aquaculture companies and WUAs in Changxin (常信) township. In 2017, Ningxia Tongwei Modern Fishery Technology Co. Ltd and Ruifu Ecological Aquaculture Co. Ltd bought 800,000 m^3 for a price of 0.17 RMB/m^3. The total price of 136,000 RMB covered the canal water fee (36,000 RMB), management and maintenance costs by the WUAs (23,000 RMB) and monitoring and implementation costs by the county water resource bureau (77,000 RMB) (Helan County 2017).

Temporary agricultural water trading: Gansu province, Shiyang River

Due to chronic supply and demand imbalances, the Gansu provincial government and Department of Water Resources developed a restoration plan in 2007 to reduce basin water consumption by 60 million m^3 annually (Gao 2007). The water allocation reform was primarily driven by desertification downstream and serious sandstorms that could even reach Beijing from the Shiyang River Basin (BJ170804, LZ170726). As one interviewee stated, "the major objective of the water allocation reform is to reduce the irrigation water use at the middle of the stream and increase ecological water to downstream" (BJ170804). From the central government, the reform brought in national funds to the tune of 4.749 billion RMB for the modernization of the irrigation infrastructure and water allocation reform for the period 2006–2020. In the context of river basin closure, increasing water savings and higher value crops, investment in irrigation and monitoring technologies were supplemental to the distribution of water-use rights to end users (Zhu and Li 2014). One interview informant confirmed that "changes in cropping structure and promotion of technologies were necessary for implementation of the plan" (LZ170726). In Shiyang Basin, the annual mean runoff was estimated in the basin and water-use quotas were allocated to the following five counties – Liangzhou (701.5 million m^3), Minqin (283.7 million m^3), Gulang (81.45 million m^3), Jinchuan (172.6 million m^3) and Yongchang (237.4 million m^3) (Gansu 2007).

Under their water-use cap, farmers in Liangzhou county can buy and sell water at will on a temporary basis (LZ170726; Xu et al. 2016). However, since the farmland and water use of individual farmers is low, the leader of a water-user association in a village will collect whatever water is saved under the entitlement and sell it on the farmer's behalf. In fact, informal transactions between WUAs were occurring in the Heihe River Basin even before managers formalized the market (BJ170926). The water market developed in the Shiyang Basin consisted of different kinds of infrastructures. There were natural infrastructures in the form of coupled surface and groundwater resources; soft infrastructures in the form of initial water rights, institutions and regulatory frameworks such as a trading platform; and hard infrastructures in the form of canals, reservoirs and water-saving technologies. The role of the water market is to ensure that the reallocation of water among WUAs is more flexible and timely. As one interviewee (BJ170804) put it,

> the huge amount of WUAs in the irrigation districts leads to a very high cost for the irrigation management bureau of allocating and reallocating water among them in a timely way. The water market in the Shiyang Basin provides a method that can reduce the government's administrative cost by allowing WUAs to communicate and trade water among each other by themselves.

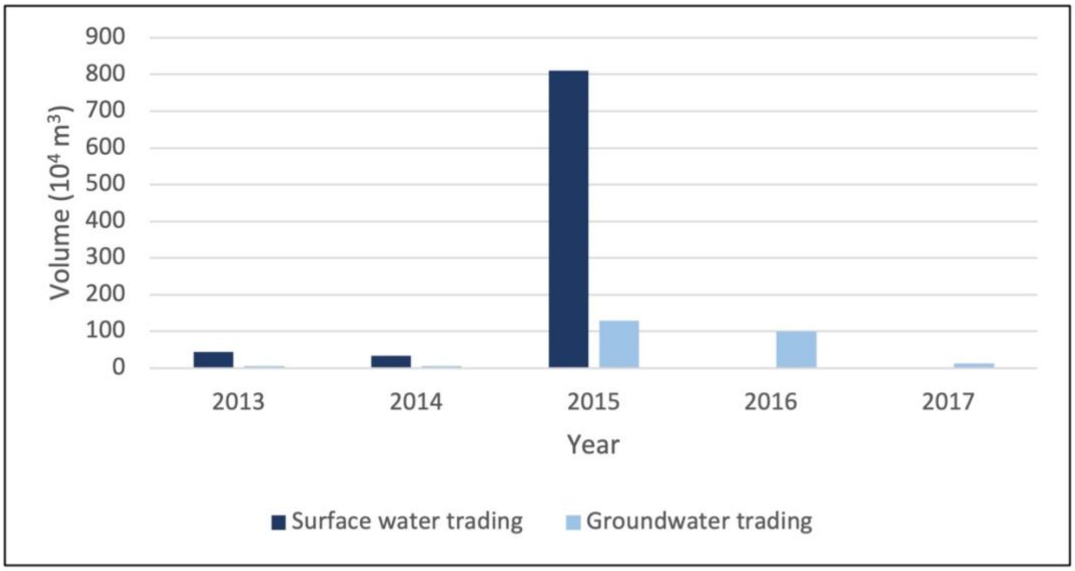
These insights from the Shiyang River Basin support Wang's (2018) argument that water markets reduce the government's administrative cost of reallocating water among WUAs.

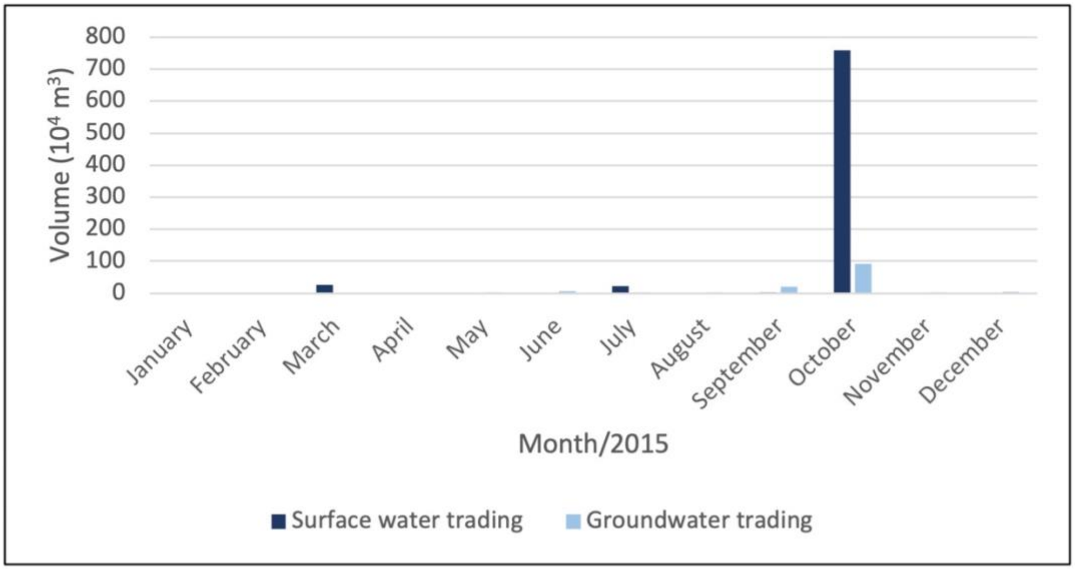
Moreover, if the amount of water traded between two WUAs is large, the Liangzhou county government reviews the application. If, however, large-scale trading is conducted between irrigation districts, the Shiyang River Basin authority reviews the application (Wang 2018). In the Qingyuan irrigation district, each WUA in a village is allocated a water account in the online trading system to record water allocation, use and trading. Since 2017, WUAs have been assigned two accounts – a private one through which the leader submits trading applications, and a public one for all the farmers. However, despite the government's wish to increase the transparency of the water market in the public account, it remains difficult to distribute the profits from water sales equitably among the farmers within a particular WUA. According to one prominent scholar who set up the platform, "the water use of each farmer is generally not monitored accurately enough by most WUAs in Qingyuan and Xiying and this affects the distribution of the profits" (BJ170926). In Liangzhou county, three authorities check, review and approve the trading applications online – (i) the irrigation management station of the irrigation district, which is in charge of water delivery and canal management; (ii) the water bureau of the township government; and (iii) the irrigation bureau of the whole district, which is the highest-level institute of the irrigation management station (BJ170926; LZ170726). The local authorities and the Shiyang River Basin administration check the applicant's water supply capacity, infrastructure quality, and trading prices before approving the trading. The qualified seller and buyer are then matched according to their bids in a pooled exchange system based on the experience of the Australian water market. Although the trading contract is completed online, in practice all stakeholders are required to sign paper contracts (BJ170802).

The accumulated volume of groundwater traded between 2013 and 2017 in Qingyuan district was 2.65 million m^3, and the price ranged from 0.03 RMB/m^3 to 0.20 RMB/m^3 (Shiyang River Basin

Trading Centre 2017). As in the Heihe River Basin, the government stipulates that the price of selling water should not exceed three times the current irrigation water price (BJ170926). A recent study in Xiying district by Xu et al. (2016) shows that trading activity remains a fraction of total water allocation, just 0.37–3.3 per cent of the total water allocation was traded between 2008 and 2014. Figure 4 shows that WUAs in Qingyuan and Xiying traded most of their water at the end of the irrigation season before winter.

Figure 4. Annual and seasonal trading in Qingyuan (groundwater) and Xiying (surfacewater) districts, Shiyang River.





4.6 DISCUSSION AND CONCLUSION

In this chapter, we have analysed the contrasting experiences of water markets and associated water-rights reforms in north-western China from a combined CIS and path dependency perspective. From the early years of the establishment of the People's Republic of China in 1949 until the end of the 1980s, China's water management approach was mainly characterized by an emphasis on a hard human-made infrastructure in the form of dams, reservoirs and irrigation works. The construction of large-scale flood controls and a water-supply infrastructure significantly altered the natural infrastructure in the basins of the Heihe, Shiyang and Yellow rivers. The construction of surface water facilities, such as the Hongyashan reservoir in the Shiyang River Basin, for example, allowed for the regulation of water inflows into the counties of Wuwei and Minqin. The increased surface water consumption in Wuwei, however, reduced the water inflow to the Hongyashan reservoir and to downstream Minqin county and this led to a shift in the use of groundwater resources (Zhu and Li 2014). As such, physical human-made infrastructure (reservoirs) interacted with soft infrastructure (rules in use) to produce a declining groundwater table (natural infrastructure) in Minqin. Before 1998, China's water conservancy was primarily focused on national economic development. Policy choices during this period influenced subsequent developments. Soft infrastructures – water allocation plans and water withdrawal permits in 1998 and 2002 – developed the components of the national water rights framework in the 2000s and laid the foundations for developing water markets.

The insights from the three cases suggest that path dependency matters. River basin closures became the defining challenge in all three basins between the 1990s and 2000s as downstream needs were increasingly difficult to meet. These closures highlighted the political and socio-economic drivers of water scarcity as evolving demand strained water supplies. As China's political economy evolved, the objectives of water resource management changed from a strict focus on development to one on environmental sustainability. In terms of path dependency, the crisis in 1998 served as a critical juncture or formative moment. According to this logic, new conditions disrupt the specific mechanisms that previously reproduced the existing behaviour (Hall and Taylor 1996). Under these circumstances, Wang Shucheng, the minister of water resources from 1998 to 2007, acted as a policy entrepreneur and drove the policy process by introducing the concepts of water rights and markets. This critical juncture in 1998 and the subsequent series of decisions that followed to create a water saving society gave rise to institutional complementarities to the existing water infrastructural pathway. Evolving water demands and limited supplies came at a time of larger economic and political change within China, prompting the government to establish cap, allocation and trading regulations. In this context, trading and transferring water-use rights became the response to water allocation challenges associated with basin closures.

Indeed, water market evolution, including a cap, initial allocation and trading rules has been sequential as in other countries. In Spain, the convergence of nationwide droughts and high costs of expanding water supply infrastructure triggered the emergence of water markets in the 1990s to enhance system flexibility (Garrick et al. 2018). Thus, consistent with international experiences (Breviglieri et al. 2018), scarcity and competition were primary justifications for water markets and cap-and-trade water allocation reforms in China. However, informal transactions were prevalent in the Heihe and Shiyang river basins before the formalization of markets began. Yet, none of the three cases can be explained by a single factor. The emergence of water markets rather display configurations, such as the combination of a water rights system, water saving technologies, crop pattern change programmes, canal rehabilitation, water-trading platforms and the creation of WUAs by the governments of the Heihe and Shiyang river basins. Over time, capping, allocating and trading water in Ningxia in the upper Yellow River area has been shaped by changing internal and external circumstances. The drying up of the Yellow River in 1998 and the arrival of new players, such as industrial users and the environment, combined with improvements in irrigation efficiency, resulted in the transfer of water from irrigators in the Yellow River to urban users. However, the trajectories of market-enabling reforms in the three basins have not been linear. Trading activity is more limited in the Heihe and Shiyang basins, whereas trading activity in Ningxia province has expanded. Two types of trade occur in Ningxia – the spot trade of seasonal water allocation between irrigators, and long-term forward water trades between agriculture and industry.

While water markets have emerged and evolved institutionally over time, the state exerts a dominant influence over communities and markets. As illustrated by the three cases, the state supports water markets and communities (farmers and WUAs) by monitoring water use and providing an infrastructure based on the state's administrative capacity. Unlike the international cases such as Australia, Chinese water rights are tied to the land. A large number of farms on tiny plots raise the cost of trading water among individual households, which in turn illustrates the lingering effects of institutional path dependence. Therefore, collective negotiations are a key feature of the water-rights trading forms in which WUAs facilitate interactions between farmers. At the same time, water infrastructure development has remained a constant feature in China's water policy reform, as highlighted in the tenth, eleventh and twelfth five-year plans. The development of mega water diversion projects continues to play a major role in China, as illustrated by the eastern, middle, and western routes of the South-to-North Water Diversion Project, which connects the Yangtze, Huai, Yellow and Hai rivers. In addition, another mega water diversion project across river basins, called “the Hongqi River” (also known as “the Red Flag River Project”), has been proposed for north-western China (Yang et al. 2018). As mega water diversion projects have gathered pace, the market-oriented water allocation reform programmes – as in Gansu and Ningxia provinces – have also increasingly become critical responses to China’s water resource challenges. From a CIS perspective, the physical human-made infrastructures (water-diversion projects) and soft infrastructures (provincial water-rights trading platforms) are co-evolving into a path of water conservation development in contemporary China. A configurational perspective shows that the three cases display bundles of mechanisms and that water markets complement rather than compete with the supply side of the water infrastructure.

Going forward, this chapter has pointed to two directions for future research in China using the CIS perspective. First, a comparison of China’s water markets with those of other countries can advance theoretical insights into how the macro-institutional context can enhance or inhibit the self-governing capacities of water-rights trading activities. Finally, future research should attempt to answer how interactions between state, community and market mechanisms (pricing and water markets) influence resource outcomes.

5. HOW HYBRID ENVIRONMENTAL GOVERNANCE WORKS? EXAMINING WATER-RIGHTS TRADING IN CHINA (2000–2019)

5.1 ABSTRACT

In several countries, increasing competition for water stimulates the growth of markets for sharing water between rural communities and cities. While there is growing recognition that the adoption of market mechanisms for environmental governance requires the state to make different institutional arrangements, much less is known about how the interconnections between the state, market tools, and the community work in practice. In China's distinctive political system, the central government operates a "two-hands" approach (两手发力) to water governance – strong central regulation and infrastructure development on the one hand, and the adoption of market principles to improve water reallocation on the other. While a recent study has explored the policy evolution underpinning this transition, none has systematically examined the implementation of the two-hands approach to reveal the underlying institutional hybrid patterns in environmental governance. This study fills that research gap by employing a fuzzy-set qualitative comparative analysis (fsQCA) to analyse how the interplay between central government, the market, and local governance shapes water-rights trading patterns. A total of 29 water-scarce cities using water-rights trading were investigated for the period between 2000 and 2019 by combining evidence from fsQCA and qualitative case studies. The implications drawn from interpreting the results are that (1) the central government shapes the development of the market and its transactions, expressed mainly through pilot projects and the national water exchange platform; (2) establishing water markets and investing in water infrastructure are mutually reinforcing rather than mutually exclusive; and (3) local governments employ different property rights arrangements to adapt water markets in China's centralized politically institutional context.

5.2 INTRODUCTION

Growing competition between cities and rural regions over limited water resources demands attention to types of property rights and governance mechanisms to share water within and between sectors (World Bank Group 2016). The use of water markets has responded to water scarcity in several countries ranging from early adopters such as Australia, Spain, the western USA, and Chile to more recent initiatives in China spanning two decades (Garrick, Hernández-Mora and O'Donnell 2018; Grafton et al. 2011). Water trading in these markets involves the reallocation of water entitlements or allocations on either a temporary or permanent basis.

Literature review

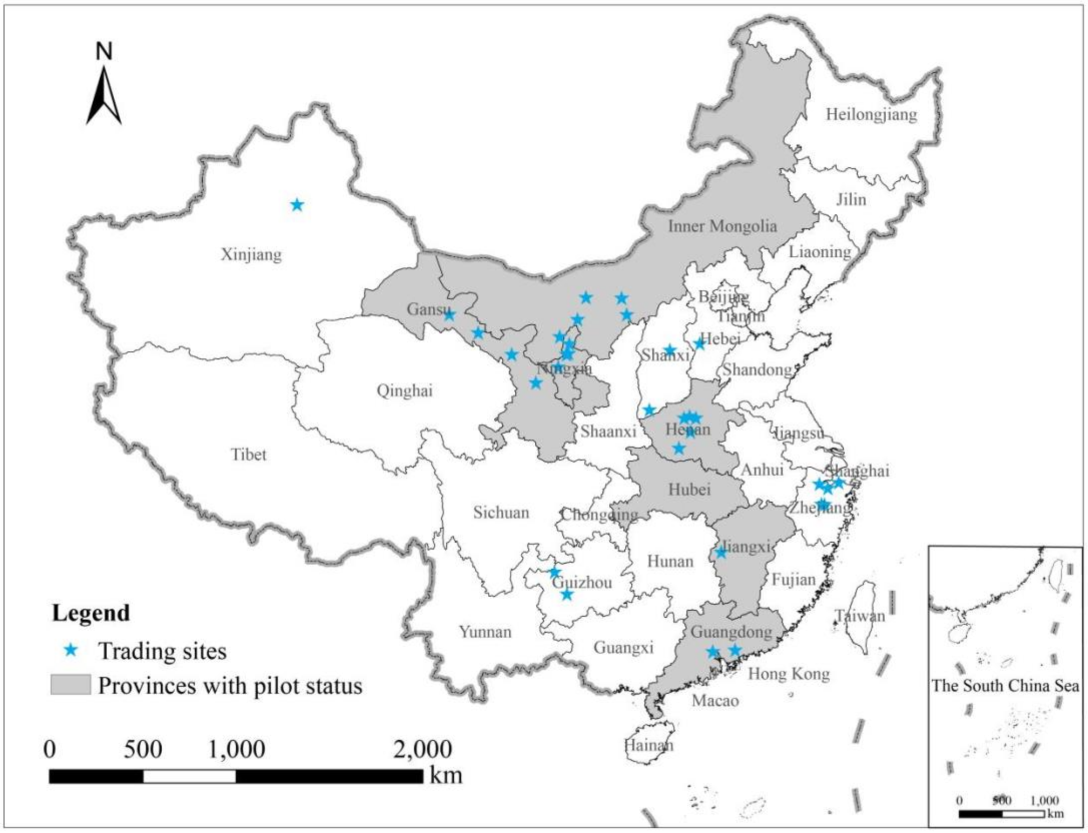
This chapter responds to two trends in environmental governance. First, environmental challenges increasingly call for market mechanisms, but their operation depends on careful institutional design, including property rights and water governance arrangements (Wheeler and Garrick 2020). Studies of water markets (Easter and Huang 2014; Grafton et al. 2011, 2012) highlight adaptive water governance structures that can reduce impediments to trading while simultaneously managing negative impacts related to trading. Factors include types of property rights arrangements in resource allocation; enforcement and monitoring of changing use arrangements; and a market design that is fit for the context. Scholars have begun to acknowledge the importance of enabling institutions to facilitate and/or allow water trade, but these studies go beyond narrow prescriptions of private rights (Grafton et al. 2011; Wheeler and Garrick 2020).

Second, the application of market principles has involved hybrid forms of environmental governance. The earlier literature studied the institutional arrangements of water-rights trading as a binary between market and state. Meinzen-Dick and Ringler (2008) identified three types of formal water reallocation approaches – administrative reallocation; collective negotiations; and market-driven reallocation. In reality, however, a mixture of approaches is applied to reallocate water (Marston and Cai 2016). Rather than a "free market", water markets rely on strong government and community roles, the so-called "institutional tripod" of state, self-governance, and markets (Meinzen-Dick 2007). In particular, Lemos and Agrawal's (2006) review of environmental governance highlights the hybrid forms of governance across the state–market–community divisions, including payment for ecosystem services and the co-management of forests. Villamayor-Thomas (2014) documents such hybrid forms in the context of water markets, illustrating the nesting of irrigation-level trading within multiple stages of coordination. Garrick (2015) identifies how water markets rely on polycentric governance arrangements to cope with coordination challenges across sectors and jurisdictions. In both instances, the roles of physical infrastructure and central regulation are contextual and deserve more explicit attention and integration into the institutional analysis. While there is a growing consensus that market adoption in environmental governance is hybrid rather than binary, there is still a limited understanding of the institutional hybrid between the government and market.

China is an ideal place in which to explore these trends, as well as the form and function of hybrid governance in a location experiencing shifting roles of governments, society, and markets. Scholars are increasingly attributing importance to China's system of "regionally decentralized authoritarianism" in the practice of environmental management, in which political centralization is combined with decentralization in economic governance (Wang, Eisenack and Tan 2019). The paradox of establishing water markets in an authoritarian political context fits into debates about a variety of hybrid governance (Lemos and Agrawal 2006) and institutional diversity rather than the typical binary of markets versus states (Ostrom 2010). The various kinds of water-rights trading in China involve a combination of administrative and market-based approaches at multiple levels. These include trading temporary water rights among irrigators (user-level); trading long-term rights between industry and agriculture (group-level); trading either long- or short-term water rights between governments (regional-level); water banks; and inter-basin trading (for example, the South-to-North Water Transfer Project) (Wang 2018). The total amount of trading annually accounted for 0.2 per cent of total water consumption in 2019, thus indicating that water-rights trading is supplementary to meeting China's water resource challenges. Nevertheless, water markets have spread across more than thirty cities over the last two decades (Figure 5). Trading between companies and irrigation districts is the most common form in terms of volume, followed by regional trading between cities (Graph 1). Indeed, cities are becoming increasingly connected to each other and dependent on water reallocation from agriculture. In this context, the dynamics for markets in one phase may move water from agribusiness to municipal users, and in another phase may involve reallocation between cities.

More recently, China's water governance policy has been to combine a strong state with an effective market, what it describes as the two-hands approach in which one hand, in the form of the government, divides and allocates water-use quotas through regulation and compliance, and the other hand adopts market mechanisms to improve water reallocation (Wang 2014; Wang and Xu 2020). In this context, Jiang et al. (2020) argue that the relationship between the state and market supports water governance in a complementary rather than a contradictory manner. The state has maintained its authority over water by allocating the water rights and by constructing the water infrastructure projects and provincial experiments that entail water-rights trading. However, there is a gap in the knowledge about how the "two-hands" approach to water governance (which mixes the government and the market) works in practice. The elucidation in this chapter on the diversity of institutional hybridization outcomes in the Chinese context perhaps goes some way towards filling that gap.

Figure 5. Diffusion of water markets in China



GRAPH 1. **TRADING VOLUME (MILLION M³)**

Studies on China's water markets have proliferated (Lewis and Zheng 2019; Liu, Peng and Zhang 2018; Sun et al. 2016) and there is a sense that these markets have specifically "Chinese characteristics" (Speed 2009a: 279), including such features as a high level of government control. Moore (2015) argues that in addition to their legacy of administrative control, China's water markets have other distinct features, such as an agricultural structure that accommodates communal water rights, and the nature of central–local relations. Sun et al. (2016) recently evaluated market-based policies for irrigators in the Heihe River Basin in north-western China and found that, for a range of reasons, including high implementation costs, inadequate water metering systems, and interannual variability in water supplies, irrigators, including many farmers with small-sized holdings, gained little benefit from trading their water certificates. A study by Xu et al. (2016) found that the water market in the Shiyang River Basin in western China offered favourable trading conditions, including an annual water-use cap for each WUA, and an irrigation infrastructure through which to distribute the water resources. Several studies have also examined water-rights trading in the upper reaches of the Yellow River Basin (Wang 2012; Wang et al. 2018).

More recently, Liu, Peng and Zhang (2018) embarked on a study of ten water markets in China in an attempt to discover what conditions increase the resilience of water-rights trading. By focusing on four conditions – ownership of water entitlements, market intermediaries, water pricing, and spot/forward trade categories – they identified two pathways. The first necessitates the presence of a strong intermediary, non-competitive pricing, and a strategy of forward water trading, whereas the second is characterized by the privatization of water entitlements, spot contracts, and competitive pricing. While their institutional set-ups contain combinations of government, market and community roles, the government's role is weakly articulated, and its various functions in different contexts remain unspecified. Furthermore, the array of biophysical and infrastructural features that influence trading patterns and outcomes has so far attracted little attention from scholars. On the grounds that "context matters", and following the broader developments in environmental governance, the framework adopted here is with a view to establishing how the institutional infrastructure (that is the role of central and local governments) varies in accordance with the natural infrastructure (namely water scarcity) and with different types of physical infrastructure (such as storage). This gives us a diverse perspective on how the two-hands policy approach is applied in China and offers to improve our understanding of the different patterns of state, market and society that shape the development of water markets. Drawing on data from documentary evidence, interviews, and an original transactions data set, we employ a fuzzy set qualitative comparative analysis (fsQCA) in an attempt to answer the following critical question – how does the interplay between central government, the market, and local governance influence patterns of water-rights trading in China?

The remainder of this chapter is structured as follows. In Section 5.3, the analytical framework and methodology are presented. Section 5.4 contains the modelling and results. Section 5.5 covers different patterns of trade and their explanatory factors and concludes with a discussion of the results and their significance.

5.3 ANALYTICAL FRAMEWORK AND METHODOLOGY

In this section, we develop the analytical framework in which to link the theory and evidence of governance patterns shaping water-market development in China. Theoretical perspectives that apply insights from hybrid environmental governance to examine water markets in the context of China's two-hands policy guide our outline of the material and methods. Fuzzy-set qualitative comparative analysis (fsQCA) is then introduced as the methodological framework through which to unpack the different institutional and physical infrastructures that shape water trading patterns across those Chinese cities that rely on water transfers. Finally, we define the major concepts and measurement approaches used in the comparative analysis, which correspond to the "operationalization" and "calibration" steps of an fsQCA process.

Theoretical perspectives

A large body of scholarship has applied the institutional analysis and development (IAD) framework to problems associated with collective action in common-pool resources (Kiser and Ostrom 1982). The IAD framework outlines a set of components, namely (1) exogenous variables (biophysical conditions, attributes of community, rules in use); (2) action arena (action situations, participants); (3) patterns of interactions; (4) resource outcomes; and (5) evaluative criteria. At its core, this framework emphasizes how interactions among biophysical conditions, attributes of the community, and rules-in-use affect the human propensity to cooperate. In turn, the collective action that emerges within the action situation affects resource outcomes. Scholars have, however, raised concerns about the persistent focus on institutions downplaying the significance of other factors, such as technology, ecosystems, or infrastructure (Anderies, Janssen and Ostrom 2004; Anderies, Janssen and Schlager 2016; Baggio et al. 2016). In recent years, the idea of an infrastructure has replaced the components of the IAD framework, which better captures the complexity of the biophysical environment and technology and provides consistent terminology across diverse research disciplines. Instead of viewing biophysical conditions, the community's attributes, and rules-in-use as external variables, the coupled infrastructure system (CIS) perspective views institutions (soft infrastructure) as endogenous. This means that institutional characteristics arise from the interactions between different classes of infrastructure (human, social, natural, soft and hard).

In this chapter, water markets are conceptualized as coupled-infrastructure systems (CISs) made up of interconnections between technological, infrastructural, institutional and natural processes (Svensson, Garrick and Jia 2019). The CIS framework is applied against this background to make the connections between market-based mechanisms, regulation and technology more explicit. The choice of a CIS framework allows one to take into consideration the attributes of the transaction between the buyer and seller at the city level and to see how markets are responding to the coordination challenges between sectors (rural and urban) and across levels of governance (central–local relations). The CIS framework is also used in this study to understand how water markets fit within the changing governance landscape consisting of hybrid arrangements with particular attention to the interplay of central and local levels and the interaction of different groups.

FsQCA

Fuzzy-set qualitative comparative analysis (FsQCA) is well suited to studies of anything from five to fifty cases (Schneider and Wagemann 2012). It accommodates comparative analysis in the middle ground between in-depth case studies and large-N multivariate studies. A qualitative comparative analysis is uniquely suited to this task. It addresses the limitations of either case study research or large-N multivariate studies on their one. Unlike a single case study, QCA supports generalizations about different causal mechanisms across a larger group of case studies; it identifies the various conditions that induce an outcome, permitting multiple paths or causal recipes that apply to different groups of cases. Unlike large-N multivariate regression modelling, QCA treats causal explanations as a configuration of factors rather than the net effect of independent variables. QCA offers a middle ground that features the breadth of comparison and the depth of individual cases.

FsQCA uses Boolean algebra to analyse cases as arrangements of variables and results (Ragin 2000). While crisp-set QCAs (csQCA) uses Boolean logic of either 0 or 1, the conditions and the outcomes of fsQCA are measured along a line that runs from 0 to 1. The benefit of fuzzy sets is their attention to a finer-grained variation in which a simple binary classification is neither feasible nor credible. The thresholds for set membership within this continuous scale are defined according to theoretical criteria and expert judgement through a careful and iterative exploration of the cases. The moderate N sample size, combined with an interest in exploring different configurations of factors, makes fsQCA a suitable analytical tool with which to identify the diverse pathways that lead to water-rights trading (Ragin 1987, 2000).

In this study, fsQCA is more useful than csQCA for the data analysis because it provides greater flexibility in assigning fuzzy-set membership scores. With fsQCA, "different shades of grey" can be empirically captured for variables like trading activity and scarcity levels (Schneider and Wagemann 2012: 14). FsQCA 3.0 software aided the analyses of the necessary and sufficient conditions that affected the spread of water trading activity. The analysis of necessary conditions was conducted first, followed by an analysis of sufficient conditions (Wagemann and Schneider 2010). Following Rihoux and Ragin (2009: 99–109), a condition is regarded as necessary when it is present anytime the outcome occurs, though the presence does not ensure that occurrence. A condition is defined as sufficient when it is observed across the cases and appears when the outcome occurs.

There are two criteria for assessing necessary and sufficient conditions – consistency and coverage. Consistency means the extent to which a causal combination generates an outcome. This is calculated by determining the proportion of cases exhibiting the outcome of interest that also exhibit a given condition. Coverage indicates the number of cases with the outcome that display a particular causal condition. A condition is regarded as necessary for an outcome when the consistency score is 0.9 or higher and 0.3 or higher for coverage (Schneider and Wagemann 2012). Our analysis of necessary conditions follows this practice with a consistency threshold of >0.9 and a coverage threshold of >0.3. Truth tables refer to all rationally plausible combinations of conditions with each row of the table comprising a unique sequence. This step involves using Boolean algebra on a minimization process, namely identifying only the rows in the table associated with cases. Therefore, the truth tables include a row for each "solution" to the causal model linking causal conditions and the outcome of interests. Following Ragin (2009), a raw consistency threshold of 0.8 was used by carrying out a consistency threshold as near to 1.0 as plausible. It is suggested that analyses of necessary and sufficient conditions are performed for both occurrence and non-occurrence of the outcome (Schneider and Wagemann 2012: 115). In other words, we describe the causal mechanisms that explain the presence or absence of trading activity. We exclude cities that do not trade water at all, which restricts the analysis solely to those cities in which a minimum platform of enabling conditions has already been achieved, and evidence of trading activity has already been observed. Thus, we focus on established trading zones, rather than on the emerging or potential ones. The factors associated with the *potential* for trading present a ripe area for future research.

Case selection and defining the outcome variable

Lijphart (1971) suggests that comparative analyses should focus on cases with similar contexts. Following his suggestion, we focus on patterns of governance in 29 water-scarce cities that shape water market development, and in which such development is captured by trading activity. The cases in the sample consist of 385 transactions in 23 prefecture-level and 6 county-level cities in 11 provinces of China. The latter cover regional water-rights trading between county-level governments, as well as between county-level and prefecture-level governments. Two county-level cities trade with each other (Dongyang-Yiwu) and four county-level cities (Cixi, Dengfeng, Xinzheng and Xinmi) trade with three prefecture-level cities (Shaoxing, Nanyang and Pingdingshan). The information on volume, price, number of transactions, duration, and trading participants came from the original trading database. Accordingly, the data were collected from the online platform of the China Water Rights Exchange Company Ltd (n = 280), a study by the YRCC (2008) (n = 84), six peer-reviewed publications (n = 16) and content analysis of five news articles (n = 5) (Appendix).

The cases selected for this chapter fall into the first three categories described by Wang (2018). The classification of user, group, and local-government-level transactions is similar to that of the MWR's China Water Rights Exchange Company Ltd, which classifies water trading in China in terms of irrigation, water withdrawal, and regional water rights (Guo et al. 2019). The choice of cases is determined by their theoretical relevance and access to reliable information. In short, we are interested in finding the water-scarce cities with the most trading activity and exploring what different institutional arrangements at the central and local levels explain how these trends occur. Here, we conduct one comparative analysis of water-rights trading among 29 water-scarce cities from 2000 to 2019 regardless of user-level, group, and regional levels by focusing on annual volume of trading in a city as a percentage of a city's water quota (Table 5). Trading activity (TRADING) offers an indicator of water market development and allows for insights into the hybrid patterns of governance that shape the development of water markets.

Table 5. Operationalization of trading activity

Outcome	Indicators	Operationalization	Number of cases in each of the classes
Trading activity (TRADING)	Ratio of transferred water per year (transaction amount/total quota)	0–0.10 = 0 (very low) 0.10–0.20 = 0.33 (low) <1= 0.67 (moderate) >1= 1 (high)	0 = 6 0.33 = 2 0.67 = 5 1 = 16

We chose trading volume as a percentage of a city's quota as our outcome measure because it accurately captures the variation from low to high trading activity and generates a distribution of the cities and their trading activity that conforms to a detailed understanding of the cases. Fuzzy-set QCA requires the calibration of the measures to distinguish the presence versus absence of conditions and outcomes, including a threshold for presence and absence and a "cross-over" point of indeterminacy between the two. The calibration scheme is not merely a mechanical exercise but rather a dialogue between theory and evidence. For trading activity, we seek a scheme that can classify cities into categories of higher and lower levels of trading activity, while allowing some intermediate cases. Consequently, a four-value scheme was adopted, and the intervals in Table 5 were anchored according to natural breaks in the data that distinguish between lower and higher levels of trading.

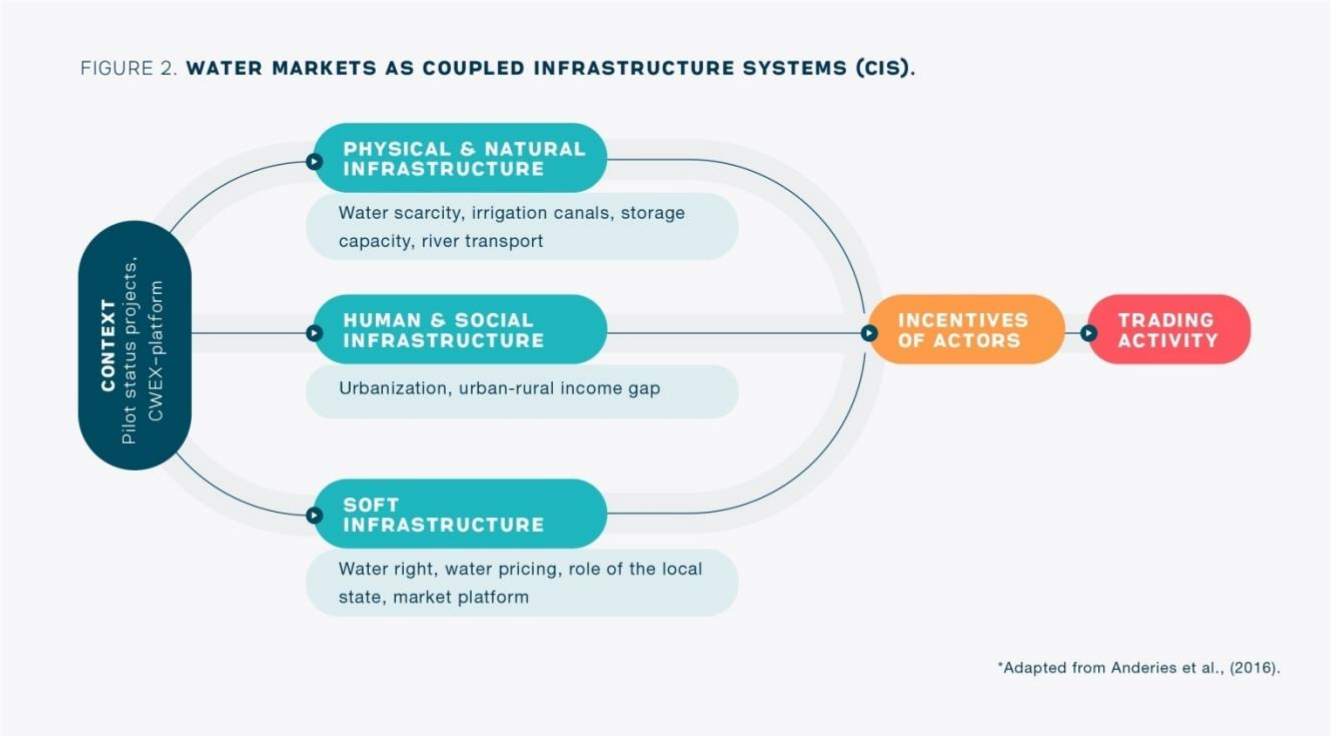
Identifying potential causal conditions

Our analysis identified ten causal conditions, but we focus on eight (1 to 8 below) because these are related to institutions and infrastructure, and are based on the literature and focus groups. Following the fsQCA approach, a common practice focuses on three to eight causal conditions (Ragin 2000).

The hard human-made natural, social, and soft elements of the CIS are represented by these factors (Figure 6). The causal conditions were calibrated through a four-value scale along the interval from "fully out" (0), "more out than in" (0.33) to "more in than out" (0.67) and "fully in" (1) respectively. This technique is recommended when researchers have a considerable amount of material about cases, though the features of evidence are usually not the same from one case to another, which is the case in our sample (Ragin 2009: 7). However, we were unable to acquire adequate in-depth information on four causal conditions to calibrate a four-value scheme.

Data on storage capacity, urbanization and on the per capita disposable income of urban and rural households are based on time series statistics from EPS China Data, while that on water consumption are derived from provincial and prefectural water resources bulletins. In addition, data on six causal conditions – transfer infrastructure, property rights, price discovery, role of the local state, market intermediary, and pilots – are based on qualitative sources (Tables 11-15 in Appendix). Accordingly, the data came from a review of peer-reviewed articles, government documents, and interviews. The authors conducted a total of six focus groups with officials involved in water-rights trading at the user and group levels in Cheng'an (Hebei), Wuwei (Gansu), Taiyuan, Yuncheng (Shanxi), Hohhot (Inner Mongolia) as well as at the regional level in Zhengzhou (Henan). We also discussed causal conditions with two water resources experts in Beijing. We asked the informants what they considered were the top three most important factors, and their replies largely matched our expectations based on economic theory: water scarcity is a necessary condition, while water rights and a cap on extractions and support from the government are key enabling conditions for establishing water trading. We also conducted field visits to the sights. Information on the causal conditions, calibrations, and sources of the causal conditions can be found in the Appendix. The case descriptions in the Appendix highlight the rationale for the calibrations of the conditions for each case. We expect to find that the central government has an important role, and it is channelled through multiple mechanisms and conditions that depend on context.

Figure 6. Analytical framework



The first causal condition chosen is water scarcity (SCARCITY). Regarding natural infrastructure, the natural resource conditions of scarcity and competition over water are often cited in the literature as a key factor that motivates water markets (Easter, Rosegrant and Dinar 1998). Consistent with the existing literature, we expect water scarcity to be a common factor, and water-rights trading is more prominent in water-scarce areas in northern and north-western China compared with other parts of the country. For operationalization and calibration of water scarcity (SCARCITY), we draw on the water shortage index used by Zhao et al. (2015) where no water stress, moderate water stress, severe water stress, and extreme water stresses occur when the ratio of annual freshwater withdrawal to renewable freshwater resource is 0–20 per cent, 20–40 per cent, 40–100 per cent, and more than 100 per cent, respectively. However, the operationalization of the causal condition, water scarcity (SCARCITY), was based on a city's water consumption as a percentage of the water quota/cap. In other words, a city's water usage at the prefecture level was averaged for the transaction period and divided by the government's water allocation quota for 2015. We obtained the hydrological data from the *Water Resource Bulletin* published by provinces and prefecture-level cities.

More recently, there has been a recognition that physical infrastructure is critical to make trading possible by moving water, particularly across jurisdictions or basins. In this light, a supply and distribution infrastructure is essential to ensure that buyers can obtain the exact volume they have bought (Wheeler et al. 2017). More importantly, infrastructure is an extension of the government's role, particularly that of the central government. Therefore, we have chosen physical transfers of water resources through reservoirs (RESERVOIR) as the second causal condition. A two-value scheme (0 and 1) was used for physical transfer infrastructure (RESERVOIR), indicating whether reservoirs or inter-basin transfers enabled the transaction between the seller and buyer by drawing on press research and official reports.

We chose storage provision in a province (STORAGE) as the third causal condition because storage capacity is vital to store, access, and regulate water, which may affect trading activity in a province. We conceptualized it as the total storage capacity of a province, drawing on data from EPS China Statistics, which is the largest and most comprehensive collection of data on China. A four-value scheme was adopted for this condition.

A well-functioning water market is said to require a wide range of institutional factors (soft infrastructures), such as (a) a quantity cap that is monitored and placed on the market to limit the resource used in a defined area; (b) distribution of water rights that can exclude others from using water; and (c) rules that can restrain the adverse effects of trading (Easter and Huang 2014; Grafton et al. 2011). Against this background, we chose private tradable water rights (PRIVATE) as a fourth causal condition. Here, we draw on the classification compiled by Liu, Peng and Zhang (2018), which is operationalized on a scale from 0 to 1 with 1 representing the right to use and transfer water at the household and WUA-level and 0 absence of private tradable water rights, indicating state control. Although Dai et al. (2017) use a three-value scheme based on global comparisons, we justify a two-value scheme for this condition, given the calibration in the scholarly literature. In many cases, the state and the community hold water rights, but the bulk of water entitlements are not allocated to farmers.

According to economic theory, market pricing enhances water use efficiency by confronting water users with the opportunity costs of their consumption (Brookshire et al. 2004). Therefore, our fifth causal condition is market-based price discovery and valuation of water (MARKET PRICE). We conceptualize price discovery (MARKET PRICE) as how prices are determined. In the Chinese context, we coded and calibrated water prices on a three-value scheme because the literature defines this as a key distinction between free-market price, capped price, and fixed price (Liu, Peng and Zhang 2018). The government sets fixed prices without bargaining, as well as the capped and bottom price, but allows bargaining between the seller and buyer. Market pricing means whether the seller and buyer can negotiate to decide the trade price (Liu, Peng and Zhang 2018).

Other critical institutional factors include the administrative capacity of coordination institutions to cope with changing use arrangements. Given the political nature of capping and trading water in allocation systems, and the socioeconomic effects of redistributing water, water markets require robust institutional structures (Wheeler et al. 2017). A recent study by Garrick, Hernández-Mora and O'Donnell (2018) showed that coordinating institutions can assume many forms, which, dependent on the context, might include settings for planning, financing, and conflict management. The existence of strong coordinating institutions and formal water markets is particularly important when water trading occurs across sectoral, jurisdictional, or basin borders. Meinzen-Dick (2014) differentiated between three types of coordinating institutions – the state, self-organization by resource users, and the market. She also argued that coordination becomes important with a greater spatial scale.

The coordination institutions are of central concern in the literature on water markets. Given that China has different types of water markets, we chose the role of the local state (STATE) as the sixth causal condition. We conceptualize STATE as the local government's participation in the market, which is how Dai et al. (2017) employed it. They operationalized government participation in terms of leading, partial, and no participation (supervision) in decisions concerning the transfer amount, the terms of the transfer, and the compensation methods. We undertook a similar calibration of STATE via a three-value scheme. We conducted a review of government reports and talked to people in these different settings about the role of the local state and realized that it varied between taking a leading role, partial participation, and merely granting administrative approval. The value scheme is based on a spectrum from 0 to 1 with 0 implying administrative support and 1 full participation of the local state in terms of trading amount and terms of trading.

A water market intermediary (PLATFORM) is the seventh causal focus condition. We include it because exchange platforms provide market transparency and facilitate trade (Möller-Guland and Donoso 2016). At present, there are two types of market platforms in China. The first has financial attributes that use investments to save, purchase, store and sell water for long-term trades. Four market platforms fit this category – the national China Water Exchange (2016–); the Inner Mongolia Autonomous Region Water Right Purchase, Storage and Transfer Centre (2013–); the Henan Water Right Purchase, Storage and Transfer Centre (2017); and the Guangdong Environmental Rights Exchange (2010). The remaining market platforms in China are bulletin boards providing intermediary services for temporary trades, including publishing information and water prices (Tian and Gu 2019). We operationalized PLATFORM as the percentage of the total volume of traded water in a city facilitated by a market platform based on a four-value scheme. Data sources include the China Water Exchange and other platforms.

The central government can promote water-rights trading locally by selecting provinces to run pilot projects. We chose pilot province (PILOT) as our eight causal condition, operationalized as the number of pilot projects in a province by drawing on press reports and peer-reviewed articles. Urbanization rate (URBAN) and urban–rural income gap (GAP) are the ninth and tenth conditions we investigate because researchers have emphasized that drivers of water demand and competition influence trading patterns (Wheeler et al. 2017). These two conditions represent the CIS's human and social elements and are based on quantitative data from the China City Database and the China Labor Economy Database. A four-value scheme was adopted for these two conditions.

5.4 RESULTS

Our fsQCA results on necessary conditions show that no condition meets the necessity threshold for the occurrence of trading activity (Table 8, Appendix). Furthermore, we also analysed the necessary conditions for producing the negation of the outcome, and found that no single necessary condition leads to lower levels of trading activity. Following Schneider and Wagemann (2012), we used the intermediate solution for the sufficiency analysis because it balances the parsimony and the complexity solution. When applying the logical minimization process to the eight causal conditions, five configurations of factors are revealed (Figure 7).

First, we observe trading activity in situations of relatively high decentralization and limited infrastructure, although this is rare (n= 1 city). In Path 1, pilot status in combination with a capped price, private tradable water rights, and absence of local state participation, a market platform (CWEX), low storage provision, and no use of a reservoir to connect traders are sufficient to trigger trading. Temporary trading among irrigation water users or WUAs in Wuwei, Gansu can be explained via this pathway, which we named the "community path".

Second, pilot status, a market price, absence of private tradable water rights, local state participation, a market platform, and no use of a reservoir are sufficient to trigger trading. We named this configuration the "firms path 1". Prefecture-level cities with this combination of conditions are found in Inner Mongolia (Wuhai, Alashan) and Guangdong (Guangzhou, Huizhou). Trading in the former two water markets was brokered jointly by the Inner Mongolia Water Rights Storage and

Transfer Centre and CWEX, whereas the Guangdong Environmental Rights Exchange finalized the trading in the latter.

Third, a mix of conditions, including pilot status, a market price, absence of private tradable water rights, local state participation, low storage provision, and no use of a reservoir are sufficient to induce water-rights trading. Prefecture-level cities in Inner Mongolia (n=5) and Ningxia (n= 2) that represent this configuration have companies that secure long-term water contracts from irrigation districts, mostly through irrigation efficiency investments. This third path is called the “firms path 2”.

Fourth, pilot status combined with a fixed price, absence of private tradable water rights, local state participation, a market platform (CWEX), high storage provision, and the operation of an inter-basin infrastructure creates a path to enable long-term reallocation between cities in Henan province. We named it the “south-to-north path”, and it represents three county-level cities (Dengfeng, Xinzheng, and Xinmi) and two prefecture-level cities (Nanyang, and Pingdingshan). CWEX and the Henan Water Right Purchase, Storage and Transfer Centre acted as brokers.

Fifth, non-pilot status, a market price, the absence of private tradable water rights, local state participation, no market platform, high storage provision, and the presence of interconnecting reservoirs create a sufficient path to enable long-term reallocation. Along this pathway, which we named the “east-to-south path”, three county-level cities (Dongyang, Yiwu, Cixi) and three prefecture-level ones (Shaoxing, Pingxiang, Bijie) trade water regionally in Zhejiang, Jiangxi, and Guizhou provinces in eastern and southern China.

The high solution consistency scores (1, 0.90, 1, 0.93, and 0.87) show that the configurations of factors are consistently associated with trading activity. High coverage scores, in turn, suggest that many cases in the sample are represented in the various configurations of factors (Ragin 2009). The low coverage scores (0.04, 0.16, 0.23, 0.23, and 0.23), however, demonstrate that there is no dominant pathway in China for cities with a trading activity. Yet, the overall solution consistency and coverage scores were high with a solution consistency of 0.92 and coverage of 0.80. Even if there is no single pathway that strongly features the cases, certain traits are shared by multiple pathways.

The sufficiency analysis revealed that three causal pathways inhibit trading with a solution formula that shows a consistency score of 0.93 and a coverage score of 0.51 respectively. According to Legewie (2013: 21), a solution formula below 0.75 for consistency and coverage scores is a sign of a poor model related to the insertion of insignificant conditions and/or missing relevant conditions, among others. Nevertheless, path 1 combines non-pilot status, a capped price, private tradable water rights, absence of local state participation, a market platform, and no use of a reservoir to implement the trading. Taiyuan in Shanxi province, Changji in Xinjiang province, Shijiazhuang in Hebei province, and Hangzhou in Zhejiang province, represent examples of this path. CWEX brokered the trading in the former three water markets, whereas the trading in Hangzhou relied on a local bulletin board. Path 2 combines non-pilot status, a fixed price, absence of private tradable water rights, local state participation, a market platform (CWEX), high storage provision, and the use of a reservoir to facilitate trading. The water market in Anshun, Guizhou, fits this path.

Finally, a mix of conditions including non-pilot status, a market price, private tradable water rights, local state participation, a market platform (CWEX), low storage provision, and reservoir usage creates a sufficient path leading to lower levels of trading in Yuncheng, Shanxi province. The inhibiting pathways indicate that less active water markets lack pilot status. Meanwhile, the centrally coordinated CWEX brought traders together in five out of six cities associated with less active water markets. This may indicate a nexus of initiating water markets and political support from the central government.

Figure 7. Multiple pathways related to higher levels of trading activity

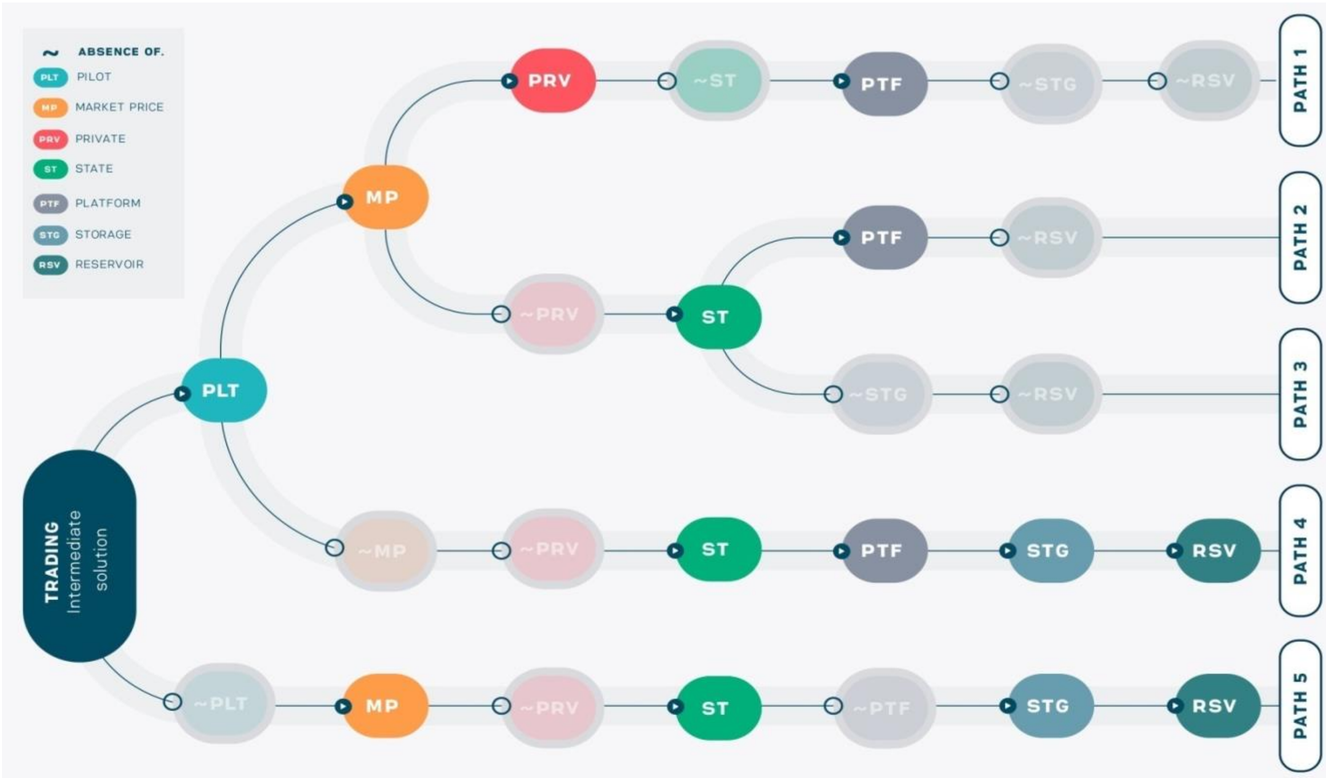


TABLE 1. **FOCUS CONDITIONS AND DEFINITIONS**

Focus conditions	Nickname	Description
Central-government pilots	PLT PILOT	Whether pilot projects have been implemented in the jurisdiction to experiment with water rights initialization and trading
Price discovery (Market price, capped price, fixed price)	MP MARKET PRICE	Price bargaining is allowed in water trade negotiations
Assignment of water entitlements	PRV PRIVATE	Privatization of water entitlements to water user associations (WUAs) or rural households
Role of the Local government at or above county-level	ST STATE	The local government participates in the trading regarding decisions over the transfer amount, the terms of the transfer, and the compensation methods.
Water market platform	PTF PLATFORM	A water market platform brought traders together and brokered the majority of the trading
Storage capacity	STG STORAGE	Indicates the total storage capacity of a province (high versus low)
Physical transfer infrastructure	RSV RESERVOIR	Reservoirs or interbasin water transfers enabled the transaction between the seller and buyer

5.5 DISCUSSION AND CONCLUSION

Growing competition for limited water resources has stimulated innovations in water governance in China through the so-called "two-hands" approach to water management (两手发力). This water policy is characterized by the government's hand providing the initial water-rights allocation and infrastructure development, and the market's hand providing the market tools with which to support water reallocation. While Jiang et al. (2020) show that state control is compatible with marketization, little is known about how the hybridization (the blending of the government's and market's hand) works in practice. The CIS framework treats institutions as a class of infrastructure and explores their relationship with other forms of infrastructure (hard, natural, human) that jointly shape the application of the two-hands approach. The objective of the study was to reveal how the interplay of the central government, the market, and local governance influence water-rights trading in China to shed light on hybrid environmental governance. A total of 29 water-scarce cities trading water rights were analysed from 2000 to 2019, with annual trading volume as a percentage of a city's quota as the primary unit of analysis. We identified five distinct causal pathways that induced trading and three pathways that inhibited it, thus demonstrating that the institutional diversity of water markets coexists in China's regionally decentralized authoritarian regime. The insights derived from the distinct pathways makes several contributions to the literature on hybrid environmental governance.

First, we pay more explicit attention to the roles of central government and the physical infrastructure, and to their integration into the institutional analysis. We also extend the Jiang et al. (2020) study on the two-hands approach to water governance in China by illustrating and illuminating the mechanisms with which the central government shapes the developments of the market in the transactions. The central government leans on two distinct vertical mechanisms embedded in China's governance system – pilot projects and CWEX. Accordingly, the "fingerprints" of the central government in the two-hands policy take many diverse forms. Despite no single pathway assuming dominant coverage, we find pilots in four out of the five pathways. Among the causal conditions, 18 cities out of 29 have pilot status, and the coverage score is 0.91 from the necessity analysis. This score indicates that pilot status has empirical importance for the occurrence of trading. As our analysis has shown, pilot provinces feature higher trading activity levels than the rest of the country. The highest trading activity is in Ningxia and Inner Mongolia in north-western China, and these provinces contain the highest proportion of cities that have adopted water markets. Besides, the central government uses CWEX to incentivize local governments to facilitate trading. We find the CWEX "fingerprint" on three of the five paths that induce trading and all three of the three paths that exhibit lower trading levels. While CWEX administers and approves trading related to the South-to-North Water Diversion Project in Henan (south-to-north path), they played a distinct part in setting up the information design in the Shiyang River Basin and Wuzhong (community path). Thus, the combination of pilot programmes and market platforms tied to the central government lead to the most water-rights trading at the local level.

Second, in an important way, the mutual inclusivity of infrastructure and markets shows how central and local governments shape the development of water markets. In contrast to the earlier literature, which emphasized water reallocation as an alternative to new water infrastructure (Cody and Carter 2009; Meinzen-Dick and Ringler 2008), we find that the development of China's infrastructure is concurrent with trading rather than that trading is a substitute for infrastructure. More importantly, the central government interacts with the market and farmer organizations in the implementation of pilots, the construction of infrastructure and the reform of property rights. In Zhangye, Gansu province, the central government invested in different types of infrastructure, including canals and metering systems as part of the ecological restoration of the Heihe River in 2002 (Zhang 2007). In the Shiyang River Basin, east of the Heihe River, the central government also invested in physical infrastructure to implement the comprehensive water management plan in 2007 and to enable the development of water markets. Of the total investment of 4.948 billion Yuan, 13.4 per cent came from local governments, with the vast majority – 86.6 per cent – coming from the central government (Yao et al. 2017). Cities located in central, eastern, and southern China that trade water regionally can be explained via the east-to-south path and the south-to-north path that feature reservoirs and higher storage provision levels. In both these paths, the state is both administrator and participant in regional-level trading. As an MWR official stated, "trading between governments at or above county level relies on the national water administration or river basin authority for administrative approval. Group-level trading is between water users and it is almost fully market-based" (BJ180323). While the east-to-south path features free-market pricing, the south-to-north one features fixed prices. The provincial government of Henan determines the trading price without local–local bargaining across the jurisdictions. The current transfer period is designed for 20 years, and the transfer contract is adjusted for every third year depending on the rise of the water supply price. Horizontal coordination between local jurisdictions involves setting trading volumes between local water authorities who want to trade the water. The Construction and Administration Bureau of the South-to-North Water Diversion Middle Route Project influenced trading between cities in Henan through the operation and management of the SNWDP. As such, the water diversion capacity of the SNWDP sets boundaries or constraints on water trading, thus underlining the influence of the central government. In particular, the canal cannot be used to divert sold water if it is fully utilized to transfer water to Beijing. However, there are no restrictions on trading water if the water is sold from the north to the south (ZH191121). Also, CWEX plays an important coordination role in administering and approving water-rights trading associated with the middle routes of the SNWDP (ZH191121). Furthermore, several factors constrain the regional trading of water in Henan. Due to a lack of an adjustment pricing mechanism that fully reflects water scarcity, there is a mismatch between the initial allocation of water quotas and water demand (Liu et al. 2018b). As informants pointed out, "water prices of local areas are low, the value of water resources is not recognized, and there is a lack of willingness to trade" (ZH191121). Officials from the Department of Water Resources in Henan explained that, in practice, there is a lack of an operating system, illustrating the need to balance the role of the state and the market: "the seller is concerned about the loss of water rights transaction indicators after the transaction because the seller is the government, not the water supplier or water user. Once the established facts of water use have been formed, it is difficult to terminate the transaction" (ZH191121).

Third, property-rights arrangements are contextually adapted to fit temporal or permanent trading. We attribute exclusion in the design of property rights to water because the excludability of common-pool resources depends on boundary rules that define access. The cases of the Shiyang River Basin and Taiyuan (Shanxi) are forcing the hybridization of governance because they exhibit distinct decentralized features. As each of our two cases demonstrates, property rights to water are unitized, quantified and tradable so that access is limited and the exclusion of non-members to the resource system is possible. Here, the Shiyang River Basin (Wuwei) stands out in China for establishing water rights to end users. Village leaders and WUAs initiate and organize the water-rights trading, but they take their cues from the collective responses of farmers to seasonal variability and limited storage capacity in the Shiyang River Basin. In early 2008, the trading activity was informal and occurred in the absence of government supervision. The leaders of WUAs would call each other on their cell phones to match sellers and buyers (Zheng et al. 2017). An online trading platform was designed to fit the local context and enhance transparency on the trading patterns. Between 2013 and 2017, it facilitated the frequent occurrence of temporary trading between farmers in the Shiyang River area via sealed-bid double auction. The platform has more recently been terminated, but user-level trading is backed by the local government's administrative capacity and CWEX, which register trading and provide data architecture. Currently, the irrigation district authority distributes the hydrology records of each WUA to the townships, who then share them with the management stations of the townships in the irrigation district. The management stations, in turn, pass the information on to the water user associations (WW190727).

Likewise, farmer associations and informal institutions have led the development of the market in Taiyuan in Shanxi. Farmers in Taiyuan rely on social norms and traditional relations to enforce their contracts to engage in informal groundwater transactions. They either borrow electricity cards from relatives or friends to take to the village to buy the wherewithal to irrigate their land electrically, or use someone else's card to pay the cardholder's electricity fee (TY181129). By the end of 2018, the local government and CWEX had begun to formalize the informal trading systems. The implementation measures involved establishing water metering systems to control water consumption and designing village-level trading platforms and mobile software applications to clarify the rights of irrigation water users. Since 2019, farmers have either been able to trade through a mobile app or purchase water at a village-level platform. The local government provides electricity price incentives to buyers and sellers who trade on the platform for 0.05 RMB/m^3 (Shanxi News Network 2018; TY181129). Thus, farmers' associations in Wuwei and Taiyuan emerge to facilitate water trading, but their emergence relies on the incremental reforms that local governments set to formalize existing informal markets. In particular, the agricultural water that can be sold from one village to another is capped at three times the annual water fee (Shanxi Provincial Department of Water Resources 2018; WW190727). The two cases demonstrate that local government in China can play a vital role in promoting the community's interactions with the market. These kinds of puzzles and paradoxes that the exceptions to hybrid governance pose, echo Ostrom's (2005) theory of institutional diversity, which examines the polycentric arrangements of governments, markets, and self-governance in the context of China.

By contrast, the Inner Mongolia cases (firms path 1 and 2) suggest a complementarity between local state control of water rights and the marketization of water prices to enable reallocation through the modernization of irrigation. Local governments have not yet instituted water rights for each farming household. Rather, they have employed different property-based solutions to the tragedy of the commons in which enterprises and local state agencies exercise tradable water entitlements. The former secure long-term contracts for future water delivery, while local state agencies implement the financial and material compensation to the seller to offset the reduction in water availability. Indirect benefits are made available to local farmers in the form of material compensation, such as through the canal lining of the Hetao irrigation system (Dai et al. 2017; HH180403). This mechanism supports existing arguments about compensating exclusion in environmental governance (Sikor, He and Lestrelin 2017). It demonstrates that farmers in Inner Mongolia are not dispossessed of water, but excluded from direct trading benefits and decision-making processes, though simultaneously compensated through irrigation infrastructure rehabilitation.

Finally, despite its unique historical and political circumstances, the emergence of water markets in China's hybrid environmental governance shares many features with other global experiences of developing water markets. Both the state and communities can facilitate water markets, but their emergence depends on context-specific conditions. Yet, China also exhibits distinctive features, such as its reliance on pilots and the concurrent development of large-scale infrastructure. We believe that this study offers a foundation for systematic research on whether and under which conditions the state/market interactions in China produce effective, environmentally sustainable, and equitable outcomes. Future research should more clearly explore the types of water scarcity and demand drivers that prompt trading. Furthermore, local collective action, which is addressed in other work on collective action and the commons (Wang, Zhang and Kang 2019), can be further explored in the context of China's market development.

6. CHINA/AUSTRALIA COOPERATION AND THE RISE, FALL AND REVIVAL OF TRADABLE WATER RIGHTS POLICY IN CHINA, 1998–2019

6.1 ABSTRACT

To date, existing explanations for the movement of a policy from one context to another tend to overlook the interplay of agency and time in the transfer process. The objective of this study was to explore the underlying internal and external drivers associated with the rise, fall, and revival of tradable water rights policy in China. Drawing on policy documents, letters, and key informant interviews, we demonstrate that the shifting patterns of tradable water rights policy can be explained by powerful actors who took control of opportunities that time, timing, and tempo provided. Furthermore, the insights derived from the bilateral programmes are as follows: (1) the process design and location of power explain why the water entitlements and trading (WET) project (2005–2007) involved considerable learning from Queensland, Australia, and contributed to a national water rights framework; (2) the impasse in the Australia China Environment Development Partnership (2007–2012) emerged because of strategic embedded competition and the way the knowledge exchange was organized; and (3) Tsinghua scientists transferred a pooled water brokering system from Victoria, Australia to the Shiyang River Basin, Gansu province by embedding themselves into the policy process. These programmes built on the momentum of Australia's accommodation policy towards China before the relationship entered a deadlock in the late 2000s. Our findings contribute to area studies on China and policy transfer research more generally, thereby highlighting how market ideas take root in China, and the role of bilateral relations rather than multilateral agencies in the selective adoption of a policy.

6.2 INTRODUCTION

One emerging reality encountered in exploring the politics and governance of environmental challenges has been the transfer and diffusion of environmental policies across countries and cities, leveraged through transnational organizations like the International Council for Local Environmental Initiatives (ICLEI) and the World Smart Sustainable Cities Organization (WeGO), among others

(Calder 2021). There has been a growing interest in questions about how policy innovations emerge in some units and move to other units. Public policy research on diffusion usually adopts a mechanism-based perspective, using variables such as political regime type, legal system, levels of socio-economic development and socio-cultural norms (Maggetti and Gilardi 2016; Obinger, Schmitt and Starke 2013). However, this conventional wisdom cannot explain why a particular policy is exported and others are not, or why some elements of a policy or programme are adopted while others are rejected. Accordingly, actors influence the selection or rejection of policies through the effective use of time, timing and tempo (Dolowitz 2020). To advance both area studies and policy transfer studies, we explore the concepts of agency and time and how these affect the processes of the rise, fall and revival of tradable water rights policy in China.

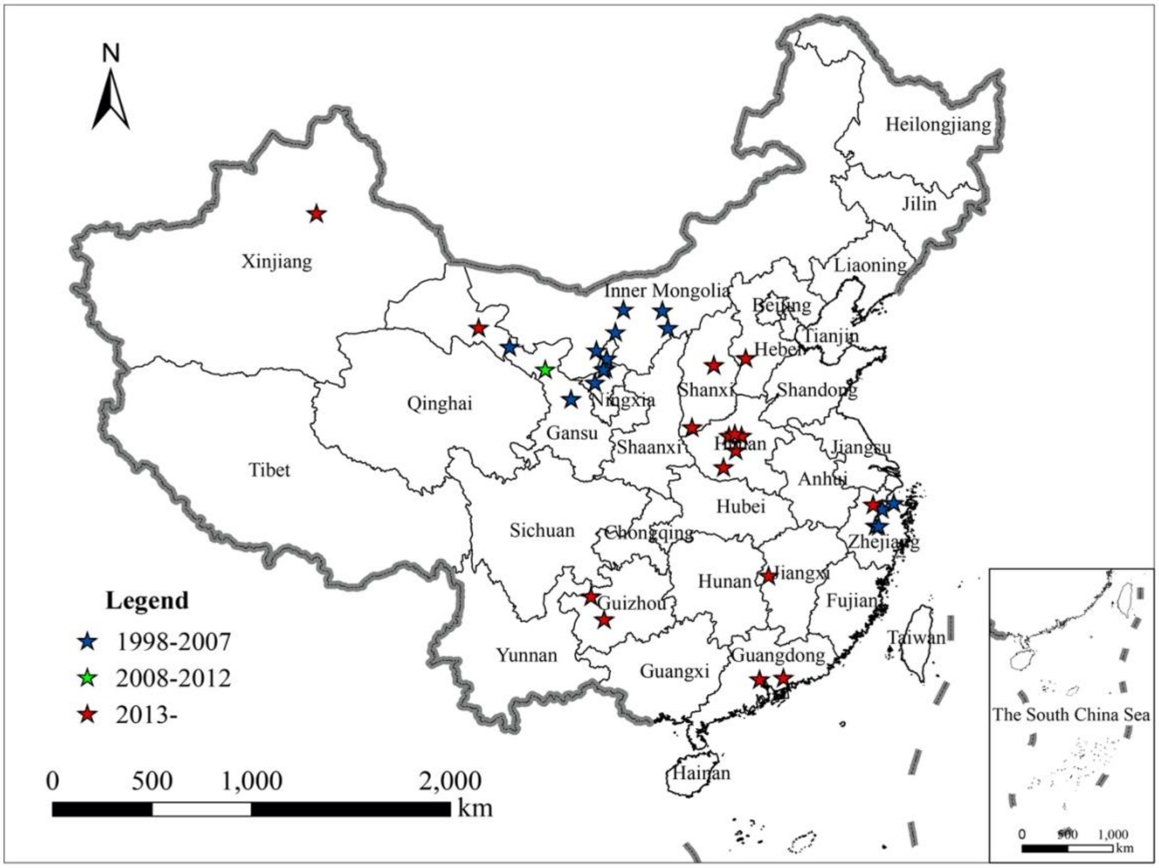
For thousands of years, a distinct feature of Chinese water governance was to allocate water resources through administrative means and address water supply–demand imbalances through engineering projects (Hu and Wang 2000). At the end of the twentieth century, the idea of establishing tradable water rights for more sustainable water use began to influence water policy and politics in China. Scholars divide the evolution of tradable water rights policy under China's hierarchical policy-making system into three distinct periods – 1998–2007, 2008–2012, and 2013 onwards (Jiang et al. 2020). In 2002, the MWR initiated the first pilot project in Zhangye City in Northwest China, designed to establish a tradable water-rights system and to allocate water resources through market-based instruments (Zhang and Zhang 2008).

Following the first trials of water-rights trading, the MWR published three documents between 2004 and 2006 about tradable water right policy, including the guidance on pilot projects in the Yellow River (2004), the Framework for Establishing a National Water Rights System (2005) and the 2006 Regulation on the Administration of Water Abstraction Permits and Water Resources Fee Collection. The government's enthusiasm to implement tradable water rights policy declined during the period from 2008 to 2012, but the decision of the eighteenth third plenary session of the CCP

Central Committee made a difference. The session agreed to strike a balance between state and market and declared that "markets would play a decisive role in resource allocation" (People's Daily 2013). The tradable water rights policy once again became the focal issue of the MWR as the policy was the focus of the eighteenth third plenary session. Subsequently, the MWR launched a nationwide water-rights pilot scheme in 2014 and released the policy document, "Provisional measures on the administration of water-rights trading" in 2016.

Such is the blending of the public and private, market and planning, that observers have begun to recognize Chinese water markets as a hybrid form of governance, a combination of state control and marketization (Jiang et al. 2020). As such, diverse water-rights trading arrangements exist in China's politically centralized system: regional water-rights trading between local governments at or above county-level, water abstraction rights trading from water abstraction permit holders, but excluding urban public water supply enterprises, and water-rights trading between irrigators, namely water users' organizations or individual users of irrigation water with clearly defined water rights (Jiang 2018). Trading can involve reallocation of water from rural regions to corporations and city–city reallocation. Since 2000, tradable water rights policy has spread to more than thirty county-level cities and prefecture-level cities in China (Figure 8).

Figure 8. **Diffusion of tradable water right policy in China, 1998-2019.**



However, while scholars attribute importance to China's national conditions in the practice of water-rights trading (Moore 2015; Svensson et al. 2021; Wang, Shu and Wu 2017), Chinese reformers have looked beyond their country's borders for guidance in designing and implementing water markets over the last two decades. Australia stands out among nations for aiding China with knowledge, experience, and technical support regarding water rights and markets. The first bilateral programme, the water entitlements and trading (WET) project, ran from 2005 to 2007 and focused on establishing a set of arrangements for establishing and managing tradable water rights across the whole country. The second programme in 2007–2012 focused on environmental governance and integrated river basin management in the framework of the Australia–China Environment Development Partnership (ACEDP). Water-rights trading exchanges dominated the third programme in 2018/19 between the China Water Exchange (CWEX) platform and the Australian government's Department of Agriculture and Water Resources (DWAR), as well as Australian business partners (Table 6). The latter two programmes involved a more diverse constellation of actors with more public and private enterprise approaches. Interconnections between foreign and domestic processes prompt the question of how do international policy transfers and domestic forces interact to shape the local adoption of water markets in China?

We attempt to answer this question but recognize that this is not the first study of China's policy transfer and diffusion (Yu and Gibbs 2018; Zhang and Zhu 2019a; Zhang and Zhu 2019b). Indeed, external processes such as international partnerships from west to east have played an important but hidden role in China's economic development in the last forty years (Gewirtz 2017). For example, the CCP adopted Soviet-style central-planning in the 1950s by involving 10,000 Soviet advisers across China "to provide technical and scientific aid to the country's industrial development" (Wu 2019: 27). Nevertheless, the impact of the domestic–foreign interactions on the design and implementation of water markets in China over the last two decades remains unknown. Although there has been a study on water, law, and development assistance programmes between Chile and the United States in the context of neoliberalism during the period between 1963 and 1978 (Bauer and Catalan 2017), the present study focuses on policy transfer around marketization through lines of state-to-state and intra-state processes.

And, this focus on China and Australia is also distinct from the conventional focus on World Bank and other multilateral organizations (Hamilton et al. 2021). This study represents an attempt to leverage the concepts of agency and time to understand how market policies and ideas take root and move in the context of a political regime that is opposite to that of a liberal democracy. We combine these concepts with the transfer framework to understand better why some elements are picked up in the transfer process between China and Australia but not others. We thereby adhere to the call of scholars to integrate the dimension of time (Dolowitz 2020; Dussauge-Laguna 2012; Wood 2015) with foreign policy and development cooperation (Porto de Oliviera 2021; Stone, Porto de Oliviera and Pal 2020) into the policy transfer analysis to enhance our understanding of policy processes. Understanding the dynamics of policy transfers via bilateral development programs between China and Australia offers the possibility to access the different power relations that are embedded in such programs, as well as Australia's positioning in Asia in relation to the re-emergence of China as a major power in the region.

This chapter is organized as follows. Section 6.3 describes the theoretical framework; Section 6.4 presents the methods; Sections 6.5 to 6.7 highlight the evolution of the rise, fall and revival of tradable water rights policy in China and the role of agency and time in the processes, and Section 6.8 contains a critical discussion of the results.

Table 6. Bilateral programmes on water markets and management

Time period	Project name	Funding	Actors
2005–2007	WET Phase 1 and 2	AUD $2.98 million	The Australian Department of Agriculture, Fisheries and Forestry (DAFF), the Australian Agency for International Development (AusAID), Chinese Ministry of Water Resources (MWR)
2007–2012	Australia China Environment Development Partnership	AUD $24.6 million	The National Water Commission (NWC); Department of Sustainability, Environment, Water, Population and Communities (SEWPAC); Department of Agriculture, Forestry and Fisheries (DAFF); Commonwealth Scientific and Industrial Research Organization (CSIRO); Murray–Darling Basin Authority (MDBA) and, observer status Department of Climate Change and Energy Efficiency (DCCEE). Chinese partners were National Development and Reform Commission (NDRC); Ministry of Water Resources (MWR); Ministry of Environmental Protection (MEP) and State Forestry Administration (SFA).

2012–2017	Memorandum of understanding between the MWR of the PRC and the Australian government’s Department of Sustainability, Environment, Water, Population and Communities.	Policy exchange and knowledge sharing were primarily through joint contributions from both parties. AWP (Australian Water Partnership) spent $78,000 on hosting CWEX’s study tour in Australia in May 2018.	DAWR, AWP, MWR, CWEX.

6.3 THEORY

The concepts of policy transfer and diffusion are applied to policy-spreading processes (Minkman, van Buuren and Bekkers 2018: 223). Accordingly, policy transfer is conceived of as a process in which “knowledge about policies, administrative arrangements, institutions, etc. in one time and/or place” is used to develop policies in another time or place (Dolowitz and Marsh 1996: 343). Policy diffusion denotes the mechanisms “that cause a policy to spread from one government to another” (Shipan and Volden 2008: 841). In the realm of environmental governance, scholars have employed a policy transfer perspective to study the following – the transfer of water management from Australia to Vietnam (Malano, Bryant and Turral 1999); water management councils’ choice of scientific models in the USA (King, Burkardt and Clark 2006); urban environmental policies from Germany to the United States (Dolowitz and Medearis 2009); watershed-based management entities from Australia and the United States into Canadian states (Michaels and de Loë 2010); water governance institutional arrangements between Australian states (Swainson and de Loë 2011); and the transfer of Dutch delta planning expertise to Bangladesh (Hasan, Evers and Zwarteveen 2020). Several studies have also identified the mechanisms behind the spread of river basin organizations in the global water discourse (Mukhtarov and Gerlak 2013); the birth and spread of integrated water resource management (IWRM) (Allouche 2016); and the diffusion of community-led total sanitation (CLTS) in South Asia and sub-Saharan Africa (Zuin et al. 2019). To this end, explanations for the transfer and spread of policies range from biophysical attributes and institutional contextual factors to political culture and ideology. However, few have focused explicitly on the role of actors and how they matter temporarily in the policy transfer process, especially regarding decisions to use market mechanisms instead of non-market mechanisms (Dolowitz 2020).

In this chapter, we outline a transfer framework (Figure 9) that captures the connection between actor interaction and time. We focus on actor interaction because the interaction of actors and the structures surrounding the transfer process often shape the selective adoption of a particular model. Besides actor interaction, the rationale for focusing on time is that the processes of transfer take time and actors may be able to manage temporal aspects, both in terms of the timing of events and/or the tempo of the policy transfer (Dolowitz 2020; Dolowitz, Plugaru and Saurugger 2020; Dussauge-Laguna 2012; Wood 2015). Closely related to actor interaction is power. Dolowitz (2020) has listed four faces of power that shape policy transfer. The first is the ability of A to achieve compliance with B, which changes how B behaves because of the power being exerted. Following Bachrach and Baratz (1962), the second face of power refers to agenda setting and the ability to control the context within which policymaking processes are made. The third is the ability of A to influence B in ways of which B is unaware and that are against B's interest. Finally, the fourth face of power is, as Dolowitz (2020: 571) suggests, "where agents work together or are embedded in supportive structures (in coalitions or networks) that enhance the power of all members of the coalition".

The first block in the framework is *process design.* Actor relations play an essential role in policy adoption (Minkman, van Buuren and Bekkers 2018). In a recent study on China's national birth control policy from 1980 to 2015, Li and Wong (2019) found that advocacy by two expert-led minority advocacy coalitions can partly explain policy change. Besides, a hierarchically superior jurisdiction, namely the most senior party leaders, imposed the significant policy changes of 2013 and 2015. Organizational arrangements can take different forms, involving formal and informal interactions between those involved in the transfer process. The ability of policy-making participants to form coalitions and engage key actors is essential to the process design. Key individuals, such as policy entrepreneurs and transfer agents (Stone 2004), can control and utilize the knowledge at different government levels to shape policy adoption. Actors can speed up and/or slow down the movement of policies (Wood 2015) and, in China, the central government can set the tempo of change through pilot projects and by tying financial transfers to local implementation (Eaton and Kostka 2018). Therefore, we believe that actors and their strategies play an essential role in moving tradable water-rights policy from one setting to another.

From the source actor's perspective, we also believe that the reputation of Australia's water market has been crucial in mobilizing the policy for transfer abroad. Policymakers pay attention to policies proven effective elsewhere and may be more willing to adopt a policy from another jurisdiction when perceived as successful (Metz and Fischer 2016; Ovodenko and Keohane 2012). For example, Minkman and van Buuren (2019) have shown that, as a form of development cooperation, the "Dutch Delta approach" (DDA), which the Dutch government used as an export product to help countries update their delta management, became an international label.

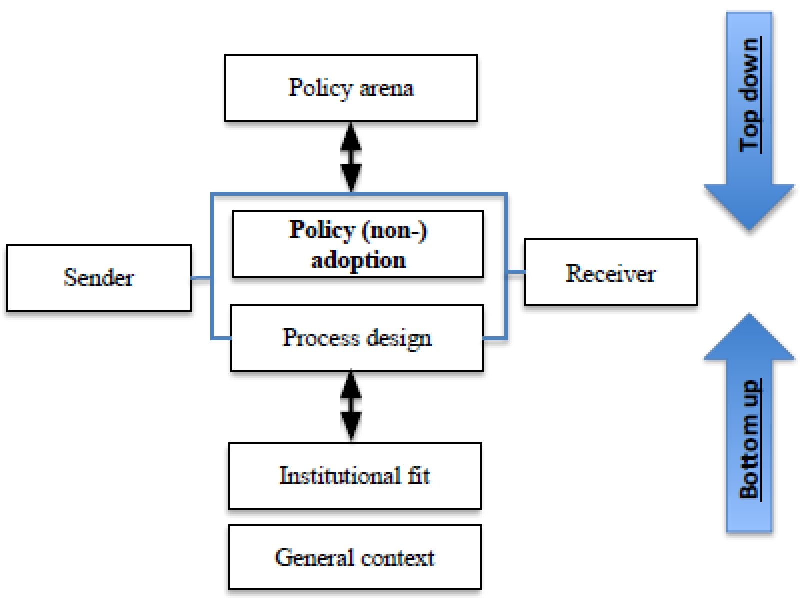
The second block of the framework, *the policy arena*, is widely cited in the literature and is important to the policy transfer process. Linked to timing, the political climate can open or close a window of opportunity (Busch, Jörgens and Tews 2005). A change of government can alter the policy arena in beneficial ways and open up a transfer process (Delpeuch and Vassileva 2016). Still, it can also put an abrupt end to completed transfers (Dussauge-Laguna 2012). Time, on the other hand, is "the period through which a transfer occurs and the time it takes the transferred information to enter and work its way through the policymaking and implementation processes" (Dolowitz 2020: 577). As Dolowitz noted, the more control and better positioned actors are in the policy process, the more likely they are to move forward with a preferred policy model as planned (Dolowitz 2020: 452).

The third block concerns *institutional compatibility*. Policy transfer is conditioned by the compatibility of the transferred policy, both in terms of integrating the policy in institutional arrangements and its ability to fit with existing policy instruments (Minkman, van Buuren and

Bekkers 2018). When the institutional fit is high between source and receiving jurisdictions, there is a greater likelihood that transfer will be appropriate and successful (Michaels and de Loë 2010). Policy decisions made in the past can generate path dependency. Under these circumstances, policy paths can be challenging to reverse and facilitate the transfer (Gullberg and Bang 2015) or impede the transfer from changing the policy course (Zhang 2012).

The final block of the framework addresses the *general context* in which the policy transfer takes place. The transferability of a policy from one setting to another within the domain of environmental governance is dependent on similarities in biophysical settings (Malano, Bryant and Turral 1999; Plummer and Hashimoto 2011; Swainson and de Loë 2011).

Figure 9. Framework for analysis of policy transfers in China



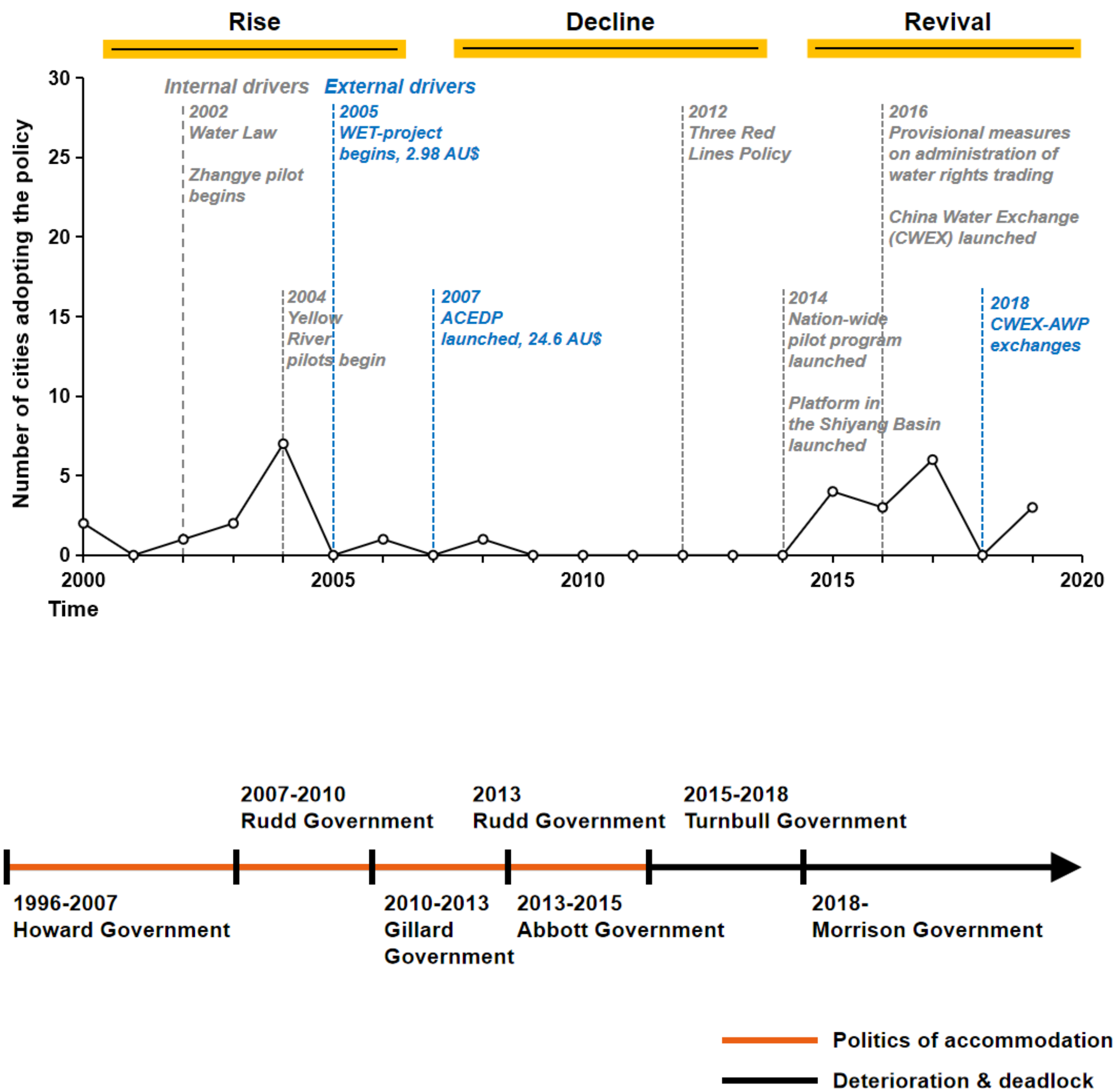
6.4 METHODOLOGY

For an actor, the structure constitutes the factors that shape the number and characteristics of the action alternatives. For different types of actors, such a structure can mean both obstacles and opportunities. As Karl Popper (1972) noted, a main purpose of social science research is to "trace the unintended social repercussions of intentional human actions” (quoted in Falkemark 2006: 39). According to Popper, the unintended consequences of the actions of previous actors significantly shape the social situation facing an actor (Falkemark 2006: 40). The analytical framework in this study calls for a method that can allow us to understand the sender and receiver and patterns of interactions, outcomes of interactions, and the perception of the interactions from both sides of transfers. To do that involves a process-tracing approach combined with both archival sources and interviews.

According to Bennett and Checkel (2014: 6), process tracing is “the examination of intermediate steps in a process to make inferences about hypotheses on how that process took place and whether and how it generated the outcome of interest”. In this study, process tracing is a qualitative analysis strategy, and it offers an evidence-based explanation of the rise, fall and revival of tradable water rights policy processes in China. Data collection concerns each block of the framework. It relies on the interactions between the sender and receiver and the evidence of those interactions from meetings and financial exchanges. Also, it involves perspectives and perceptions of those interactions and the outcomes of interactions based on interviews. Archival sources include programme reports and evaluations, letters written by officials as well as peer-reviewed articles.

We operationalized the theoretical framework by translating the abstract factors in the framework into interview questions (Appendix). Thus, the sampling aimed to document diverse variations in perspectives and perceptions and to identify common patterns between them (Creswell 2007: 127). The lead author held 12 semi-structured interviews with senior Australian and Chinese government officials, scientific experts, and Australian private-sector consultants (Appendix). Interviews typically lasting 90 minutes were held, and the respondents were selected by using snowball sampling, with seminal reports and the list of stakeholders in those reports used as a starting point for exploring actors and capturing interviews from both the senders and receivers of policy. Besides, the main author interviewed two leading scholars on water markets in China. All interviews were transcribed, and a written summary report created that the respondent reviewed to confirm statements. Our analysis used three-time series of major policy events between 1998 and 2019 based on a study by Jiang et al. (2020), during which the high-level approach to water management shifted (Figure 10).

Figure 10. Key internal and external drivers of tradable water rights policy in China over time



The analysis relied on a semi-structured approach to the process-tracing to identify a critical juncture in each stage of the three periods. Here, we broke down and compared the framework elements in those periods and used the interviews to illustrate and substantiate our findings. Also, key meetings, financial flows, and statistical data from the China Water Exchange (CWEX) were used to link the literature to the adoption of tradable water rights policy. We used triangulation to ensure the validity of the different interviews and archival data. Although the outbreak of the coronavirus prevented us interviewing officials from various local governments in China, most of the interviewees had already interacted with local officials and one of us has extensive experience of working with both the MWR and local governments on tradable water rights policy. A further limitation was that the framework elements failed to represent the full diversity of China. We acknowledge this limitation but at the same time recognize that the elements of the framework complement the dominant diffusion mechanism perspective in the literature.

6.5 THE RISE OF TRADABLE WATER RIGHTS POLICY (1998-2007)

In this section, we examine two documents (WET 2006; WET 2007), combined with two letters and eight interviews (AC1; AC2; AC3; BC2; AG2; CC1; CC2; CG1) to show the role that the location of powerful actors, time and timing play in explaining the rise of tradable water rights policy, particularly the role of water rights reform, which was the main feature between 1998 to 2007.

The emergence of flooding and drought issues between 1994 and 2000 signalled the beginning of having to rethink the human and water relationship. As early as 1999, the then water minister Wang Shucheng introduced the idea of shifting from traditional "engineering-oriented water resources development" towards "resources-oriented water resources development" (Wang 1999). He used his authority to frame activities in forums at the central level around explaining market mechanisms and mobilizing political support. The minister's new concept inspired many workshops, publications, and research projects in China on water rights, markets, and pricing. As a former senior MWR official (CG1) put it:

I started to work for the MWR in 1998 and I translated a book from America called *Water Pricing and Water Market* from English to Chinese. Wang Shucheng came to the MWR and thought we needed to pay more attention to water rights and the market for water management. It rose from 2002 and went down from 2007.

A book from Australia on water entitlements was also translated into Chinese. As another key informant from the MWR (CC1) put it: "in 2001 an Australian book called *National Approach to Water Trading* was translated into Chinese. These experts thought that this book could be relevant to the Chinese water market and water rights development."

In October 2000, Wang Shucheng delivered a speech entitled "Water Rights and Water Markets: Economic Measures for Achieving Optimal Allocation of Water Resources" at the annual conference of the Chinese Hydraulic Engineering Society (CHES), where he called for the adoption of tradable water-rights policy. A month later, two cities in Zhejiang province, Yiwu and Dongjiang, implemented an interregional water-rights transfer agreement (Jiang 2018: 58). Together, water rights at both macro and micro levels and water-rights transfer to promote optimal water resource allocation formed the core of the government's effort to develop a "water-saving society" (Wang 2001; Wang 2004). In this period, the 2002 Water Law updated the law of 1988 by incorporating water rights and the water resources conservancy strategy put forward by Wang Shucheng. This led the MWR to undertake a pilot project in Zhangye, Gansu province, to establish water-rights trading between farmers. Furthermore, jointly with local governments the YRCC launched inter-sectoral trading schemes in Ningxia and Inner Mongolia (Jiang 2018: 92). However, since Wang Shucheng was at the time gradually moving the idea of tradable water rights into the policy arena, the exploration on developing and implementing a water-rights system in China was more theoretical than real (CC1; CC2; CG1).

Water entitlements and trading (WET) project phases 1 and 2, 2005–2007

Although elements of a water entitlement system were in place, such as duration-based water rights (Zheng et al. 2012), they were scattered on a case-by-case basis and applied in an ad hoc manner rather than as a comprehensive system. Yet, there was growing recognition that over-allocation, pollution, and the absence of environmental flows in the river systems were created a pressing need for a new planning process to start driving water allocation issues in a new direction. However, according to one respondent, the Chinese government at the time "did not know how to move forward" (CG1). The Chinese government believed that Australia was better placed than other countries to teach it about tradable water rights because, as one interviewee explained, Australia "had built a completed house and were the first to pay attention to environmental flows" (CG1). At the international level, Australia's recognition of China's market economy status in 2005 highlighted the Howard government's accommodation policy towards China (He 2012: 69). Besides, the biophysical similarities between China and Australia in dealing with arid conditions and highly variable rivers that drive the allocation systems were well recognized at the time (AC2; AC3:AG2; CC1; CG1).

Meanwhile, in 2005, the Chinese government reached out to AusAID, which, with its new approach to its aid programme, was seeking "to provide assistance focused on governance issues rather than infrastructure construction or management projects" (SunWater 2006). In these discussions, the Chinese government was seeking assistance in putting together a set of arrangements for establishing and managing tradable water rights across the whole country. As a former senior official and MWR negotiator explained, "we wanted the experience from them and to work with them to find which principle can be used. We knew before the cooperation that we needed to do something about water rights definition and clarification, but we were not sure at that time how to do it" (CG1). Because the federal government believed that Queensland had a better track record of putting together a comprehensive framework than any other Australian state (AG2), in 2005 the then Department of Agriculture, Forestry and Fisheries (DAFF) engaged a former official and water consultant from

Queensland to help the Australian government design an aid project that would achieve these objectives.

The Australian negotiator from Queensland who wrote the proposal (AG2), explained that:

> the deal was that they did not want us to walk in and say this is the answer for you. They wanted to develop a system for them with our assistance and guidance. It was their working group, and they had major drivers to make it happen, but working through Australian principles and elements.

Accordingly, a team of experts nominated by the Chinese MWR and two Australian advisers from Queensland structured the project. An Australian panel of four members, three of whom were Queenslanders, was formed to give the project the best possible advice (SunWater 2006). Through a sense of political delicacy, the Australian negotiator from Queensland selected someone from Victoria to chair the panel and to minimize the impression that "Queensland was running the whole world" (AG2). The Australian team's involvement in the project was – according to one key interviewee – to remind the Chinese members "not to throw that bit away because if you throw away one of the elements of the building blocks you will have no house. You have to put the bits together" (AG2). As one team member explained, "the one we recommended in China was really about having a reallocation system where you can reallocate in a transparent but also accountable way that minimizes negative impacts" (AC2). However, neither the Chinese nor the Australian sides knew what would happen before starting the engagement and what principles would best fit China's circumstances and requirements (AC2; AG2; CC1; CC2; CG1).

Subsequently, in 2006, with AusAID support, the Chinese MWR and the Australian DAFF jointly launched phase 1 of the WET project when, according to one informant (CC2), both countries were "in a honeymoon relationship (蜜月期)". Between April and July, the working group reviewed the current systems, laws and practices in China related to water entitlements and trading. In addition, the team conducted extensive site investigations in Zhejiang, Fujian, Jiangxi and Gansu provinces, Ningxia Hui, Xinjiang Uyghur and Inner Mongolia autonomous regions and Tianjin municipality (WET 2006). Indeed, bottom–up insights from site observations and brainstorming were instrumental in designing the water rights framework (AC2; CC1; CC2; CG1). One Chinese team member commented that, "pilot projects matter, and we needed some bottom–up approach to summarize the experiences for the national level" (CC1). In the words of another key informant (AC2),

> we started off by mapping out that there are long-term allocation decisions, but then there are short-term, annual allocation processes that happen under that. Then there are also allocations happening at multiple levels. We started to pull out those levels spatially and temporally and how those allocation decisions are made. It was a pretty fluid process, but it was an unstructured process.

In September 2006, eight senior officials from the MWR, the Ministry of Finance, and other water-related departments in Zhejiang and Inner Mongolia embarked on a 12-day study tour of Australia to witness the operation of the country's water-trading and water-delivery services first hand (WET 2006). The project was completed in November 2006, and phase 2 to test the proposed framework in two provinces, Zhejiang and Inner Mongolia, began in March 2007 (WET 2007). In Inner Mongolia, the WET phase 2 focused on defining and allocating water rights in Hangjin Irrigation District on the Yellow River. With MWR consent, the Chinese–Australian team developed a more scientific, technically robust way of allocating water to user groups and individuals under the cap that the irrigation district's authority had been giving. The cap for Hangjin was cut to reflect "savings" made by the channel-lining programme on the grounds that the irrigation returns saved could be reallocated to downstream users (BC1). The WET team, by contrast, used a Queensland quality/quantity water-planning model to demonstrate environmental flows in the Jiao River in Zhejiang province. However, it was not quite ready to implement, so was more about showcasing the steps of the WET system in a Chinese context (AC1; AC2; AC3).

Results of the WET project

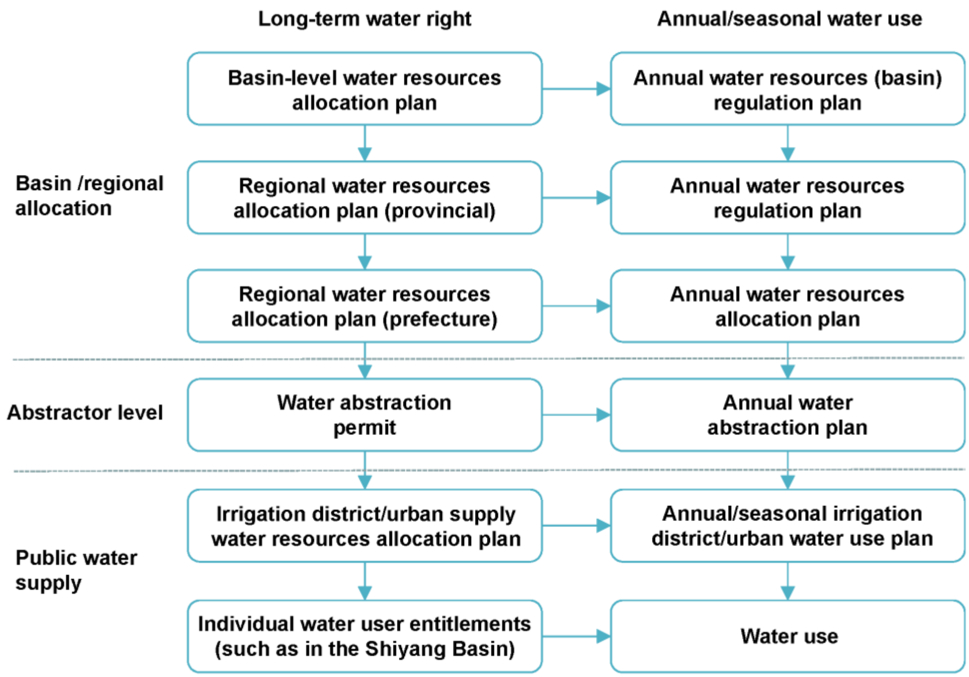
During the summary of the WET phase 2 project, in December 2007, the director-general MWR's Department of Water Resources Management (2007) sent a letter (MWR 2007) to the deputy secretary of the Department of Environment and Water, the director-general of Queensland's Department of Natural Resources and Water, and to the counsellor of AusAID in Beijing to the effect that,

> the water rights development framework outlined through the project provides a solution to many key issues in China and will play a significant role in promoting water rights all over China. The WET project concepts have been adopted in the work of legislation for water abstraction permitting and in the design of water abstraction caps. The project reports on water resources allocation planning and environmental flow management provide a sound framework and methodology, and will also be integrated into national-level water policy by my department.

A key former Chinese official on these matters responded by saying that, "after the project we broke through the wall, and everything was clear" (CG1).

In summary, the programme developed a framework that has guided the water-rights trading system in China. The elements of annual water rights and planning, as well as of long-term rights and planning, were based on the Queensland policy and experience and adopted across three levels (Figure 11). In addition, exposure to the WET project's phases 1 and 2 had a major impact on the professional development of the Chinese team members involved, who afterward worked to develop China's water entitlement and trading system. As a key informant (AC2) stated, "learning from the Australian experience through study tours and the collaborative policy development process set them up to be leaders over the subsequent 10+ years in driving public partners and other processes as well as refining parts, building onto and discarding parts. They took ownership and drove things forward."

Figure 11. Framework for water entitlements and allocations in China



Source: Adopted from the WET (2006) report.

6.6 THE FALL OF TRADABLE WATER RIGHTS POLICY (2008–2012)

Drawing from interviews (CC1; CC2; CG1), our analysis in this section suggests that a decline in the tradable water-rights policy defined the 2008–2012 period, and that the chief mechanisms responsible for it were domestic, and caused mainly by a changing constellation of MWR actors and their shifting preferences in the policymaking process. Furthermore, we analyse one key document (Hancock and Xiubo 2012), and use qualitative interview data (AC1; AC3; AC4; AG1) from officials and consultants to show that structurally embedded competition in the Australia China Environment Development Partnership (ACEDP) caused an impasse in the policy transfer process. Based on a project document (Tsinghua 2012), original research (Lewis and Zheng 2019) and an interview (CC2) with a key project manager, we also show that a group of scientists from Tsinghua University successfully embedded themselves into the policy process in Gansu province to implement a water market in the Shiyang River Basin based on experiences in Victoria, Australia.

When the minister of water resources Wang Shucheng retired in 2007, the core team of the MWR's Department of Water Resources Management began to formulate water allocation plans and to develop water abstraction and water-use control indicators for more than a hundred rivers. As one informant (CG1) explained, "we prepared the No 1 central document in 2009 and that needed a lot of time. We drafted it by the end of 2008 and then started working on the 'three red lines' policy, which was promulgated in 2012." Between 2008 and 2012, however, as a result of changes within the Chinese polity and economy, the tradable water-rights policy attracted less government attention and the tempo of the reform slowed down. In the words of the same informant (CG1),

> the economic boom that China experienced from 2003 to 2010 changed and slowed down. The framework was clear, and the water rights and market were not as pressing as before. Between 2011 and 2012, there was also a political transition time both at the higher and lower levels of government.

Notably, senior leaders who had played critical roles in incorporating market-based mechanisms into the administrative allocation system left the MWR, including an important policymaker behind the 2002 Water Law in China, who retired in 2009, and a high-level official who moved to another organization in 2011. In addition, the new MWR leadership, which assumed control of decision making in 2007, opposed the state-led, market-based approach to managing water resources (CC1; CC2; CG1). As one informant (CC2) explained,

> the leaders thinking matters in China. The new ones of the MWR did not want to continue with the tradable water rights policy and preferred the original government-led administrative system. The road map was not clear just as like what is happening in Australia now with the Murray–Darling Basin crisis.

As the constellation of actors and their preferences changed within the MWR, the number of cities adopting the policy decreased between 2008 and 2012 (Figure 10).

Australia–China Environment Development Partnership (ACEDP), 2007–2012

Alongside developing the three red line policy, referred to as the strictest water resources management system, the Chinese government continued collaborating with its Australian counterparts and launched the Australia–China Environment Development Partnership (ACEDP) in July 2007. The transition from the WET project to the ACEDP was originally conceived of in terms of broadening cooperation between Australia, the MWR and the MEP (AC1; AG1). AusAID agreed to fund this comprehensive programme for five years until 2012, with environmental governance, integrated river basin management, and programme management as its core components. China's Ministry of Water Resources (MWR) and Ministry of Environmental Protection (MEP) were primarily interested in and led the activities associated with river health and environmental flows. Accordingly, river health and environmental flow assessments were undertaken in the Pearl, Yellow, and Liao Rivers with a view to developing a national framework for environmental flows. Under an Australia–China legal development programme, significant training activities had been carried out to improve the capacity of Chinese water managers (Hancock and Xiubo 2012), but despite planning to run the partnership as a joint exercise, the ACEDP in the end ran the two activities in parallel. In the words of one informant (AC3), "the moment you tried to organize a senior meeting for a senior director for the MWR, it was difficult to get someone senior from the Ministry of Environment to turn up."

Initial implementation and expenditure of ACEDP was slow due to the lack of an overarching context for the programme combined with a lack of a common understanding of objectives among core partners. An independent progress review completed in 2010 highlighted several design factors that contributed to limited progress and delays, including the contractor/sub-contractor model, limited analysis of context, and limited integration of lessons from previous experience into the design

(Hancock and Xiubo 2012: 6). One respondent (AG1) stated that “a lot of the resources went to the managing partner and not many went to the actual project itself. A lot of the focus was on research and really not implemented and not focused on practicality.” At the heart of this was the conflict between the facility approach desired by AusAID and the technical assistance approach pursued by the private managing contractor GHD Ltd. Despite that, AusAID had to force changes on GHD Ltd, for the long lead times and high costs associated with contracting in the initial phase meant that much of the implementation was locked in before the focus was reaffirmed. As a result, the initial phase of ACEDP generated competition between the Chinese partners (Hancock and Xiubo 2012: 10) and, according to another interviewee (AC1), the programme “lost momentum and interest from counterparts when trying to determine new activities”.

During this period, the ACEDP also supported a joint Tsinghua University, China Institute of Water Resources and Hydropower Research, and University of Melbourne project called “Integrated Watershed Management: Managing the Threat of Sustainable Water Development”. Marked by their similarities in biophysical conditions, the programme aimed to strengthen China’s ability to respond to water shortage crises in its inland river basins by transferring Australian experience and technology to the Shiyang and Shule rivers in Gansu province. Prior to the project, scientists from Tsinghua University, who had taken part in phases 1 and 2 of the WET projects, had designed a water resources allocation plan for the Shiyang River in north-western China, which complied with the Water Law of 2002 and which the State Council approved in 2007 as part of a restoration plan for Shiyang River Basin (Gansu WRD and DRC 2007; see also WET 2006). One Chinese team member played a mediating role in instituting rights to water for each farming household in the Shiyang River Basin. Through face-to-face interactions with six mayors of Wuwei at the prefecture–city level, and high-ranking officials at the provincial level, the scientist showcased and explained hydrological models to build support among decision-makers. According to the scholar (CC2), the strategy was in every case to have a model behind the river basin planning to make it very robust. All the scenarios were analysed. Then, we used this to communicate it to the local officials to explain what would happen if they followed a certain trajectory. You have to involve their thoughts in the model. You should have the ability to translate their thoughts into mathematics.

Subsequent to the WET project's phases 1 and 2, joint collaboration with the University of Melbourne started for a year in 2010 with the focus on producing a comparative analysis of river basin conditions; assessing and advising the pilot sites on modelling approaches; and reviewing the application of water permits and markets for China (Tsinghua 2012: 1–5). More specifically, the team designed and applied a water-rights trading platform in the Shiyang River Basin. The water market in the state of Victoria, Australia was embraced because it was – according to the project report – perceived as "having 20 years of practical experience" and "the operation mechanism, operation method and management platform of its water rights transaction are worth learning from for our country" (Tsinghua 2012: 83). Besides, a pilot system for accurate measurement and control of water resources in the Shule River Basin was developed with Rubicon Water, a privately held company headquartered in Melbourne. Attempts to install automated control and measurement devices in the Shule River Basin from Australia were thought necessary because "accurate, intelligent and automated water monitoring is a strong guarantee for operating the Australian water rights management and water markets" (Tsinghua 2012: 79). A private company executive who works with Tsinghua University in Gansu and Ningixa provinces to automate the delivery of water at the farm level stated that, "decision-makers are always worried about what happens if all of these demonstrations fail. They need backup support with solutions and that is where Professor X comes in to persuade and give decision-makers confidence in how to manage the water with all the measurements in place" (ACP1).

The policy transfer process involved Chinese participants organizing a field trip to northern Victoria, Australia, from 28 August to 8 September 2011 to learn about water-rights distribution and the operational process of water trading. Likewise, Australian experts visited the Shiyang and Shule rivers between 7 and 11 March 2011. Accordingly, Tsinghua University applied the ideas and policies that the Waterpool Co-Op, a major water-trading broker in Victoria, Australia, had devised, albeit with modifications to suit the geographical and cultural context of Gansu province. The process design included site selection, field survey, design of trading rules, development of an online platform, data loading and update, training activities and application, and trading results and feedback from stakeholders (Tsinghua 2012). At Tsinghua, an online platform was designed and applied in 2014 in two irrigation districts, Xiying, a gravity surface water irrigation area, and Qingyuan, a groundwater irrigation district. In this context, scientists from Tsinghua were involved in funding and organizing workshops in which to teach WUA leaders how to increase the knowledge and ability of farmers to participate in the market by using the online platform. With a view to finding out about local situations and encouraging the take-up of water trading, for a week in 2013 and again in 2014, the project managers invited a former key official, with nearly twenty years' experience of being in charge of water trading in Victoria, to sit in on the meetings being held with basin officials and farmers (Lewis and Zheng 2019).

Results of the ACEDP project

Both the respondents (AC1; AC3; AC4; AG1) and the independent evaluation report of the ACEDP project pointed out that the ACEDP project lacked focus on practicality, and that a lot of resources were being spent on managing national-level partners who were competing for funds. Although the independent evaluation report stated that "there was some policy impact through the No. 1 Document of 2011 – Decision from the CPC Central Committee and the State Council on Accelerating Water Conservancy Reform and Development" (Hancock and Xiubo 2012: 2), the respondents failed to indicate whether and how the ACEDP influenced China's policy development.

Nonetheless, the influence of the "Integrated River Basin Management" component has been noticeable in China. In summary, the Shiyang River Basin selected and adopted all the elements of the Waterpool Co-Op, except for its bidding process, which faced geographical and cultural constraints. Compared with Australia, the platform's water use, and trading account could only be updated manually, and the financial and credit systems were not linked to the platform in the Shiyang Basin (see also Appendix). Because of the conservative nature of rural culture, paper contracts with signatures, seals, or fingerprints were necessary to confirm the water trades and only the current year's water allocations could be traded (Lewis and Zheng 2019). Between 2014 and 2017, the platform became a useful tool for local WUAs and water authorities, for each user had a separate water account containing annual water allocation information, as well as evidence of the amount of water used, traded and the balance. China's first online water-trading platform is widely regarded as a milestone in China's water rights reformation (CC1; CC2; CC3; CC4). The selective transfer of a key model can be explained by a dominant group of scientists who engaged in learning from Victoria and then integrated lessons into the policy processes in Gansu province.

6.7 THE REVIVAL OF TRADABLE WATER RIGHTS POLICY (2013–)

In this section, we provide an explanation for the revival of a tradable water-rights policy. The power of the CPC's decision-making agency moved the idea to the MWR, which took advantage of tempo to control the policy process. The MWR assisted the spread of tradable water-rights policy through running pilot programmes and by establishing a national level water-trading platform, the CWEX. Based on documents (AWP 2018a, 2018b; DFAT 2017) and interviews (ACP1; AG1; CC1; CC2), we also demonstrate that no policy transfer was initiated between Australia and China during this period. For Australia, we observe a shift from accommodation to competition with China.

Under Xi Jinping's leadership, during the third plenary session of the eighteenth CPC Central Committee on 12 November 2013, the Central Committee paved the way for a renewed interest in water markets by announcing that it would let the market play a “decisive role in resource allocation”. Spurred by the central government’s market preferences, the MWR announced a nationwide water-rights pilot scheme to scale up previous local-level pilot experiences to build a national trading system (CC3; CC4; MWR 2014). Pilot programmes were subsequently launched in seven provinces. These focused on verifying and registering water rights in Ningxia, Jiangxi, and Hubei, and on various forms of water-rights trading in Inner Mongolia, Henan, Gansu, and Guangdong (Jiang et al. 2020). Moreover, in June 2016, the MWR and Beijing government jointly launched the China Water Rights Exchange Company Ltd (CWEX) in Beijing to promote water-rights trading across the country. Indeed, insights from the local trading platform in the Shiyang River Basin were transferred to the central level. Accordingly, Tsinghua University shared the knowledge and techniques of the platform with the national water-rights trading platform. As a result, CWEX employed the framework, the structure of the database, and the online trading platform interfaces in the Shiyang River Basin (see also Appendix).

Water-rights trading exchanges, 2018–2019

Although Australia stopped funding joint research activities on water markets in China after 2008, water markets remained a continuous and ongoing topic of discussion in every high-level policy dialogue under the memorandum of understanding (MoU) between the two countries (ACG1). In mid-2017, the MWR directed CWEX, the water markets’ operational agency, to contact the Australian Department of Agriculture and Water Resources (DAWR). At that time, Australia had established the Australia Water Partnership (AWP) in 2015 under the Department of Foreign Affairs and Trade (DFAT) to facilitate overseas demand for Australian expertise and service in water management. As a 2017 Australian government foreign policy White Paper stated, “Australia is a leader in water management. We will share our water management expertise to help enhance agricultural productivity, improve health outcomes, strengthen economies and reduce poverty. … We have also established a $20 million Australian Water Partnership to share Australia's water sector expertise internationally" (DFAT 2017). The AWP emphasizes partnerships and has upgraded its ties with Southeast Asian countries, which has grown out of Australia's increased diplomatic attention to ASEAN to "support a balance in the Indo-Pacific favorable to our interests and promote an open, inclusive and rules-based region" (DFAT 2017: 4).

Nevertheless, the DAWR directed CWEX to AWP, which asked for a study tour in Australia to acquire a better understanding of the mechanics and economics of water markets (ACG1; AG1). CWEX wanted to identify a partner, or equivalent agency in Australia, with a view to establishing a long-term mechanism for continuing cooperation and collaboration. Between 14 and 18 May 2018, the International Centre for Excellence in Water Resource Management (ICE WaRM), Marsden Jacob Associates, and the DAWR organized a comprehensive study tour for CWEX delegates. Nineteen Australian and eight Chinese participants took part in it. They learnt about (1) water-rights trading methods and practice in each Australian state and in the Murray–Darling Basin; (2) the operation of electrical trading systems; (3) how water is delivered after trades occur; (4) how water-use data are captured and water users and regulatory agencies informed of it; (5) the role of government agencies in the marketplace; and (6) and the profitability of water trading for market participants (AWP 2018a: 3). In May 2019, the DAWR visited CWEX and the MWR, which agreed that the water market would continue to be a priority based on the existing MoU (ACG1; CWEX 2019a).

Results of the water-rights trading exchanges

In terms of impacts, the study tour exposed the CWEX delegates to Australia's water rights and trading systems and gave them some idea of what a long-term relationship in which China and Australia shared information and experiences might yield (AWP 2018a: 12). According to a senior member of Marsden Jacob Associates, the tour was important "not only for the higher-level exchange of policy across a variety of important economic and environmental areas but also in terms of business-level knowledge and technology exchange" (AWP 2018b). However, neither the interview respondents (ACG1; AG1) nor the AWP performance evaluation were able to attribute specific outcomes to the study tour or organize a return visit by Australia.

Nonetheless, both countries were successful in jointly securing international support for adopting new ISO (International Organization for Standardization) standards on water-efficiency labelling and testing. However, although there appears to be a commitment to collaborate further on the development of water markets, there has been no high-level water policy dialogue between Australia and China since 2015 (ACG1). Informants have come up with several explanations for why this should be the case. For instance, in 2017/18 China underwent massive government restructuring, and organizational restructuring following Australia's election in 2019 put the country on hold. Furthermore, several informants pointed to a deterioration in Australia–China relations in recent years, which has affected the progress of agreed priority engagement activities (ACP1; AG1; CC1; CC2). As one key informant (ACG1) stated, "the vice-minister-level visit or high-level policy dialogue could not be proceeding in the foreseeable future as planned, but at the technical or subject-matter level, we still work very well. In China, the central government endorsement is crucial for engagement between counterpart line agencies."

6.8 DISCUSSION AND CONCLUSION

The objective of this study has been to explore the underlying internal and external drivers associated with the rise, fall, and revival of tradable water-rights policy in China. Its contribution, which is based on a combination of interviews and documentary evidence, is to area studies on China and policy transfer research more generally. First, it fills a knowledge gap about how market ideas, or decisions to use market mechanisms, take root in China, which is an aspect of power on which Dolowitz (2020: 594) has failed to elaborate. Initially, Minister Wang Shucheng took advantage of timing, occasioned by a series of environmental crises in 1998, to place his idea of tradable water-rights policy on the policy agenda. Accordingly, he shaped the discourse and promoted the idea at the Chinese Hydraulic Engineering Society (CHES) and other policy-related forums. Building on his position as the minister of water resources, he remained in power for a long time (1998–2007), so could actively work to guide his idea through to its final policy implementation. This finding supports existing arguments that the power of agents depends on their ability to remain in the policy process for extended periods (Dolowitz 2020; Dolowitz, Plugaru and Saurugger 2020).

However, between 2008 and 2012, the number of cities adopting the policy decreased. The entry of new actors into the MWR's decision-making process brought ideological preferences that altered the policy arena. The new minister of water resources, Chen Lei, as well as other high-ranking officials, favoured the administrative (re)allocation of water rights at the expense of market mechanisms. In 2013, however, the central government reinstated the tradable water-rights policy and moved its preferences instrumentally to the MWR. Subsequently, the MWR made active efforts to speed up the pace of adopting a tradable water-rights policy by selecting pilot provinces, and by establishing a national-level water trading platform. From 2013 onwards, the adoption of the policy accelerated. This finding supports the argument that powerful agents use tempo to control the movement and transformation of a policy (Dolowitz 2020).

Second, we contribute to the understanding of the role of bilateral (China–Australia) and international relations through the selective adoption of policy models from one context to another. Here, the set-up of the knowledge exchange process and the location of powerful actors in the WET project (2005–2007) stand out as relevant to an explanation of why the bilateral programme contributed to a national water-rights framework, and why elements of annual and long-term water rights were adopted from Queensland, Australia. Consistent with the literature (Minkman, van Buuren and Bekkers 2018: 232), the WET project's process design demonstrated a mutual understanding and adaptation of values and practices among the Chinese and Australian team members. In short, one former Chinese official (CG1) summarized the key features of the WET project as, "for a good project, you must do it with the right person at the right time at the right place. The Australians and Chinese had the same vision about the national water rights framework." Another Chinese informant (CC1) claimed that:

> the consultant teams in Australia and China had very good communication with the local governments. You must discuss with local experts on equal levels based on their knowledge of developing a suitable framework for their context. You must have an open mind and learn by trying. The process design matters, and perhaps it would not have happened if the right persons had not met.

The second explanation points to the role of securing access to a key decision-maker early in the transfer process, thereby highlighting the location of the power identified in the literature (Dolowitz 2020). One Chinese decision-maker, the key drafter of the 2002 Water Law in China and a senior MWR official provided credibility to the process and played a bridging role between the Australian–Chinese team and the provincial governments (AC1; AC2; CC1; CC2). These individuals acquired the legitimacy to sanction the project through building trust and collaboration among local governments and the Chinese–Australian team.

By contrast, the process design, plus structurally embedded competition within the ACEDP (2007–2012), helped to create an impasse between the Chinese and Australian partners in the policy-transfer process. Drivers from within the ACEDP included (a) conflict between the facility approach desired by AusAID and the technical assistance approach pursued by the private managing contractor GHD Ltd; and (b) competition between the Chinese partners (the MWR and the MEP) for funds. Overall, though, these two bilateral programmes need to be understood in the context of the broader development cooperation at the time with China graduating from being a developing country while Australia was phasing out its aid to China. The transition from WET to ACEDP came at a time when the Rudd government (2007–2010) deepened Australian accommodation policy toward China (He

2012). For Australia, however, the Turnbull government's (2015–2018) hardening stance towards China signalled a shift from accommodation to competition and rivalry with China.

Finally, our findings reveal that the Shiyang River Basin in Gansu is a frontrunner in allocating individual water rights and the birthplace of China's first online trading platform. This confirms a connection between learning policy from Australia and developing water markets in China. Indeed, to design the allocation plan, scientists pursued strategies such as face-to-face interactions with decision-makers and showcasing hydrological models. Moreover, these scientists helped to build the online trading platform through (a) mounting training programmes for farmers, and (b) bringing Australian expertise into the process of implementing and evaluating the market. In Gansu, Tsinghua scientists worked overtime to embed themselves into the local state's governing units and they successfully adopted the pooled water exchange system from Water Partners (Aust) Ltd, Victoria, Australia. This type of embedding supports existing arguments regarding "embedding lessons" into policy-relevant governing units (Dolowitz 2020).

In summary, this study demonstrates that influence on water-sector reform in China does not only flow from the principles of gradualism, local experimentation, and hierarchy that Moore and Yu (2020) suggested. It is also profoundly shaped by the power of actors such as ministers or scientists who take advantage of opportunities that time, timing, and tempo provide.

7. CONCLUSION

7.1 SUMMARY OF FINDINGS

I started this dissertation by trying to establish what might explain the emergence, diffusion, and diversity of water markets in China from a coupled-infrastructural perspective. In the earlier chapters I advanced the argument that different water-market configurations emerged at critical junctures in China's political development, which were the result of various mechanisms that the central government employed combined with a joint decision by China and Australia to engage in development cooperation. The findings of this dissertation contribute to theories of institutional choice (Mahoney and Thelen 2010; Ostrom 2005; Pierson 2000) insofar as they emphasize that the legacy effects of hydraulic infrastructure construction, path dependence, and distributional struggles can help us understand the divergent paths observed in Chinese water markets over time.

In Chapter 4, by using the concepts of a coupled infrastructure system (CIS) and path dependence to examine post-1949 water-rights systems in arid northwest China, I was able to capture an important aspect of co-evolving institutions and infrastructure within a comparative framework that is relevant for many contexts beyond China. Path dependency provides a first institutional perspective on how to understand the divergent paths of water market development in the basins of the Heihe, Shiyang and Yellow rivers. Path dependency emphasizes that institutional choices made at formative moments in the past determine future institutional trajectories and raise the cost of reversal. According to this view, initial institutional choices give rise to institutional complementarities and that initial choices can be difficult to reverse (Pierson 2000). The cases of the Heihe, Shiyang and Yellow rivers are illustrations of this kind of path dependency.

In the 1980s and 1990s, the combination of a legacy of a hydraulic infrastructure and river-basin closures compelled Chinese leaders to undertake costly water allocation reforms. In parallel with the large flood and water-supply projects, the early policy choices, including a water resources allocation plan for the Yellow River (1987) and the introduction of a system of water abstraction permits (1988), influenced the subsequent developments of the water markets. A water resources allocation and regulation plan emerged in response to water-allocation challenges associated with the closure of the Yellow River basin at a critical juncture in 1998. The institutional setting of this plan became law in 2002 but was emulated in and applied to the Heihe River in 2000, and to the Shiyang River in 2007. Despite the three cases sharing similar institutional characteristics, including the allocation plan and design of the river-basin management authorities, the water-rights reforms undertaken in each basin since 2000 have generated different water-market trajectories.

In Chapter 5, by adopting a CIS lens through which to recognize the pathways and patterns of institutional development in Chinese water markets, I identified five coupled-infrastructure pathways that induced higher levels of trading activity, and three pathways that caused lower levels. In doing so, I highlighted the critical, but hidden role of the physical infrastructure in these pathways. The first pathway, which bore the status of a pilot programme, included a capped water price, private tradable water rights, a local state administration (supervision), a market intermediary (CWEX), low storage provision, and no use of a reservoir to implement the transaction between a seller and a buyer. The water market in the Shiyang River, which is dominated by temporary contracts, is a prime example of this coupled-infrastructure pathway. The pathway associated with higher levels of trading activity in Shiyang shares similarities with the pathway that induces lower trading activity levels in Zhangye in the Heihe River. Accordingly, private tradable water rights, a capped water price, the status of a pilot programme, the absence of a market intermediary, local state administration (supervision), low storage provision, and no reservoir usage to implement the change contributed to lower levels of trading activity in Zhangye.

Four water markets fit the second pathway: these are Wuhai and Alashan in Inner Mongolia (the Yellow River), and Guangzhou and Huizhou in Guangdong (the Pearl River). This pathway combines the status of a pilot programme, a market price, state-owned water entitlements, local state administration and participation, a market intermediary, and no use of a reservoir to facilitate water trading. In both cases in Inner Mongolia, the Inner Mongolia Autonomous Region Water Right

Purchase, Storage, and Transfer Centre brokered the water trade jointly with CWEX. The Guangdong Environmental Rights Exchange, by contrast, brokered the regional transaction between Guangzhou and Huizhou. Both platforms in Inner Mongolia and Guangdong use investments to save, purchase, store, and finally sell the water to industries. This type of water bank is aligned with a long-term contract for future water delivery. The third pathway includes the status of a pilot programme, a market price, state-owned water entitlements, local state administration and participation, low storage provision, and no reservoir use to implement the transaction between a seller and a buyer. Cities representing this pathway are located in Ningxia and Inner Mongolia. Although inter-basin transfers and storage infrastructure are not highlighted in the second and third pathways, these group-level transactions between irrigation districts and companies in the Yellow River secure water for buyers by increasing the efficiency of irrigation and/or, as in the case of the Pearl River, relying on river transport as water delivery forms.

A second insight from institutional theory can cast light on the choice of water rights and on the relationships that institutions have with different types of infrastructures. As Mahoney and Thelen (2010) point out, patterns of institutional change are determined not only by responses to exogenous shocks or shifts but also by the power-distributional struggles that take place when problems of rule interpretation and enforcement open up spaces in which actors can implement existing rules in new ways. Institutions are, Mahoney and Thelen suggest, “distributional instruments laden with power implications” (Mahoney and Thelen 2010: 8). For Mahoney and Thelen (2010), institutions are vulnerable to struggles when there exist “gaps” or “soft spots” between the rule and its interpretation or the rule and its enforcement” (Mahoney and Thelen 2010: 14). These struggles in turn have implications for resource allocations because many formal institutions are specifically intended to distribute resources to particular kinds of actors and not to others. Their logic of institutional change emphasizes “the interaction between features of the political context and properties of the institutions themselves as crucially important for explaining institutional change” (Mahoney and Thelen 2010:

31). More specifically, they have distinguished four types of institutional change, namely displacement, layering, drift, and conversion.

In accordance with this logic, my analysis of the empirical cases in Chapter 6 showed that powerful actors played a pivotal role in reforming water rights and initiating water markets. Starting with Zhangye in the Heihe River Basin, the central government helped with the adoption of a water-rights trading policy by granting about 200 million yuan (US$ 28.4 million) towards the construction of the "Building a Water-Saving Society" programme, which the then minister of water resources, Wang Shucheng, proposed in 2002 in an attempt to reshape China's water management trajectory following a series of water crises at the turn of the century. Because, as a policy entrepreneur, Wang Shucheng had the power to carry through his preferences, he seized the opportunity to advance his idea of a tradable water-rights policy conceptually and strategically. As a result, water certificates were granted to farmers as proof of their permanent water rights, and water tickets issued as temporary rights linked to actual water use. The water conservation programme for the Shiyang Basin followed the Heihe example of granting water rights to farmers and, in like manner, there was central government-financed investment in modernizing irrigation. Associated measures, which included water-saving technologies, lining canals and providing intelligent water and electricity meters to monitor abstraction, underpinned the idea of creating water markets between the different irrigation users. Although the water markets that emerged in the Heihe River resembled those that had been developed in the Shiyang River, there were some key differences.

As I highlighted in Chapter 6, a group of scientists from Tsinghua University designed the allocation plan and, over time, implemented an exchange-based online water trading platform in the basin in 2013. As part of the Australia China Environment Development Partnership (2007–2012), this group transferred the functions of water accounting, trading applications, tracking payments, and pooled exchange from Victoria in Australia to the Shiyang Basin in Gansu province. Between 2013 and 2017, the trading platform helped to formalize informal trading in the basin by increasing the transparency of the water market's information. More importantly, the success of the policy transfer depended on strategies designed to convince domestic actors, such as basin officials and WUA leaders, of the appropriateness of preferred Australian solutions. Accordingly, scientists affiliated to Tsinghua University actively worked with a former key official responsible for water trading in Victoria to develop the platform, and then jointly trained basin officials and WUAs to bridge the decision-making and implementation processes. The reform process undertaken in the Yellow River since 2003, however, failed to follow the model of granting water rights at the farmers' level, but instead developed the idea of "investing in agricultural water-saving and transferring saved water to industry".

To summarize, while the processes taking place in the Heihe and Shiyang rivers resemble what Mahoney and Thelen (2010) call *layering*, in which new elements are added to existing institutions, those occurring in the Yellow River can be understood in terms of *conversion*, where the existing elements of an institution are enacted in new ways because of their strategic redeployment. Through such redeployment, and with the help of the 2002 Water Law, the MWR and YRCC (Yellow River Conservancy Commission) transformed the water abstraction permit system from an administrative instrument to control water use into the legal basis of trading water abstraction rights. Yet, the government did not dismantle the old water abstraction permit system. Instead, local governments in Ningxia and Inner Mongolia harnessed the water abstraction permit to enable energy project developers to serve new ends. As the Yellow River example illustrated, conversion meant that the holders of water abstraction rights in the industrial, agricultural, and service industries were able to transfer corresponding water abstraction rights to other eligible units by adopting water-saving measures, such as improving the efficiency of irrigation and/or adjusting industrial structures. Taken together, this institutional choice perspective can help one understand why seemingly similar transactions in the three cases are governed by different institutional arrangements.

Furthermore, in Chapter 5 I extended the analysis of the two-hands approach to water governance in China beyond policy descriptions by showing that the central government influences trading in infrastructural and non-infrastructural ways, specifically through pilots and in the form of the China Water Exchange (CWEX) platform. Accordingly, the central government's fingerprint can be seen in the following way: four out of five pathways associated with higher levels of trading activity had pilot status whereas the CWEX platform played a brokering role between water users in three out of five paths. Meanwhile, all three pathways that exhibited lower trading levels bore the fingerprint of CWEX. Moreover, the fourth pathway (Xinmi, Xinzheng, Dengfeng, Pingdingshan, and Nanyang) and the fifth pathway (Cixi, Shaoxing, Dongyang, Yiwu, Bijie, and Pingxiang) revealed an infrastructure that accommodated physical transfer and higher levels of storage to enable regional-level trading between administrative areas located in the same watershed or in different watersheds but with water diversion conditions. The fingerprint of the central government in the two-hand policy can be seen in the fourth pathway where the financing and operation of the South-to-North Water Diversion Project (SNWDP) is an extension of the central government.

In Chapter 5, I also demonstrated that informal water-rights trading emerged in the Shiyang Basin in Gansu province and in Taiyuan in Shanxi province. These exchanges were self-organized by farmers and involved a variety of water-sharing practices ranging from purchasing water via cell-phones to informal swapping of electricity cards. However, although farmers used collective action to organize the trading, over time these water markets became embedded in local and central government. For example, in 2018 CWEX began to register the trading in the Shiyang River and in Taiyuan jointly with local governments. This combination of government, market and community-based governance speaks in turn to a third insight from institutional theory identified by Ostrom (2005, 2010), namely institutional diversity.

Finally, one key factor is often overlooked in the literature on governing the commons (Stern 2011; van Laerhoven, Schoon and Villamayor-Tomas 2020): this is geopolitics. In Chapter 6, I showed how Australia aided China's water rights and market development in two important ways – (1) through the development of a national water rights framework, and (2) through the development of an exchange-based online water-trading platform in the Shiyang River, China's first online market intermediary. While the framework incorporated Queensland's annual and long-term water rights, as well as planning, the market intermediary adopted all the elements of the Waterpool Co-Op in Victoria, apart from the bidding process. In sum, the timing of the bilateral development cooperation proved critical because it was taking place when Australia was pursuing a policy of accommodation, and the international consensus was to integrate China into global institutions, which drew both countries into the water entitlement and trading (WET) projects (2005–2007), and the Australia–China Environment Development Partnership (ACEDP) from 2007 to 2012. This insight into the role of time and bilateral development cooperation in the dynamics of policy transfer makes a contribution to the literature on policy transfer and diffusion (Porto de Oliviera 2021).

In the remaining conclusion, I highlight the core contributions of the thesis by drawing on the chapters of the thesis and the gaps in the literature. As such, the focus of the thesis has been on the following three themes: (1) infrastructure plays a key role in the evolution of water markets; (2) there are multiple institutional pathways associated with water trading activity; and (3) international relations and individual actors play a pivotal role in policy transfer between and within countries. Finally, I conclude the dissertation by outlining future scenarios for developing China's water market and proposing future research on which to build from the findings in the thesis.

7.2 REFLECTIONS ON CORE CONTRIBUTIONS TO THREE CORE THEMES

The key role of infrastructure in the evolution of water markets

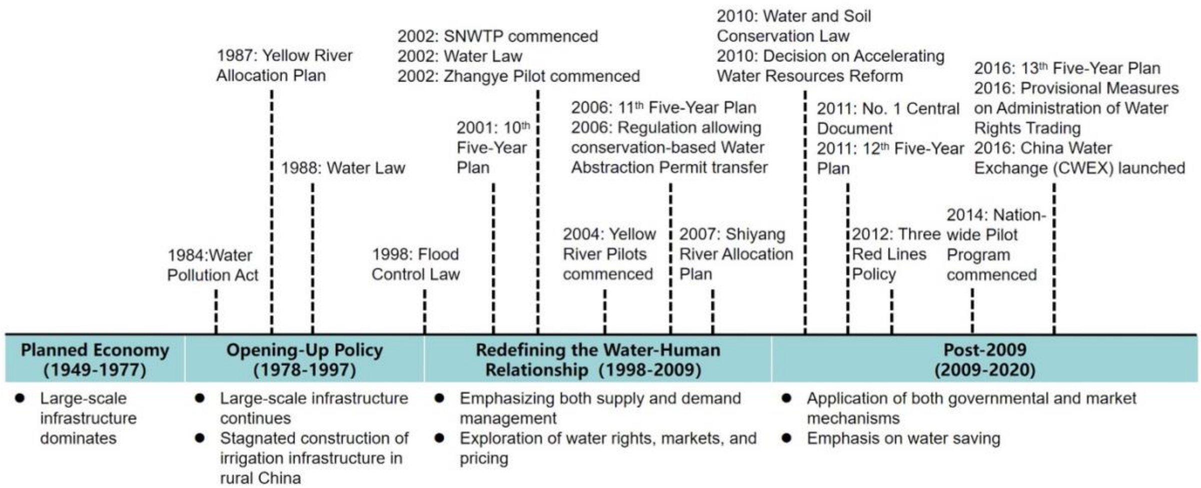
As my longitudinal analysis in Chapter 4 suggests, the creation of a water market in China has been an incremental process marked by multiple stages of reform, including the 2002 Water Law, which recognized the need to build a water-saving society and water abstraction rights, the Yellow River pilot schemes of 2004, the 2006 water permit regulation, the 2007 water allocation plan for the Shiyang River Basin, the 2009 "strictest water resources management strategy", the No.1 central document of 2011, the "three red lines policy" of 2012, the nationwide pilot schemes of 2014, and the "provisional measures on the administration of water-rights trading" of 2016 (Figure 12). Alongside these initiatives, there has also been an exponential growth of investments in water infrastructures, as witnessed, for example, in the tenth (2001–2005), eleventh (2006–2010), and twelfth (2011–2015) five-year plans (Figure 13). The gradual blending of physical human-made and soft infrastructure to manage water resources are together co-evolving into a path for water conservation in contemporary China, which has culminated in the "two-hands" approach (两手发力) to water governance (namely those of the government and of the market) in the thirteenth (2016–2020) five-year plan.

As I highlighted in Chapter 5, developing water markets and building infrastructures are interconnected and mutually reinforcing. The main buyers of the Yellow River water are industries located in Inner Mongolia, which purchase their rights to secure permanent water supplies from the irrigation districts by investing in schemes to improve the efficiency of irrigation. The trading parties rely on the Inner Mongolia Autonomous Region Water Right Purchase, Storage and Transfer Centre to stock the water. The various cities in Henan province seek their supplies from other cities and manage demand through a linked infrastructure in the form of the South-to-North Water Diversion Project. These trading parties rely on intermediary support from the Henan Water Right Purchase, Storage and Transfer Centre to facilitate the long-distance transfers. To secure temporary water supplies from the Shiyang River, farmers purchase their rights from agricultural sellers via bulletin boards. This type of trading is dependent on a canal infrastructure that is mainly financed by the central government.

In sum, these findings help to corroborate recent arguments about moving beyond the analytical distinction between government and market-based water governance (Lemos and Agrawal 2006;

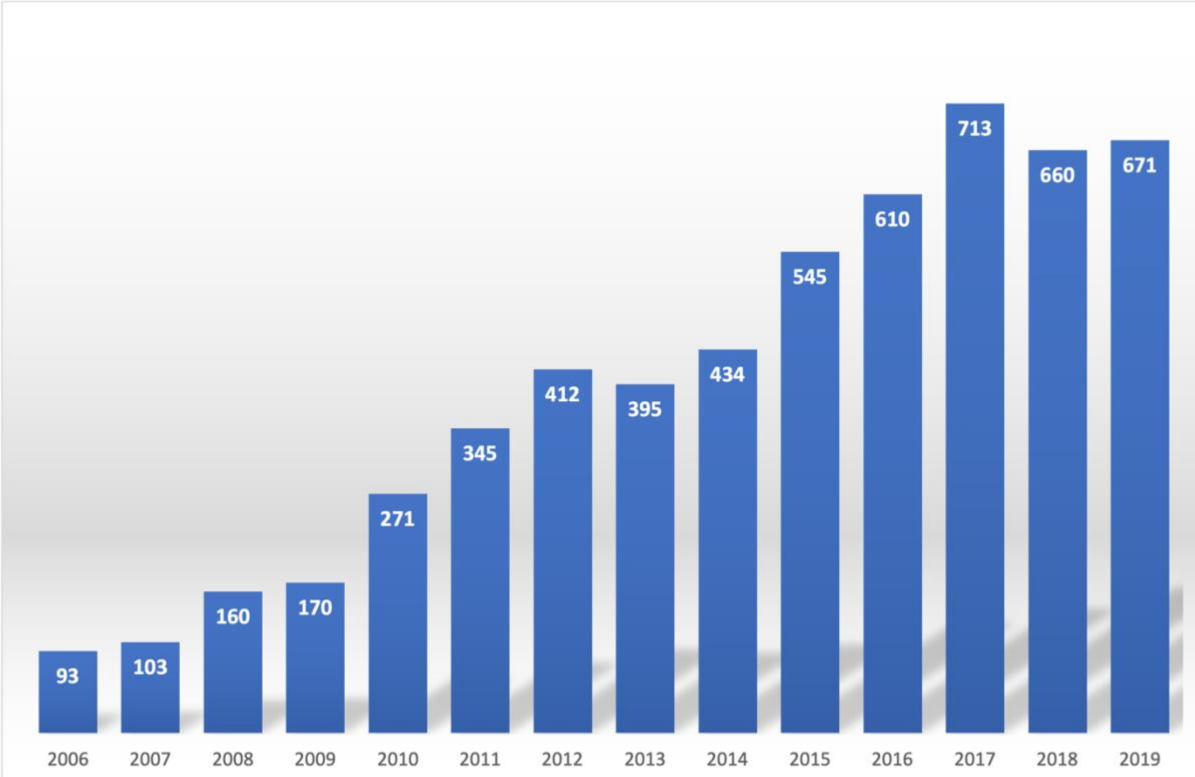
Villamayor-Tomas 2014). Accordingly, the findings here seem to fly in the face of the notion that the Chinese state designed water infrastructure only to increase supply and to control nature (Crow-Miller, Webber and Molle 2017; Crow-Miller, Webber and Rogers 2017; McCormack 2001).

Figure 12. Timeline showing the coevolution of water infrastructure and institutional reforms



Note: The data for stagnated irrigation infrastructure construction in the 1990s is from Wang, Wan and Tortajada (2018: 6). Source: Author's illustration based on Svensson, Garrick and Jia (2019).

Figure 13. Total water infrastructure investments annually (tenth–thirteenth five-year plans)



Note: Tenth five-year plan (2001–2005): water resources projects (29.7%), flood control projects (52.4%), soil and water conservation and ecological restoration (5.1%), other projects (12.8%). Eleventh five-year plan (2006–2010): water resources projects (39.7%), flood control projects (47.1%), soil and water conservation and ecological restoration (7.2%), other projects (6%). Twelfth five-year plan (2011–2015): water resources projects (46.59%), flood control projects (35.6%), soil and water conservation and ecological restoration (3.4%), hydropower development (14.6%). *Source:* National Statistical Bulletin on China Water Activities, MWR, PRC.

The multiple institutional pathways associated with water trading activity

Combining evidence from fsQCA and qualitative case studies offered a way to understand the breadth and depth of water markets. This study makes several contributions to the literature on market mechanisms in environmental governance. First, the findings support existing arguments regarding the 'two hands' approach to water governance in China. The overarching implication drawn from the institutional pathways associated with water trading activity in China holds that other developing countries that intend to design water markets should abandon binary distinctions (e.g., the state versus the market) when creating institutional arrangements in environmental governance. Second, the findings from the Shiyang River and Taiyuan case studies corroborate the polycentric arrangements of government, market, and community-based governance identified in the literature (Ostrom 2005, 2010). The implication of the hybrid patterns identified in the Shiyang River and Taiyuan suggests that it is better to select water-scarce areas with existing informal water trades to determine how these informal exchanges can be strengthened through various measures.

Third, the insights derived from the second and third institutional pathways associated with higher water trading activity resemble what the literature calls compensated exclusions in environmental governance (Sikor, He and Lestrelin 2017). Compensated exclusions describe a process where farmers remain excluded from the exercise of tradable water rights but gain indirect benefits from the infrastructure modernization provided by the enterprises and irrigation districts involved in the trading.

Finally, framing the study of water markets from the perspective of exclusion mechanisms can help to shed new light on collective action in the commons. Much of the common-pool resource literature focuses on Ostrom's eight design principles, with a growing interest in how different combinations of design principles work in diverse CPR settings (Baggio et al. 2016; Schlager 2016). However, this work on the commons shares an underlying interest in excludability and the boundary rules that define access to resource systems. The dissertation has covered various trading practices, ranging from community-based trading in Shiyang Basin and Taiyuan to group-level trading in Inner Mongolia and regional-level trading in Henan, which can be regarded as local adaptations to context-specific conditions. However, these cases all share an overarching key element: mechanisms of exclusion. Here, the Shiyang Basin stands out in China in instituting rights to water for each farming household. This property right solution might help mitigate the problems of free entrance in irrigation commons concerning water resources' overuse. In contrast, Inner Mongolia's cases operate a different property/regulatory regime and have not allocated tradable water rights to end-users yet. Enterprises obtain water-use rights from the local government by investing in water-saving irrigation projects, which may or may not translate into benefits to farmers. Also, the examination of the regional trading in Henan province in Chapter 5 reveals that while local administrative units can trade water, the central government can influence transactions involving the South-to-North-Water Diversion Project (SNWDP). This influence arises from the operation and management of the SNWDP, underscoring the deployment of institutional/technological exclusion.

A greater focus on exclusion mechanisms, including physical exclusion, institutional exclusion, and technological exclusion, and how it relates to boundary rules can open up a new avenue of theoretical and empirical research to study of collective action in common-pool resources. This focus on exclusion mechanisms fits into debates about surveillance capitalism (Zuboff 2019), and the recent development of emerging technologies and big data analytics in China, such as the emerging Social Credit System (社会信用体系), which is designed, according to Kostka (2019: 1566), to set up systems of benefits and sanctions that "aim to steer the behavior of individuals, businesses and other organizations in China".

International relations and individual actors play a pivotal role in policy transfer between and within countries

In the thesis, which makes a contribution to the literature on policy transfer and diffusion, I highlight the importance of the time dimension and of bilateral development, which are considered to be among the current topics at the forefront of knowledge in the area (Porto de Oliviera 2021). I build on Dolowitz's (2020) categories of time by showing that the interplay between agency and time can explain the patterns apparent in the rise, fall, and revival of tradable water-rights policy. The idea of a tradable water-rights policy took root in China because Wang Shucheng was in the driver's seat for long enough (1998–2007) to integrate the idea of building a water-saving society into legislation, which he achieved in 2002. The decline in trading water rights (2008–2012) can in turn be attributed to the entry of new actors into the MWR, including Chen Lei and others, who reshaped policy formation by actively working towards altering the policy in favour of a government-based allocation system. In addition, a window of opportunity opened up when the central government moved policy decisions back to the MWR, which, leveraged by a nationwide pilot programme, in turn, took advantage of the political climate of 2013 to set the tempo of change.

In Chapter 6, I also drew attention to the different power relations embedded in the China/Australia bilateral development programmes. In the case of the WET project, for example, the location of power proved critical insofar as early on in the project it secured access to a key decision-maker within the MWR and thus facilitated the policy transfer process. By contrast, the lack of a clear process design, combined with the various players having different preferences, hampered the ACEDP. One exception was the transfer of the web-based exchange platform from Victoria in Australia to the Shiyang River, which resembled what Dolowitz (2020: 582) called "embedding lessons into governing units", in which actors integrate overseas lessons into the policy process.

The findings here expand and complement the notion that the institutional reforms of China's water sector are a function of gradualism, local experimentation, and hierarchy (Moore and Yu 2020). Gradualism refers to a step-by-step policy-making process in which the impact of the modification is tested and studied. Local experimentation refers to a policy in which selected pilot programmes are given considerable scope to try out different policy implementation methods before being applied on a national scale. Finally, hierarchy means that China's policymaking relies on the direction and control of the central government and CCP. Yet, this conventional approach to institutional reforms in China needs to include a more pluralistic discussion of actors and how individuals or coalitions make use of time, timing, and tempo to shape the movement and transformation of a policy.

Finally, the findings of this thesis also have a contribution to make towards realist theories of international relations. Recent insights into structural realism (Mearsheimer 2001), which emphasize the anarchic order of the international system and the primary concern of all states with power and security, can potentially contribute to our understanding of bilateral development cooperation between China and Australia. One driving force behind the Australia–China attempt to engage in environment cooperation was structural. Timing was critical, as seen in the proceedings of the WET project (2005–2007) and the ACEDP (2007–2012), when China and Australia emerged as trading partners tied by interdependence, followed by the politics of accommodation. The Australian policy of accommodation with China, pursued until the Turnbull government (2015–2018) took over, occurred during a unipolar moment when the United States was still the unchallenged superpower. However, the transitioning out of unipolarity and into multipolarity ushered in a return to great power competition. This realist account – the structure of great power rivalry – might explain why the collaboration between CWEX and AWP failed to materialize in 2019.

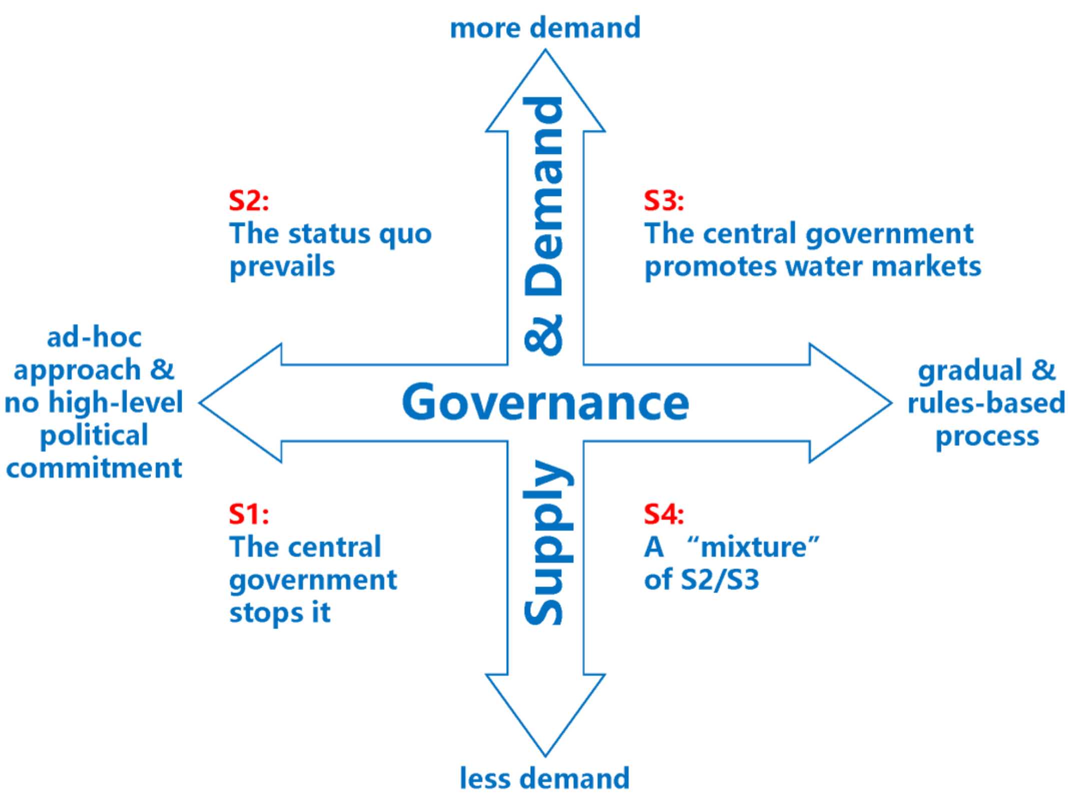
Yet, structure is not destiny and one needs to acknowledge the possibility of a new kind of diplomacy in the near future. Transnational issues potentially offer the best area of easing the downward spiral in Australian–Chinese relations and promoting cooperation.

7.3 FUTURE DIRECTION OF WATER MARKET DEVELOPMENT IN CHINA

A joint interplay of China's political-economic system and supply and demand dynamics will determine the future trajectory of the country's water market development. From the thesis findings, I can think of four possible scenarios for China's future water market development (Figure 14). In the first scenario, the central government stops promoting water markets in China by constructing an infrastructure, and selecting and launching pilot programmes in response to a combination of low demand and lack of political will to make market-oriented reforms. From my point of view, this is the least likely of the four scenarios simply because of Xi Jinping's removal of term limits, and the lingering effects of path dependency. In the second scenario, the status quo prevails. Although the central government does not issue any centrally-formulated policies, each province, city, county, and township in China is given enough flexibility to use its socioeconomic autonomy to promote markets in its jurisdiction. In the third scenario, high demand and a strong political mood promoting market-oriented reforms at the central level set the stage for a "third wave" of water-rights trading in China, including an ambitious new piloting programme.

Finally, the fourth scenario, which is the most likely, is a combination of the second and third scenarios, which leads to gradual water-market reforms. Under this scenario, the central government provides legal and policy guidance to water markets while local experimentation with previous pilot programmes moves forward as supply/demand evolves. This scenario is most likely because it takes into account (a) China's incremental water market journey, and (b) the intra-national variation in the design and progress of water markets, while (c) recognizing that reversing or shifting 20+ years of investments in water markets is costly for central policy-makers.

Figure 14. Scenarios on the future of water market development in China



Source: Author's illustration.

7.4 PRIORITIES FOR FUTURE RESEARCH

An important avenue for future research would be to acquire a better understanding of the role of local collective action by resource users. While the dissertation has provided some evidence of the local characteristics of water markets, more empirical research remains to be done. For example, little is known about the participation in water markets of resource users, particularly on the seller's side. Although to some extent I was able, through the dissertation's data set, to track the statuses and trends of the transactions of farmers and householders who trade water in China, I surmise that the transactions I identified under-represent the actual demand. To engage in bargaining, farmers use collective action through informal groups and formal cooperatives, but because details about the distribution of water rights to end users remain unclear and water accounting is generally weak, determining or recording the real trading activity, and showing how it varies geographically, is still far from perfect.

Important questions that then arise include what existing social structures and incentives are in place to encourage farmers and households to buy or sell water? Do water markets mean the same thing to buyers and sellers, or are they different? Under what circumstances do informal trading systems become formal? And if or when they do, does the transition to formality feature tipping points? How can external interventions by local governments influence market formality? Addressing these questions can add interesting and important insights to the role of local collective action in Chinese water markets. Also, because there are geographical differences in China, scholars may need to conduct comparative institutional analyses of water markets in similar geographical contexts.

From a buyer's perspective, it is important to disclose the explicit nature of the firm operating in the Chinese water market. This omission in my dissertation exposes an unfilled gap, not only because most of the data-set transactions are between companies and irrigation districts, but also because a study of the firm will reveal whether companies (buyers) are state-owned, private, or a mixture of both. A focus on the nature of the firm in water markets can shed light on the applicability of the "two-hands" approach to water governance, and how the state penetrates the economy in general.

Another line of research of importance to the literature is water-market performance. A suggested approach in this respect would be to focus on the connection between market performance and the presence of exclusion mechanisms. It is assumed that a water market can generate different outcomes, including win–win, win–lose, and lose–lose for sellers and buyers at both local (farmers, inter-sectoral) and regional (inter-jurisdictional) levels. The following key questions remain. Which institutional, technological, and geographical configurations contribute to win–win outcomes? How does the water-market performance vary for different trading types (user, group, and regional level)? Can water markets fulfil multiple objectives, including economic efficiency, social equity, sustainability, or are they mutually exclusive? How do water-market arrangements address the tension between exclusion to preserve water resources and inclusion to meet social and economic goals?

In addition to providing a more comprehensive understanding of water-market performance, scholars are well advised to examine the role of transaction costs in limiting the adoption of water markets. Accordingly, places that adopt water markets are expected to have lower transaction costs. Moreover, it is assumed that transaction costs differ across types of water-market platforms. How are types of market platforms in China, including bulletin boards and water banks, associated with high versus low transaction costs? Although this is a promising next step for the literature, it will be difficult to isolate the role of CWEX from that of local platforms.

Finally, I suggest that there is a need to broaden the theoretical lens of institutional diversity to other policy domains in China. How do attempts to create hybrid governance arrangements align with or depart from other areas of resource management or other areas of policy in general? Since the country embarked on its reform and opening up under Deng Xiaoping in 1978, China has expanded its political, economic, and military influence internationally. Traditionally, research into China's rise has primarily focused on its economic evolution and its role in international relations. However, other global impacts of China’s transformation have until recently received less scholarly attention, including science, technology, and climate change.

A good example in this respect is China’s transition to low-carbon energy. How do central and local governments interact with market forces and other actors to shape the energy sector? Another example is the high-speed rail (HSR) in China. What governance arrangements were applied to build the world’s most extended HSR network? An interest in hybrid governance arrangements is also relevant in the light of China’s launch of “Made in China 2025”, for this state-led ten-year plan is designed to upgrade China’s industrial capability by developing ten high-tech industries. Specifically, are there patterns in the way the state, firms, and market forces interact in the design and application of artificial intelligence?

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APPENDIX

DECLARATION OF AUTHORSHIP

Name: JESPER SVENSSON | Candidate number: 856812

College: ST EDMUND HALL | Supervisor/Adviser: DUSTIN GARRICK

Title of Thesis: “TWO HANDS, MULTIPLE FINGERPRINTS”: UNDERSTANDING THE DEVELOPMENT OF WATER MARKETS IN CHINA

Word count:71, 313

I have read and understood the University’s disciplinary regulations concerning conduct in examinations and, in particular, the regulations on plagiarism (*The University Student Handbook* Section 8.7; available at https://www.ox.ac.uk/students/academic/student-handbook).	X
I have read and understood the Education Committee’s information and guidance on academic good practice and plagiarism at https://www.ox.ac.uk/students/academic/guidance/skills?wssl=1 .	X
The [thesis/dissertation/extended essay/assignment/project/other submitted work] I am submitting is entirely my own work except where otherwise indicated.	X
It has not been submitted, either partially or in full, either for this Honour School or qualification or for another Honour School or qualification of this University (except where the Special Regulations for the subject permit this), or for a qualification at any other institution.	X
I have clearly indicated the presence of all material I have quoted from other sources, including any diagrams, charts, tables or graphs.	X
I have clearly indicated the presence of all paraphrased material with appropriate references.	X
I have acknowledged appropriately any assistance I have received in addition to that provided by my [tutor/supervisor/adviser].	X
I have not copied from the work of any other candidate.	X
I have not used the services of any agency providing specimen, model or ghostwritten work in the preparation of this thesis/dissertation/extended essay/assignment/project/other submitted work. (See also section 2.4 of Statute XI on University Discipline under which members of the University are prohibited from providing material of this nature for candidates in examinations at this University or elsewhere: http://www.admin.ox.ac.uk/statutes/352-051a.shtml).	X
I agree to retain an electronic copy of this work until the publication of my final examination result, except where submission in hand-written format is permitted.	X
I agree to make any such electronic copy available to the examiners should it be necessary to confirm my word count or to check for plagiarism.	X

Candidate’s signature: ……………………………………………..Date: 2March 2021

Co-author agreements

Detailed contribution of co-authors for Paper 1 (Chapter 4)

Chapter Title: Coupled infrastructure systems: comparing the development of water rights and water markets in Heihe, Shiyang and Yellow Rivers

First author: Jesper Svensson (School of Geography and the Environment (SoGE) and Smith School of Enterprise and the Environment (SSEE), University of Oxford)

Co-authors:

Dustin Garrick (SoGE, SSEE)
- Provided conceptual supervision for the development of the analytical framework;
- Provided substantial edits and comments for the paper;
- Provided substantial feedback for the development of the methodological approach.

Jia Shaofeng (Institute of Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences)
- Provided supervision for the investigation process and data collection;
- Provided financial support for the project leading to this publication;
- Provided overall comments for the paper.

We confirm that Jesper Svensson led the paper design and methodology, collected and analysed the data, led the development of the results and findings, drafted the paper and managed the submission and revision process – with our contributions as specified above.

Dustin Garrick, 3 March 2021

Jia Shaofeng, 3 March 2021

Detailed contribution of co-authors for paper 2 (Chapter 5)

Chapter Title: How hybrid environmental governance works? Examining water-rights trading in China (2000–2019)

First author: Jesper Svensson (School of Geography and the Environment (SoGE) and Smith School of Enterprise and the Environment (SSEE), University of Oxford)

Co-authors:

Yahua Wang (School of Public Policy and Management, Tsinghua University)
• Provided substantial feedback for the development of the theoretical framework;
• Provided comments to final draft of the article;
• Provided feedback for the visualization/data presentation.

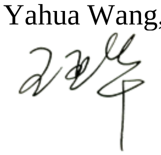
Dustin Garrick (SoGE, SSEE)
• Provided supervision of the core team;
• Provided substantial edits and comments for the paper;
• Provided substantial feedback for the development of the methodological approach.

Xiaoping Dai (North China University of Water Conservancy and Electric Power)
• Provided substantial feedback for the data curation and validation;
• Provided substantial feedback for the investigation process and data/evidence collection;
• Provided substantial edits and comments for the paper.

We confirm that Jesper Svensson led the paper design and methodology, collected and analysed the data, led the development of the results and findings, drafted the paper and managed the submission and revision process – with our contributions as specified above.

Dustin Garrick, 3 March 2021

Yahua Wang, 3 March 2021



Xiaoping Dai, 3 March 2021

Detailed contribution of co-authors for Paper 3 (Chapter 6)

Chapter Title: China/Australia cooperation and the rise, fall and revival of tradable water rights policy in China, 1998–2019

First author: Jesper Svensson (School of Geography and the Environment (SoGE) and Smith School of Enterprise and the Environment (SSEE), University of Oxford)

Co-authors:

Hang Zheng (Dongguan University of Technology)
• Provided substantial feedback for the development of the paper data analysis;
• Played a key role in the investigation process in terms of data/evidence collection;
• Provided substantial edits and comments for the paper.

Dustin Garrick (SoGE, SSEE)
• Provided substantial feedback for the development of the methodology;
• Provided substantial edits and comments for the paper;
• Provided substantial feedback for the overarching research goals and aims.

We confirm that Jesper Svensson led the paper design and methodology, collected and analysed the data, led the development of the results and findings, drafted the paper and managed the submission and revision process – with our contributions as specified above.

Hang Zheng, 3 March 2021

Hang Zheng

Dustin Garrick, 3 March 2021

LIST OF INTERVIEWS

#	Interviewee	Organization	Code
1	Scholar	University in Beijing	BJ170802-1
2	Scholar	University in Beijing	BJ170804
3	Scholar	University in Beijing	BJ170926
4	Scholar	University in Zhengzhou	ZZ170711
5	Senior official	River Basin Commission	ZZ170710
6	Focus group	Provincial Water Bureau	YC170717-1
7	Focus group	Provincial Water Bureau	YC170717-2
8	Focus group	Village leaders in Henan county, Ningxia	HL170718
9	Focus group	City Water Bureau	ZY170724
10	Focus group	City Water Bureau	LZ170726
11	Focus group	Irrigation District Water Bureau	GT170725
12	2 Senior officials	MWR	BJ180323
13	Focus group	County Water Bureau	CA180327
14	Focus group	City Water Bureau	YC180330
15	Focus group	Inner Mongolia Water Trading Platform	HH180403
16	Focus group	County Water Bureau	TY181129
17	Focus group	Henan Water Trading Platform	ZH191121
18	Focus group	Irrigation District Water Bureau	WW190729
19	Chinese researcher and consultant	Chinese University	CC1
20	Chinese researcher and consultant	Chinese University	CC2
21	Chinese researcher and consultant	Chinese University	CC3
22	Chinese researcher and consultant	Chinese University	CC4
23	Chinese former high-level official	Department of Water Resources Management, MWR	CG1
24	Senior official, Australian citizen of Chinese ancestry	Department of Agriculture, Water and the Environment	ACG1
25	Company manager, Australian citizen of Chinese ancestry	Rubicon Water	ACP1
26	Australian senior official	Australian Water Management and International Development Organization	AG1
27	Australian former senior official	Queensland Department of Natural Resources and Water, executive governor of corporation	AG2

28	Australian consultant	Independent consultant in Queensland	AC1
29	Australian former official and consultant	Queensland Department of Natural Resources and Water, Independent consultant	AC2
30	Australian researcher and consultant	Australian University in Queensland	AC3
31	Australian researcher and consultant	Australian University in Victoria	AC4
32	Australian researcher and consultant	Australian University in Queensland	AC5
33	British consultant	International organization	BC1

Note: Interviews are numerically coded: two letters indicate location (BJ=Beijing, HH= Hohhot, TY= Taiyuan and so forth); the following six numbers indicate the date of the interview (180323 = 23 March 2018). All interviews used in Chapter 6 are coded with the first letter indicating nationality (C for Chinese, A for Australian, CA for Chinese Australian), the second letter indicating profession (C for consultant, G for government official, P for private sector), and the numbers indicating the interview number within a category.

FOCUS GROUP INTERVIEW QUESTIONNAIRE

Letter of Consent

Purpose of the Study:
I sincerely invite you to participate in an interview that lasts about 60 minutes. My mentor and I are conducting research on the spatial and temporal distribution of China's water-rights trading transactions between 1999 and 2019. In the data collection part, we will interview water resources management scholars and officials to understand the driving factors affecting water-rights trading, including science and technology, infrastructure, etc., as well as related quantitative and qualitative information.

Procedures involved in the Research:
How the interview is conducted will depend on your preference and logistics of conducting the interview. The interview is expected to take less than one hour of your time, but will be conducted in an open format allowing you to contribute as much information as you would like to provide.

We will appreciate if you can provide specific qualitative data and references to support your replies whenever possible. Data collected in this research will be assimilated across all participants of interest. Participants who chose to remain anonymous will be allowed to do so. Responses will be coded and analysed to identify particular themes across the responses.

Potential Harms, Risks or Discomforts:
The risks involved in participating in this study are minimal. You may feel concerned about the accuracy of the information provided through this study or that you may lose professional status and reputation and be at economic risk. However, these risks will not be greater than what you experience in everyday professional life, and I am strongly committed to verifying our work and giving you every opportunity to review its accuracy and clarity. As such, location for interviews will be determined according to participants' convenience.

You may choose not to provide an answer to any question based on any reason that makes you feel uncomfortable or otherwise unwilling to do so. You do not need to answer any questions that would pose a risk of government censure, harassment or loss of future income. To minimize or mitigate these risks, you will be provided ample time to prepare and convey your responses. I will provide you with the semi-structured interview questions in advance and you can reschedule your participation if you need more time to answer questions.

Confidentiality:
This letter provides the full details of the study and you should have ample time to review it before deciding to participate. In order to be eligible for participation, you must send written consent to Jesper Svensson (jesper.svensson@seh.ox.ac.uk) to certify that you have read, understand, and agree with the procedures put forth herein. You will also be able to confirm verbally your informed consent at the beginning of any oral interview, and be given the opportunity to ask questions, listen to responses, review the procedures and proceed with or withdraw from the study.

The identity of the participants will be masked in the final research outputs, unless the source agrees otherwise. Data collected during interviews and/or workshops will only be entered into the research outputs in a processed form, no direct quotes or any other information allowing the identification of the source will be included. In addition, written permission to quote or identify a source will be required should the project benefit from doing so. Transcripts will be anonymized, that is they will not include the name, position, workplace, home country or any other personal data of the participant. The transcripts will be stored in password protected computer files.

Participation and Withdrawal
Participation in the study is strictly voluntary. If you decide to be part of the study, you can stop (withdraw from) the interview, questionnaire or follow-up for any reason, even after signing the consent form or part of the way through the study until approximately XXXX. If you decide to withdraw, there will be no consequences for you. In the case of withdrawal, any data you have provided will be destroyed unless you indicate otherwise. If you do not want to answer some of the questions, you do not have to, but you will still be in the study.

CONSENT

- I have read the information presented in the information letter about a study being conducted by Jesper Svensson of the University of Oxford.
- I have had the opportunity to ask questions about my involvement in this study and to receive additional details I requested.
- I understand that if I agree to participate in this study, I may withdraw from the study as any time or up until approximately XXXX.
- I have been given a copy of this form.
- I agree to participate in the study.

____
____
Interviewee Signature Date

Further Contact:
____ Yes, I would like to receive a summary of the study's results. Please send them to the following email address: ____
Or to the following postal address:
____
____
____

____No, I do not want to receive a summary of the study's results

Consent for the interviews and questionnaires will be documented via email, letter, or in extenuating circumstances, via the written elements of teleconferencing software. The Letter of Confirmation will be circulated in advance, allowing for ample time for review and questions. Participants will be eligible for the study when they certify in writing that they have read, understood and agreed with the Letter of Information/Consent.

Participant consent will involve the recognition that the data they provide will be used in other research projects and that their names might appear as validating the data examined in the current research project. It will also recognize that the data will be kept for an indefinite amount of time.

学习目的

我诚挚的邀请您参与一次时间约为 60 分钟的对话采访。我与我的导师教授正针对 1999 年至 2019 年间中国水权交易的时空分布开展研究。在数据搜集部分，将访谈水资源管理的学者和官员，了解包括科技、基础设施等在内的影响水资源再分配的驱动因素，以及有关的定量和定性信息。

研究过程中涉及的步骤

这次采访将采用面对面交流的方式，预计时长不会超过一小时，但是会采用开放对话的形式，希望您尽可能多的提供您想要提出的意见和传递的信息。我们非常希望您在采访过程中通过提供一些有效的定向、定量数据和参考文献去支持您的观点，提出您的意见。
数据的收集将针对于所有有兴趣的河流流域和参与者。参与者有权保留匿名参与的权利，同时，所有收集到的信息将通过编译和分析被划分成不同的主题和类型。

潜在伤害、风险和不便

参与这项研究的风险是最小的。您可能会担心信息的精确度，或者信息专业性的丢失，或者存在经济上的风险，但是这些风险会小于日常生活中的经历，同时我在这里保证，我将致力于核查我们的工作并使您有随时检阅信息的精确度和清晰性的机会。同样的，采访地点将依照参与者意见，根据参与者的方便程度确定采访是在其家中或是工作地点或者是公共区域。如果出现以下风险，您有权拒绝回答任何问题：

- 问题涉及参与者隐私
- 参与者感到不方便或者不愿意回答
- 问题涉及政府机密或者回答同类问题会受到政府部门谴责
- 回答此类问题会影响未来收入

为了减小或消除这些可能存在的风险，您会有充足的时间考虑和传递这些问题的答案。同时，我也会提前将采访所准备的部分问题提供给您，您可以根据内容调整您的受访时间。

机密性

这封同意书包含了研究内容的细节和参与可能涉及的风险，在您决定参与之前，您有充分的时间阅读这份同意书。为了确保参与资格，您需要确认您阅读，理解并同意本同意书中所涉及内容，同时填写本书最后一部分内容，并将填写完整的同意书发送给 Jesper Svensson (jesper.svensson@seh.ox.ac.uk)。同时，在正式采访之前，您可以口头确认知情同意，并有机会提出问题，倾听回应，审查程序并有权从研究中退出。
在最终研究成果展示中，除非经过参与者同意，否则参与者身份将被隐藏。采访过程中的数据收集将会以过程处理的形式展现在研究成果中，间接引用或其他任何允许识别源资料的信息将被包括在内。如果这个项目从中获益，将会需要一份额外引用或识别资料的许可。采访

笔录将会被匿名，任何有关参与者姓名、职位、工作地点、国籍或者其他涉及参与者隐私的内容均不会显示在笔录中。采访笔录会被保存在电脑中的加密文件夹。

参与和退出
项目的参与者严格按照自愿原则参与。如果您已经参与到这项研究中，即使在您已经签署同意书或者参与到研究一半进程即在 XXXX 年 XX 月 XX 日前，您可以以任何理由退出采访、问卷调查或后续活动。如果您决定退出，这个决定将不会对您产生影响。在退出的情况下，除非您明确指出，否则所有您提供的信息将被销毁。如果您不愿意回答某些问题，您有权利拒绝回答，这些不会影响您作为本项目的参与者。

同意书

- 我已经阅读了以上同意书中所说明的关于牛津大学 Jesper Svensson 先生所进行的研究的信息
- 我已经询问过关于我参与这项研究的有关问题并收到了关于更多细节的回复
- 我理解，如果我同意参与到这项研究中，我可以在 XXXX 年 XX 月 XX 日之前的任何时间无条件退出这项研究
- 我有这份同意书的副本
- 我同意参与到这项研究中

______________________________ ______________
被访者签名 日期

进一步联系：
____是的，我希望收到一份关于研究结果的总结。请把它们发送到以下邮箱中：
____
或者邮寄到以下地址：
____
____
____

____不，我不希望收到关于研究结果的总结。

采访和问卷的同意可以通过电子邮件、信件或可拓展形式进行记录，通过电话会议软件的书面形式。确认信将会在研究调查进行前发送出去，以便参与者有充足的时间进行审核和提问。当参与者在书面证明他们已经阅读，理解并同意这份同意书时，参与者有资格参与这项研究。

参与者同意事项还包括承认并理解他们提供的数据将会被用到其他研究项目中，并且他们的名字可能会作为验证当前研究项目的数据出现。这些研究数据会被保存在不确定时间内。

SAMPLE INTERVIEW QUESTIONS FOR OFFICIALS AND EXPERTS (CHAPTER 4)

1. What is the evolution of water allocation reform? What was the water allocation reform driven by, and by whom?

2. What are the roles of the government, the market and the community in water allocation and trading of water rights?

3. How are the amount of the transfer, the terms of the transfer and the compensation amount and method determined for water rights transfer schemes? By which stakeholders?

4. What regulatory and institutional mechanisms govern the water markets?

5. What are the roles and responsibilities of the Yellow River Basin Commission and the Ningxia Water Resources Department in water rights transfer schemes in Ningxia province?

6. Why are local water trading platforms constructed? Who runs the platform? What is the purpose of the platform?

7. What are the barriers to further developing the water market in the Heihe, Shiyang and Yellow rivers?

SAMPLE INTERVIEW-QUESTIONS FOR OFFICIALS IN HENAN PROVINCE (CHAPTER 5)

1. What are the objectives with reallocating water from Xinmi to Pingdingshan and from Dengfeng and Xinzheng to Nanyang? 平顶山-新密、南阳-登封、南阳-新郑水权交易的目的是什么？

2. What are the three most important driving factors for water-rights trading between the cities? 南水北调城市间水权交易的三个最重要的驱动因素是什么？

3. How would you rank those three factors and what is your justification? 这三个因素怎么排序？原因是什么？

4. a) How many levels of government are involved in water reallocation (provincial, city, county) and which departments? 有多少层次的政府以及什么部门参与到了水权交易中（省、市、县）？

4. b) How is coordination across the localities done in practice? Is the coordination more driven by upper-level authorities, such as provincial government and river basin organizations or by local governments? 水权交易是由上级政府（如省政府、流域管理委员会）推动的还是由地方政府推动的？交易是由哪个部门整体协调的？

5. c) Who has authority over the operational and management rules of the SNWDP and how does it affect the criteria for water-rights trading between localities, such as Xinmi to Pingdingshan? 哪个部门负责南水北调工程的运行管理和水量调度规则，这种调度规则怎么影响水权交易的水量、价格以及交易方式？

6. What are the operating costs of maintaining and operating the infrastructure used for water reallocation? 运行维护水权分配工程和设施的成本是多少？（保障交易的工程的运行成本）

7. What are the impacts of the trading, both positive and negative, for both seller and buyer regions? How do you measure the impacts? 水权交易对交易参与方以及第三方都有什么影响（好的和坏的）？在水权交易审查的时候怎么衡量这些影响？

8. What are the limits of water transfer? 制约南水北调水权交易发展的因素有哪些？

9. How is the water fee of the SNWDP paid? Is the basic water fee paid regardless of whether water is used? 南水北调水价的缴纳方法？基本水价是不管是否用水都需要交？

10. How is the water of the SNWDP allocated every year? 年度水量是怎么分配的？
11. How to solve the problem if the user used more water than allocated water? If a seller can find a buyer easily if he wants to buy water? 用水量超过年度水量后怎么办？在发现用水量将要超指标后，能否方便地找到交易对象？

12. Where does the water rights surplus come from? How about the condition of water rights surplus? 富余的水权的来源？目前富余指标的情况？

13. Who will pay for the transaction fee? How did the seller use the transaction fee? 谁支付水权交易费用？卖方一般如何支出水权交易收益？

14. What additional projects are needed in the transfer? 在水权交易中需要哪些配套工程？

15. What are the transaction fees of Nanyang-Xinzheng transfer and Nanyang-Dengfeng transfer? 南阳新郑的交易收益和交易价格的组成？（0.74 元/方），南阳登封的交易收益和交易价格的组成（0.84 元/方）？

16. How about the reliability of the water for long-term transfer. How to solve the problem if the water is insufficient for the transfer? 长期水权交易的水量的保证率？如南阳和新密。如果不能保证用水量怎么办？

SEMI-STRUCTURED INTERVIEW QUESTIONNAIRE (CHAPTER 6)

Factor-group	Brief description of factor	Example questions
Policy arena	Zeitgeist/timing/policy window | political climate (namely who forms the government)|	Why did the Australian government, through AusAID and DAFF, decide to export knowledge about water management to China? Why was the collaboration between China and Australia initiated in 2006?
Policy arena	Occurrence or absence of existing relations between source, adopting and third party actors (for example, membership of international organizations; policy networks; colonial history; trade and cooperation relations).	How has the structural bilateral relationship between China and Australia shaped the project processes and interactions between the Department of Agriculture and the MWR on water management?
Policy features	Reputation of effectiveness/success |	To what extent do you agree with the statement that Australia is a good model for Chinese water markets? How has your perspective changed in the light of implementation experiences in China and of the challenges Australia is now facing? Why did China want Australian rather than other consultants and water-market experts to work on its water problem?
Policy features	Reputation of effectiveness/success |	How were the Australian water consultants chosen and why was Queensland selected?
Process design	Adoption mechanism | level of coercion |	To what extent were regulations and allocation principles from Australia transferred to fit Chinese contexts, as in Hangjin irrigation district, Inner Mongolia and Zhejiang province? Why did you chose these places? What practical steps/processes do you consider vital in developing these partnerships?
Process design	Policy consensus (broad coalition of domestic or external support| support from executive officials | key actors (policy entrepreneurs) | political leadership (for example, charismatic leader or human resource transfer)	What role did the director general of the MWR play in the process design and interaction between Australian and Chinese actors exchanging knowledge? How is the exchange of knowledge organized? Which actors support water markets? Which actors oppose water markets?
Institutional fit	Degree of matching transfer object and political objectives/institutional context |	How did the MWR shape the interaction between the Australian team and Chinese local governments? How does the MWR promote adoption of tradable water right policy at the local level?
General context	Bio-physical context | cultural context | socio-economic conditions |	What are the main differences between the Chinese and Australian context? There is a perception that water markets in China have "Chinese characteristics". What are these characteristics? What are the key differences between China and others?
Others	Open questions |	What are the three most important factors that facilitate the spread of tradable water-right policy in China at the local level? How would you rank those

		three factors and what is your justification? How do factors that facilitate the adoption of tradeable water right policy in China vary depending on different kinds of trading, such as user-level trading in Shiyang River 石羊河 and Shule River 疏勒河 to group-level trading in Inner Mongolia 内蒙古自治区 and regional-level trading in Henan 河南 province? What from Australia has worked in China and what has not? What lessons can we learn today from those historical experiences? What is the continued and ongoing impact in China due to the WET project and the ACEDP? What would you say are the main benefits these project have produced for China and its water management? What is the reversed learning from China to Australia?

Table 7. Causal conditions

Causal condition	Economic theory	Indicator	Previous calibration	Reference	Proposed Calibration and frequency (N)	Data Source
Natural infrastructure	SCARCITY: Water scarcity is a common motive for implementing water markets (Easter, Rosegrant and Dinar 1998)	Levels of water scarcity (total water consumption/ water quota of 2015)	Water stress index: >1= extreme; 0.4–1= severe; 0.2–0.4= moderate; 0–0.2= no stress	Zhao et al. (2015).	0–0.20= 0 (N=0) 0.20–0.4= 0.33 (N=1) 0.40–1= 0.67 (N=16) >1= 1 (N=12)	Water resources bulletins of provinces and prefecture-level cities
Physical human-made infrastructure	INFRASTRUCTURE Inadequate or disconnected supply and distribution infrastructure can be a barrier for implementation of water markets (Wheeler et al. 2017)	SNWDP and reservoirs enable long-distance transfers			Presence (=1) (N=13) or absence (=0) (N=16) of large scale transfer infrastructure in transactions	Scholarly reports, newspapers, government documents and interviews.
	STORAGE: Storage capacity can limit and/or facilitate water transfers to other uses or places (Marston and Cai 2016)	Storage capacity of completed reservoirs (10,000 cubic meters) (2000–15)			0–1000 000= 0 (N=7) 1000 000–1500 000= 0.33 (N=6) 1500 000–3000 000= 0.67 (N=4) >3000 000= 1 (N=12)	China Water Conservancy database: www.epschinadata.com/

Soft infrastructure	PRIVATE Well-defined and enforceable water rights separated from land promote efficiency gains and other benefits (Rosegrant and Binswanger 1994).	Private tradable water rights	Occurrence of privatization or absence of privatization	Liu, Peng and Zhang (2018).	Presence of private tradable water rights to households and WUA= 1 (N=8); absence of private tradable water rights= 0 (N=21)	Scholarly reports, newspapers, government documents and interviews.
	MARKET PRICE: A sufficient number of willing market participants with different opportunity cost of water improves the economic efficiency of markets. Empirical studies largely support markets moving water from low-value to higher-value uses (Leidner et al. 2011).	Price discovery	Presence of bargaining (capped water price) or absence of bargaining (fixed water price)	Liu, Peng and Zhang (2018).	Prices are fixed and decided by the government agency= 0 (N=6). Capped water price indicates whether the government has set a capped price but allows bargaining between seller/buyer= 0.67 (N=6). Free market price indicates whether the trading price is determined through bargaining= 1 (N=17)	Scholarly reports, newspapers, government documents and interviews.

	STATE: According to Meinzen-Dick (2014), coordination institutions become more formal and important as collective action challenges span across longer and larger scales.	Role of the local state	Leading= 1 partial-participation= 0–1; no participation (administration and supervision)= 0	Dai et al. (2017).	Administrative support and supervision by the local state unless trading period between irrigation water users is less than a year= 0 (N=7). Partial participation by the local state indicates whether the state implements material and funds compensation and/or pays the fees together with willing buyers of agricultural water= 0.67 (N=10). Leading role indicates whether the local state actively coordinates and participates directly in the market= 1 (N=12)	Scholarly reports, newspapers, government documents and interviews.
	PLATFORM: Water market intermediaries, such as water banks and exchanges, increases transparent information flows, bringing traders together and providing certain insurance to traders (Möller-Gulland and Donoso 2016).	% of the total volume traded in a city facilitated by a market intermediary	Strong intermediary capacity: 1 weak intermediary capacity: 0	Liu, Peng and Zhang (2018).	absence of intermediary = 0 (N=9) 0–40 % = 0.33 (N=4) <80 % = 0.67 (N=1) >80 % = 1 (N=15)	China Water Rights Exchange Co.; Inner Mongolia Autonomous Region Water Right Purchase, Storage and Transfer Centre; Henan Water Right Purchase, Storage and Transfer Centre; Guangdong Environmental Rights Exchange.

Human and social infra-structure	URBAN: Urban population growth influences water reallocation from rural to urban regions (Garrick et al. 2019)	Proportion of urban population (2004–15)	Urbanization rate (2000–14): 40–50% 50–60% 60–70% 7–80% 80–90% 90–100%	Chen et al. (2018).	<50% = 0 (N=10) 50–60% = 0.33 (N=2) 60–70% = 0.67 (N=8) >70% = 1 (N=9)	China City Database: www.epschinadata.com/
	GAP: Gains from trade facilitate a market (Wheeler et al. 2017)	Per capita annual income of urban and rural households (2004–16)	Ratio: 1–1.5 1.5–2 2–2.5 2.5–3 3–3.5 3.5–4	Chen et al. (2018).	2–2.5 = 0 (N=5) 2.5–3 = 0.33 (N=9) 3–3.5 = 0.67 (N=11) >3.5 = 1 (N=4)	China labor economy database: www.epschinadata.com/
Other causal conditions	PILOT: The state leans heavily on political and financial incentives embedded in the vertically oriented command and control system to induce compliance from local officials	Implementation of the central policy priority aiming at promoting water-rights trading		Eaton and Kostka (2018).	not selected as pilot province= 0 (N=11) 1 case= 0.33 (N=1) >1= 0.67 (N=7) >3= 1 (N=10)	Government documents from the MWR

Table 8. Necessity analysis

Condition	Consistency	Coverage
Water scarcity	0.81	0.71
~Water scarcity	0.21	0.72
Pilot status	0.68	0.91
~Pilot status	0.38	0.54
Market price	0.76	0.72
~Market price	0.28	0.70
Private tradable rights	0.11	0.29
~Private tradable rights	0.88	0.84
Local state involvement	0.78	0.83
~Local state involvement	0.26	0.51
Market platform	0.51	0.60
~Market platform	0.50	0.83
Storage provision	0.61	0.73
~Storage provision	0.40	0.64
Reservoir	0.49	0.76
~Reservoir	0.50	0.62
Urbanization	0.60	0.80
~Urbanization	0.41	0.59
Urban–rural income gap	0.48	0.67
~Urban–rural income gap	0.61	0.84

Table 9. Intermediate solution for the occurrence of higher levels of trading activity

Causal pathway	PLT*MP*PRV*~ST*PTF*~STG*~RSV	PLT*MP*~PRV*ST*PTF*~RSV	PLT*MP*~PRV*ST*~STG*~RSV	PLT*~MP*~PRV*ST*PTF*STG*RSV	~PLT*MP*~PRV*ST*~PTF*STG*RSV
Nickname	Path 1	Path 2	Path 3	Path 4	Path 5
Consistency	1	0.90	1	0.93	0.87
Raw coverage	0.04	0.16	0.23	0.23	0.23
Unique coverage	0.04	0.04	0.11	0.23	0.23
Cases covered	Wuwei (0.67,0.67)	Guangzhou (0.67,0.33); Huizhou (0.67,0.67); Wuhai (0.67,1); Alashan (0.67,1)	Yinchuan (0.67,1); Zhongwei (0.67,1); Baotou (0.67,1); Bayannur (0.67,1); Wuhai (0.67,0.67); Alashan (0.67,1); Erdos (0.67,1)	Xinmi (1,1); Xinzheng (1,1); Dengfeng (1,1); Pingdingshan (1,0.67); Nanyang (1,1)	Cixi (1,1); Dongyang (1,1), Yiwu (0.67,1); Shaoxing (0.67,0.67); Bijie (0.67,0); Pingxiang (0.67,1)
Solution consistency	0.922				
Solution coverage	0.801				

***Note:* *=**and; +=or: = ~absence of; → sufficient for

Table 10. Intermediate solution for the occurrence of lower levels of trading activity

Causal pathway	~PLT*MP*PRV*~ST*PTF*~RSV	~PLT*~MP*~PRV*ST*PTF*STG*RSV	~PLT*MP*PRV*ST*PTF*~STG*RSV
Nickname	Path 1	Path 2	Path 3
Consistency	0.90	1	1
Raw coverage	0.37	0.07	0.07
Unique coverage	0.37	0.07	0.07
Cases covered	Hangzhou (1,1); Taiyuan (0.67,1); Changji (0.67,0.33); Shijiazhuang (0.67,1)	Anshun (0.67,1)	Yuncheng (0.67,0.67)
Solution consistency	0.932		
Solution coverage	0.519		

Note: ***=**and; +=or: = ~absence of; → sufficient for

Table 11. Raw transaction-data matrix

City	Annual trading volume (million m^3)	Water quota (2015)	Trading volume as a % of total water quota	Number of transactions
Yiwu	49.99[a]	3.03×10^8	16.5	1
Dongyang	49.99[a]	2.681×10^8	18.65	1
Cixi	66.67[b]	2.42×10^8	27.5	1
Shaoxing	66.67[b]	21.9×10^8	3.04	1
Xinmi	8[c]	1.619×10^8	4.72	1
Xinzheng	80[c]	1.785×10^8	44.81	1
Dengfeng	20[c]	1.535×10^8	13.03	1
Pingdingshan	8[c]	12.05×10^8	0.66	1
Nanyang	100[c]	28.06×10^8	3.56	2
Guangzhou	5.146[d]	49.52×10^8	0.103	1
Huizhou	5.146[d]	21.94×10^8	0.23	1
Pingxiang	62.05[e]	10.58×10^8	5.86	1
Anshun	0.79[c]	9.43×10^8	0.08	2
Bijie	0.46[f]	15.72×10^8	0.029	1
Yuncheng	1.8[c]	16.66×10^8	0.108	1
Hangzhou	0.1[g]	38×10^8	0.0026	1
Yinchuan	271.15[c, h]	16.72×10^8	16.21	30
Zhongwei	24.4[c, h]	11.21×10^8	2.17	21
Baotou	15.6[h]	10.88×10^8	1.43	3
Bayannur	60.45[h, i]	50.31×10^8	1.2	7
Wuhai	10.52[c, h]	3.13×10^8	3.36	38
Alashan	10.26[c, h]	4.9×10^8	2.09	21
Erdos	308.08[c, h]	16.58×10^8	18.58	54
Wuzhong	3.28[c, j]	14.74×10^8	0.22	5
Wuwei	3.95[c, k]	16.43×10^8	0.24	116
Zhangye	1.1[l]	23×10^8	0.0478	4
Taiyuan	0.03382[c]	7.51×10^8	0.0045	57
Changji	19.1[c, m]	23.31×10^8	0.82	4
Shijiazhuang	0.0026[c]	33×10^8	0.000078	13

[a]Wang, Y. 2018. *Assessing Water Rights in China*. Singapore: Springer Nature.

[b]Chinanews 2003. Zhejiang water rights transfer adds a new version, Cixi spends 700 million to buy water from Shaoxing. *Chinanews*, 15 January 2003. https://www.chinanews.com/n/2003-01-15/26/263915.html

[c]CWEX 2020. Transaction listing. http://cwex.org.cn/lising/

[d]Water Resources Department of Guangdong province 2018. Guangzhou and Huizhou water rights transaction information announcement. http://slt.gd.gov.cn/jcgk8785/content/post_912809.html

[e]Jxnews (2015). Shankouyan Reservoir completes cross-basin water rights transaction, creating Jiangxi water rights transaction. *Jxnews*, 30 December 2015. http://jiangxi.jxnews.com.cn/system/2015/12/30/014578899.shtml

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[l] Han, H., Zhao, L. and Wang, X. (2010). Conditions for the transfer of agricultural water rights: Empirical research based on typical irrigation areas in Gansu and Inner Mongolia. *Journal of China population, Resources and Environment*, 20 (3), 100–6. https://www.cnki.com.cn/Article/ CJFDTotal-ZGRZ201003020.htm

[m]Jiang, Q. (2017). Legal thoughts on agricultural water rights transaction in Xinjiang- Taking Changji Prefecture as an example. *Journal of Kashgar University*, 38 (1), 29–31. DOI: 10.13933/j.cnki. 2096-2134.2017.01.008

Table 12. Raw data for causal conditions

City	Trading year(s)	Total water consumption as percentage of the total water quota[a]	% of trading transactions brokered by a market intermediary[b]	Storage Capacity of Completed Reservoirs (10,000 cubic meters)[c]	Ratio of per capita annual income of urban and rural households[d]	Proportion of urban population[e]
Yiwu	2000-ongoing	95	0	3987449.6	2.32	64.5
Dongyang	2000-ongoing	101.9	0	3987449.6	2.32	64.5
Cixi	2003-ongoing	109.5	0	3987449.6	2.32	71.1
Shaoxing	2003-ongoing	91	0	3987449.6	2.32	63.2
Xinmi	2016-2019	83.5	100	4038043.8	2.78	69.6
Xinzheng	2017-2020	84.1	100	4038043.8	2.78	69.6
Dengfeng	2017-2020	80.9	100	4038043.8	2.78	69.6
Pingdingshan	2016-2019	90.2	100	4038043.8	2.78	49.1
Nanyang	2017-2020	82.3	100	4038043.8	2.78	41.3
Guangzhou	2017-ongoing	133.9	100	4454177.4	2.94	85.5
Huizhou	2017-ongoing	96.21	100	4454177.4	2.94	68.1
Pingxiang	2015-ongoing	71.2	0	2906680.2	2.61	65.8
Anshun	2019-ongoing	86.5	100	2202931.8	3.94	44.0
Bijie	2017-ongoing	73	0	2202931.8	3.94	30.9
Yuncheng	2016-2021	101	100	591212.3	3.01	46.1
Hangzhou	2015-2018	105	100	3987449.6	2.32	75.3
Yinchuan	2003-ongoing	138	10	236208.3	3.1	75.8
Zhongwei	2003-ongoing	119	4.76	236208.3	3.1	39
Baotou	2003-ongoing	93.4	0	1177888.9	3.05	82.6
Bayannur	2003-ongoing	97.5	0	1177888.9	3.05	52.5
Wuhai	2003-ongoing	89.9	97.3	1177888.9	3.05	94.5
Alashan	2003-ongoing	195	95	1177888.9	3.05	76.8
Erdos	2003-ongoing	98	51.8	1177888.9	3.05	73.1
Wuzhong	2015-ongoing	104	60	236208.3	3.8	45.8
Wuwei	2008-ongoing	124.7	100	943523.5	3.8	35.9
Zhangye	2002-2005	98	0	943523.5	3.8	42.1
Taiyuan	2019-ongoing	100.6	100	591212.3	3.01	84.4
Changji	2015-ongoing	164.5	100	1211455.0	3.09	41.3
Shijiazhuang	2019-ongoing	27.2	100	1713730.3	2.57	58.3

[a]Gansu Water Resources Bulletin. http://slt.gansu.gov.cn/xxgk/gkml/nbgb/szygb/; Guangdong Water Resources Bulletin. http://swj.gd.gov.cn/tjxx_szygb/index.html; Guizhou Water Resources Bulletin. http://mwr.guizhou.gov.cn/slgb/slgb1/; Hebei Water Resources Bulletin. http://slt.hebei.gov.cn/a/zwzx/zwgk/; Henan Water Resources Bulletin. http://slt.henan.gov.cn/bmzl/szygl/szygb/; Inner Mongolia Water Resources Bulletin. http://slt.nmg.gov.cn/xxgk/jcms_files/jcms1/web2/site/col/col56/index.html; Jiangxi Water Resources Bulletin. http://slt.jiangxi.gov.cn/col/col27420/index.html; Jinhua Water Resources Bulletin. http://slj.jinhua.gov.cn/col/col1229282095/index.html; Ningbo Water Resources Bulletin. http://slj.ningbo.gov.cn/col/col1229051287/index.html; Ningxia Water Resources Bulletin. http://slt.nx.gov.cn/pub/NXSLTGW05/SLZW_4294/ZFXXGK/GKML/GBXX/SZYGB/; Shanxi Water Resources Bulletin. http://slt.shanxi.gov.cn/zncs/szyc/szygb/; Xinjiang Water Resources Bulletin. http://slt.xinjiang.gov.cn/slt/szygb/list.shtml; Zhejiang Water Resources Bulletin. http://www.zjsw.cn/pages/nav.jsp?catId=1029; Zhengzhou Water Resources Bulletin. http://public.zhengzhou.gov.cn/D12Y/4670892.jhtml

[b]China Water Rights Exchange Co., Ltd 中国水权交易所. http://cwex.org.cn/; Guangdong Environmental Rights Exchange Co. Ltd 广东省环境权益 交易所. http://www.gdhjs.com/; Henan Water Rights Purchase, Storage and Transfer Center 河南省水权收储 转让中心. http://www.hnshuiquan.com/; Inner Mongolia Autonomous Region Water Rights Purchasing, Storage and Transfer Centrw 内蒙古自治区水权收储转让中心. http://www.nmgsqjyw.com/

[c]China Water Resources Database. http://www.epschinadata.com/data-resource.html

[d]China Labor Economy Database. http://www.epschinadata.com/data-resource.html

[e]China City Database. http://www.epschinadata.com/data-resource.html

Table 13. Raw data matrix

City	scarcity	reservoir	storage	private	state	market price	platform	pilot	urban	gap
Yiwu	95	1	3987449.6	0	1	1	0	0	64.5	2.32
Dongyang	101.9	1	3987449.6	0	1	1	0	0	64.5	2.32
Cixi	109.5	1	3987449.6	0	1	1	0	0	71.1	2.32
Shaoxing	91	1	3987449.6	0	1	1	0	0	63.2	2.32
Xinmi	83.5	1	4038043.8	0	1	0	100	5	69.6	2.78
Xinzheng	84.1	1	4038043.8	0	1	0	100	5	69.6	2.78
Dengfeng	80.9	1	4038043.8	0	1	0	100	5	69.6	2.78
Pingdingshan	90.2	1	4038043.8	0	1	0	100	5	49.1	2.78
Nanyang	82.3	1	4038043.8	0	1	0	100	5	41.3	2.78
Guangzhou	133.9	0	4454177.4	0	0.67	1	100	2	85.5	2.94
Huizhou	96.21	0	4454177.4	0	0.67	1	100	2	68.1	2.94
Pingxiang	71.2	1	2906680.2	0	1	1	0	1	65.8	2.61
Bijie	73	1	2202931.8	0	1	1	0	0	30.9	3.94
Anshun	86.5	1	2202931.8	0	1	0	100	0	44.0	3.94
Yuncheng	101	1	591212.3	1	0.67	1	100	0	46.1	3.01
Hangzhou	105	0	3987449.6	1	0	1	100	0	75.3	2.32
Yinchuan	138	0	236208.3	0	0.67	1	0.29	3	75.8	3.1
Zhongwei	119	0	236208.3	0	0.67	1	4.97	3	39	3.1
Baotou	93.4	0	1177888.9	0	0.67	1	0	5	82.6	3.05
Bayannur	97.5	0	1177888.9	0	0.67	1	0	5	52.5	3.05
Wuhai	89.9	0	1177888.9	0	0.67	1	88.37	5	94.5	3.05
Alashan	195	0	1177888.9	0	0.67	1	79.86	5	76.8	3.05
Erdos	98	0	1177888.9	0	0.67	1	20.29	5	73.1	3.05
Wuwei	104	0	943523.5	1	0	0.67	100	2	35.9	3.8
Wuzhong	124.7	0	236208.3	1	0	0.67	100	3	45.8	3.1
Zhangye	98	0	943523.5	1	0	0.67	0	2	42.1	3.8
Taiyuan	100.6	0	591212.3	1	0	0.67	100	0	84.4	3.01
Changji	164.5	0	1211455.0	1	0	0.67	100	0	41.3	3.09
Shijiazhuang	27.2	0	1713730.3	1	0	0.67	100	0	58.3	2.57

Table 14. Calibrated raw data matrix

City	TRADING	SCARCITY	RESERVOIR	STORAGE	PRIVATE	STATE	MARKET PRICE	PLATFORM	PILOT	URBAN	GAP
Yiwu	1	0.67	1	1	0	1	1	0	0	0.67	0
Dongyang	1	1	1	1	0	1	1	0	0	0.67	0
Cixi	1	1	1	1	0	1	1	0	0	1	0
Shaoxing	1	0.67	1	1	0	1	1	0	0	0.67	0
Xinmi	1	0.67	1	1	0	1	0	1	1	0.67	0.33
Xinzheng	1	0.67	1	1	0	1	0	1	1	0.67	0.33
Dengfeng	1	0.67	1	1	0	1	0	1	1	0.67	0.33
Pingdingshan	0.67	0.67	1	1	0	1	0	1	1	0	0.33
Nanyang	1	0.67	1	1	0	1	0	1	1	0	0.33
Guangzhou	0.33	1	0	1	0	0.67	1	1	0.67	1	0.33
Huizhou	0.67	0.67	0	1	0	0.67	1	1	0.67	0.67	0.33
Pingxiang	1	0.67	1	0.67	0	1	1	0	0.33	0.67	0.33
Bijie	0	0.67	1	0.67	0	1	1	0	0	0	1
Anshun	0	0.67	1	0.67	0	1	0	1	0	0	1
Yuncheng	0.33	1	1	0	1	0.67	1	1	0	0	0.67
Hangzhou	0	1	0	1	1	0	1	1	0	1	0
Yinchuan	1	1	0	0	0	0.67	1	0.33	0.67	1	0.67
Zhongwei	1	1	0	0	0	0.67	1	0.33	0.67	0	0.67
Baotou	1	0.67	0	0.33	0	0.67	1	0	1	1	0.67
Bayannur	1	0.67	0	0.33	0	0.67	1	0	1	0.33	0.67
Wuhai	1	0.67	0	0.33	0	0.67	1	1	1	1	0.67
Alashan	1	1	0	0.33	0	0.67	1	0.67	1	1	0.67
Erdos	1	0.67	0	0.33	0	0.67	1	0.33	1	1	0.67
Wuzhong	0.67	1	0	0	1	0	0.67	0.33	0.67	0	0.67
Wuwei	0.67	1	0	0	1	0	0.67	1	0.67	0	1
Zhangye	0	0.67	0	0	1	0	0.67	0	0.67	0	1
Taiyuan	0	1	0	0	1	0	0.67	1	0	1	0.67
Changji	0.67	1	0	0.33	1	0	0.67	1	0	0	0.67
Shijiazhuang	0	0.33	0	0.67	1	0	0.67	1	0	0.33	0.33

Table 15. Case-studies: calibration justifications for the causal conditions pilot status, private tradable water rights, role of the local state, price discovery and inter-basin transfer infrastructure

Case(s)	Erdos, Baotou, Wuhai, Alashan, and Bayannur	
Province	Inner Mongolia	
Pilot status	1	The MWR issued two policy-documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of the Yellow River in Inner Mongolia province and Ningxia province." (MWR 2004, No. 159); and "Notice on carrying out the pilot work on water rights" (No. 222). In addition, in 2016 the MWR issued provisional measures to administer water-rights trading across China (MWR 2016). Inner Mongolia was selected as a pilot province and it has multiple cities that have adopted water markets. Thus, we calibrated this condition as 1.
Private tradable water rights	0	Wang (2018:190) reports that "the right buyers are the enterprises of independent accounting that have emerged in the market-oriented reform and they are true market players. But the rights assigner is the irrigation area, which is not an independent market player. This is also true in other places. The current rural water withdrawing groups are mostly public organizations or state-owned units, which are not market players in the true sense. To stimulate the water rights transfer from agriculture to non-agricultural departments, local government exercises the rights on behalf of the rural areas, that is a most cost-economizing institutional arrangement." The informant in Hohhot stated that "the government has an enforceable quantity cap that limits the water resources used in an area. Based on that cap, entitlements are defined and distributed to different enterprises on behalf of the government" (HH180403). Due to local government control of water rights, this condition was coded 0.
Role of the local state	0.67	The local government is responsible for the approval process and feasibility assessment. The Irrigation district authority is responsible for water conservation implementation and the enterprises are responsible for transferring the money (HH180403). An evaluation of water transfer compensation classification of China by Dai et al. (2017) confirms this. Thus, this condition was coded 0.67.
Price discovery	1	The transfer price of water rights is 1.03 yuan/cubic meter, including five items: 1. Construction cost of water-saving project (15.00 yuan per cubic meter); 2. Operation and maintenance cost of water-saving project and water measuring facility (7.50 yuan per cubic meter); 3. Renewal and reconstruction fees for water-saving projects (1.085 yuan per cubic meter); 4. Compensation for agricultural losses due to high guarantee rate for industrial water supply; 5. Necessary compensation for economic benefits and ecological compensation (CWEX 2017). In addition, two informants who worked on implementing the agreements stated that the water price was market-based (BJ180323). Thus, this condition was coded 1.
Inter-basin transfer infrastructure	0	The informant in Hohhot stated that reservoirs are not used to enable transactions but that companies invest in water-saving projects, including canal lining (HH180403). A news-report by *Inner Mongolia Daily* (24 August 2016) stated that "the transfer of water rights is to transform water-saving projects in Hetao Irrigation District and transfer the water saved by

		agriculture to industrial projects along the Yellow River." Thus, this outcome was coded 0.
Case(s)	Yinchuan, Zhongwei and Wuzhong	
province	Ningxia	
Pilot status	0.67	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the nationwide pilot work on water rights" (MWR 2014, No. 222). In addition, the MWR issued in 2016 provisional measures to administer water-rights trading across China (MWR 2016). Ningxia is a pilot province with multiple cities which have adopted water markets. This condition was calibrated as 0.67.
Private tradable water rights	0 (Zhongwei, Yinchuan), 1 (Wuzhong)	Wang (2018: 75) reports that Ningxia province is an example of long-term water-rights trading at the group level where water rights holders at the group-level include irrigation control organizations, water supply organizations or water supply enterprises. Interviews with two experts confirm that the trading transactions in Yinchuan and Zhongwei refer to water rights holders at the group-level whereas Wuzhong has finished the allocation of water entitlements to WUAs (BJ180323). Thus, this condition was coded 0 for Yinchuan and Zhongwei and 1 for Wuzhong.
Role of the local state	0.67 (Zhongwei, Yinchuan), 0 (Wuzhong)	An industrial project invests in construction of water conservation rehabilitation projects in an irrigation district and acquires the portion of water under the irrigation district's water abstraction permit saved from irrigation through the investment (Jiang 2017: 175). The trading agreements in Ningxia are regulated according to the "water rights management method in Ningxia" (宁夏回族自治区水资源使用权用途管制管理办法) and "water rights transfer management method in Ningxia" (宁夏水权交易管理办法) by the local government. In Zhongwei and Yinchuan, the administration bureau of the irrigation districts and the enterprises negotiates the agreement, and at and above the county level the local government approves the trading agreements and implements material and fund compensation, such as canal linings, to secure water to the buyers (Yuan et al. 2007). In Wuzhong, local WUAs negotiate the trading of agricultural water rights on behalf of farmers, but the final agreement is approved and registered through the CWEX platform (BJ180323). Thus, this condition was coded 0.67 for group-level trading in Yinchuan and Zhongwei and 0 for user-level trading in Wuzhong.
Price discovery	1 (Yinchuan, Zhongwei); Wuzhong (0.67)	Two experts provided their views on this calibration. They both stated that the group-level transactions in Yinchuan, Zhongwei are based on price bargaining between sellers and buyers and not decided by the government, whereas the user-level trading in Wuzhong involves capped pricing (BJ180323).
Inter-basin transfer infrastructure	0	Jiang (2018: 92) reports that "as the absolutely dominant water-using sector in Ningxia and Inner Mongolia, agriculture has great potential in water saving by improving its water use efficiency. The challenge, however, is the difficulty in water conservation financing for most of the aged and badly maintained irrigation facilities." Two experts confirmed that enterprises secure water through irrigation efficiency improvements (BJ180323). For example, from

		2013 to 2016, the effective utilization coefficient of farmland irrigation in Ningxia province increased from 0.46 to 0.51 (Wei 2018).
Case(s)	Yiwu, Dongyang, Cixi, Shaoxing, and Hangzhou	
province	Zhejiang	
Pilot status	0	The MWR issued two policy-documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province." (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). In addition, the MWR issued in 2016 provisional measures to administer water-rights trading across China (MWR 2016). Since Zhejiang was not mentioned as a pilot province, we calibrate this condition as 0.
Private tradable water rights	0 (Yiwu, Dongyang, Cixi, Shaoxing), 1 (Hangzhou)	Yiwu-Dongyang and Cixi-Shaoxing refers to the trade of long-term water access rights between regional governments (Wang 2018). In Dongtiao river in Hangzhou city, water entitlements were clearly defined for industrial water users and the WUAs got certificates verifying their ownership of the water resources in the communal reservoirs (Liu et al. 2018; Zhejiang Channel 2015). Thus, we calibrated this condition 0 for Yiwu, Dongyang, Cixi and Shaoxing while 1 for Hangzhou.
Role of the local state	1 (Yiwu, Dongyang, Cixi, Shaoxing); 0 (Hangzhou)	Jiang (2018: 87) reports that "Dongyang transferred the water use right of 50 million cubic metres of Hengjin Reservoir to Yiwu for RMB 200 million yuan based on the following conditions: • The transfer of water use rights does not change the original ownership of Hengjin Reservoir and Dongyang is still responsible for the reservoir's operation and maintenance. • Yiwu pays RMB 0.1 yuan per cubic metre as a comprehensive management fee to Dongyang based on the actual amount of water supplied to it every year. The fee consists of the water resources fee, the cost of the reservoir operation and maintenance, the reservoir depreciation, major repairs, the environmental protection fee, taxes and profits. • Yiwu is responsible for the planning and investment of the construction of the water diversion project from Hengjin Reservoir to Yiwu. As to the part falling within Dongyang's territory, Yiwu is responsible for the costs while Dongyang is in charge of the construction. In January 2005, the water diversion project involved in this water trade was completed after three years of construction. Hengjin Reservoir began to supply water for Yiwu users. As a result of the fulfilment of the agreement, Dongyang-Yiwu water trade was praised as a win–win deal. The cost of water supply per cubic metre for Dongyang is less than RMB 1.00 yuan. Yiwu, the purchaser, would need to spend RMB 6.00 yuan for per cubic metre water if it built a new reservoir". In the second long-term water use rights transfer, the local governments of Cixi and Shaoxing facilitated the agreement. In this case, the local governments determine the amount of water transferred, the terms of transfer and compensation amount (BJ180323). Against this background, we calibrated this condition as 1 (Yiwu-Dongang, Cixi-Shaoxing), indicating full participation by the local governments. In Hangzhou city, the local government assessed and approved the transaction between the two companies who negotiated the trading price (Liu,

		Peng and Zhang 2018; Zhejiang Channel 2015). Thus, this condition was calibrated as 0.
Price discovery	1 (Yiwu, Dongyang, Cixi, Shaoxing and Hangzhou)	Wang (2018: 192) reports that "Yiwu is economically well developed and can pay the cost from its own pocket. If Yiwu had opted for reliance on the superordinate organs, the city would have to wait and it does not pay off to have the little subsidy from the superordinate finance. In such circumstances, Yiwu opted wisely for its independent solution and realized water rights turnover through market means. The reason why Yiwu opted to buy water instead of asking the superordinate organs for water quota through administrative procedures is that the cost of buying water is far less than the cost of the administrative procedures". Two experts stated that the trading transactions between Yiwu-Dongyang, Cixi-Shaoxing and in Hangzhou were associated with free market pricing where the trading price is determined through bargaining (BJ180323). In addition, Liu et al. (2018a) calibrated the trading in Hangzhou as free-market price. Thus, this condition was calibrated as 1.
Inter-basin transfer infrastructure	1 (Yiwu, Dongyang, Cixi, Shaoxing), 0 (Hangzhou)	Towards the end of 2000, Yiwu City in the Central Zhejiang basin bought permanent water use rights of nearly 50 million m^3 of water for 200 million yuan from its neighbouring city of Dongyang (Wang 2018). The Yiwu-Dongyang long-term water rights transfer used the Hengjing reservoir to implement the transfer. The normal storage capacity of Hengjing reservoir in Dongyang is 166.62 million m^3 (Chinanews 2001). The Cixi-Shaoxing long-term water rights transfer used the Shaoxing Tangpu reservoir to implement the agreement. The normal storage capacity of Tangpu reservoir is 185 million m^3 (Shi et al. 2015). The trading between Qingshan Lake Vegetable Company Ltd (青山湖蔬菜有限公司) and the Hangzhou Huawang New Materials Technology Company Ltd, Hangzhou (杭州华旺新材料科技有限公司) did not rely on reservoirs or other large-scale infrastructure (BJ180323). Thus, we coded 1 for Yiwu, Dongyang, Cixi and Shaoxing while 0 for Hangzhou.
Case(s)	Xinmi, Pingdingshan, Xinzheng, Nanyang, and Dengfeng	
province	Henan	
Pilot status	1	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). In addition, in 2016 the MWR issued provisional measures to administer water-rights trading across China (MWR 2016). We calibrate this condition as 1 because Henan was mentioned as a pilot province from 2014 onwards.
Private tradable water rights	0	The current surplus is 500–600 million cubic meters along the Middle Routes of the SNWDP. Its calculation is based on current water use and future water demand (ZH191121). Henan province spans four major river basins of the Yangtze, Huaihe, Yellow and Haihe rivers. The main canal of the SNWDP connects the four major watersheds and each water receiving area in the province has water consumption indicators from the Danjiang River. The amount of surplus water has laid the foundation for water trading (Xinhua

		2017). Since the local government governs and controls water rights at the regional level, we calibrate this condition as 0.
Role of the local state	1	Multiple government agencies are involved in the trading transactions along the SNWDP in Henan province. The Henan provincial government, not local government authorities, fix and regulate the trading price. However, the local water agencies that want to trade the water negotiate the trading volume. The national water exchange platform, CWEX, administers and approves the trading while the provincial water authority and the SNWDP's Construction and Administration Bureau of Middle Routes monitors the reallocation of water between willing buyers and sellers (ZH191121). Thus, this condition was calibrated as 1, indicating full government participation.
Price discovery	0	Wang (2018: 11) states that "the initial allocation of water rights in the South-to-North Water Transfer Project introduced market mechanisms, at least to a certain degree; however, the rights have not completely achieved market-allocation status. In fact, the project is directed by the central authorities, with investment from the central and provincial financial departments, and aims to resolve water resource shortages in the Yellow, Huaihe and Haihe basins. This project's initial allocation of water rights incorporates administrative and market methods, and its basic operation is based on the regulation of water supply between superordinate and subordinate decision-making entities". Water volumes are negotiated by the local government's water conservancy department. The transaction is reviewed by the Water Resources Department and monitored by the South-to-North Water Transfer Control Center. The water supply guarantee rate is not clearly stipulated, and the indicator is allocated according to water consumption in a normal water year and adjusted according to the incoming water situation every year (ZH191121). Prices are fixed and determined by the Henan provincial government and therefore calibrated as 0.
Inter-basin transfer infrastructure	1	Regional-level water-rights trading in Henan relied on the Middle Routes of the SNWDP (Xinhua 2017). In addition, several reservoirs were used to reallocate water: Jiangang (尖岗) reservoir and Yunmengshan (云蒙山) reservoir (Xinmi-Pingdinshan), Baisha (白沙) reservoir and Zhifang (纸坊) reservoir (Xinzheng-Nanyang, Dengfeng-Nanyang). Thus, this condition was calibrated as 1.
Case(s)	Guangzhou and Huizhou	
province	Guangdong	
Pilot status	0.67	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0.67 because Guangdong was mentioned as a pilot province from 2014 onwards.
Private tradable water rights	0	The Dongjiang river basin authority and the local water agencies in Guangzhou and Huizhou are in charge of water resources and manage water rights through licensing water withdrawals to enterprises (Sinanews 2017). Two experts confirmed this and referred the transaction between Guangzhou and Huizhou as "water use control index trading" (BJ180323). We calibrated this condition as 0.

Role of the local state	0.67	The Guangdong Environmental Rights Exchange brokered the agreement between the two companies, and the local governments implemented the water-saving measures to secure water to the buyer (Guangzhou). The amount of water transferred is the amount saved through water-saving measures (Che 2018). The local government of Huizhou implemented water-saving transformation projects of irrigation districts to improve water use efficiency (Sinanews 2017). This condition was calibrated as 0.67.
Price discovery	1	Although the river basin authority of Dongjiang Basin and local governments control and regulate the regional water rights, the two enterprises in Huizhou and Guangzhou negotiate the water price (BJ180323). This condition was calibrated as 1.
Inter-basin transfer infrastructure	0	The group-level transactions between companies in Guangzhou and Huizhou did not require inter-basin infrastructure such as reservoirs but used inter-basin connectivity along the Dongjiang River (Sinanews 2017). Two experts confirmed this (BJ180323). Thus, this condition was calibrated as 0.
Case(s)	Pingxiang	
province	Jiangxi	
Pilot status	0.33	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0.33 because Jiangxi was mentioned as a pilot province from 2014 onwards.
Private tradable water rights	0	The water authorities in Luxi county and Pingxiang city control and manage the water rights at the regional level (Jxnews 2015). This condition was coded as 0.
Role of the local state	1	The local governments in Luxi county and Pingxiang determines the transfer amount, trading price and transfer content (BJ180323). This condition was calibrated 1, indicating full participation by the local government(s).
Price discovery	1	Price bargaining is done by the local governments according to two experts involved in water-rights trading transactions in China (BJ180323). Thus, the condition is calibrated as 1.
Inter-basin transfer infrastructure	1	The long-term water rights transfer between Pingxiang city and Luxi county used the Shankouyan (山口岩) reservoir to redistribute water (Jxnews 2015). Thus, this condition was calibrated as 1.
Case(s)	Anshun and Bijie	
province	Guizhou	
Pilot status	0	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0 because Guizhou was never mentioned as a pilot province.

Private tradable water rights	0	In both Bijie and Anshun, local governments are the decision-making entities that hold the water rights and control/manage the water resources (BJ180323). We, therefore, calibrated this condition as 0, indicating local water agencies in charge of water entitlements without the occurrence of privatization of entitlements.
Role of the local state	1	The decision-making entity is the local government which determines the volume, price and period. We calibrated this condition as 1.
Price discovery	0 (Anshun); 1 (Bijie)	According to two experts involved in water rights transactions across China, the water price in Anshun between Guizhou Maomaodong reservoir management office (seller) to the China Resources Cement Co. Ltd (buyer) was fixed and determined by the local government (BJ180323). However, in Bijie, the local governments negotiated the price through bargaining (BJ180323). This condition was calibrated as 0 (Anshun) and 1 (Bijie).
Inter-basin transfer infrastructure	1	Yulong town in Bijie city secured water rights from Niupeng town in Bijie city from the Dengjiaying (邓家营) reservoir (DDCPC 2017). Moreover, Anshun city used the Maomaodong (猫猫洞) reservoir to redistribute water from the Guizhou Maomaodong reservoir management office (seller) to the China Resources Cement Co. Ltd (buyer) (BJ180323)). Thus, this condition was calibrated as 1.
Case(s)	Taiyuan and Yuncheng	
province	Shanxi	
Pilot status	0	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0 because Shanxi was never mentioned as a pilot province.
Private tradable water rights	1 (Taiyuan; Yuncheng)	Qingxu district in Taiyuan has implemented the water property reform and water entitlements have been allocated to households in irrigation districts that can trade water (TY181129). In Yuncheng, the officials stated that "we have capped the water use based on the initial water rights system, the water users who have saved water under their quota are allowed to sell the water in the market. In Huaiquan irrigation district (槐泉), the total water allocation quota is 480 x 10^4 m³ and 300 x 10^4 m³ is allowed for irrigation and 180 x 10^4 m³ can be used/transferred to industries. This quota does not change much over time. In terms of water rights, a water-use cap is allocated to the household level. Among farmers, there is little trading going on and they do not use the platform" (YC180330). Thus, we calibrated this condition as 1 for both Taiyuan and Yuncheng.
Role of the local state	0 (Taiyuan); 0.67 (Yuncheng)	The role of the local government in Yuncheng is similar to the cases in Inner Mongolia. The company and the irrigation district authority negotiate the trading content while the local government uses the investments to modernize the irrigation district infrastructure. As stated by the officials, "administrative support from local government has enabled trading. Without governmental assessments of hydrology, initial allocation of water rights and infrastructure development, it would be difficult to set up a trading scheme" (YC180330). In Qingxu district, Taiyuan, the role of the county-level government is to approve trading transactions among agricultural users. Moreover, the county-level

		government provides electricity price incentives to both buyers and sellers who trade on the platform at a price of 0.05 RMB/m^3 (TY181129; Shanxi News Network 2018). We calibrate this condition as 0.67 for Yuncheng and 0 for Taiyuan.
Price discovery	0.67 (Taiyuan); 1 (Yuncheng)	Prices for agricultural trading in Taiyuan are capped to three times the annual water resources fee (TY181129; see also Shanxi Provincial Department of Water Resources (2018). By contrast, price bargaining is not excluded from the water trade negotiations between Shanxi Zhongshe Huajin Foundry Co. Ltd and Huaiquan Irrigation District, Yuncheng, Shanxi. CWEX (2016) states that "the transaction price comprehensively considered the water resource fee, water supply cost fee, measurement and monitoring facility fee, water rights transaction management fee, tax fee and other factors. The transaction unit price was 1.2 yuan per cubic meter, and the total transaction price for five years was 10.8 million yuan. After the expiration of this transaction period, the transaction price will be determined separately when both parties renew the transaction."
Inter-basin transfer infrastructure	1 (Yuncheng); 0 (Taiyuan)	The inter-sectoral trading in Yuncheng, Shanxi province relied on investment in irrigation efficiency and other measures to reduce losses but also required transfers from the Liceyu reservoir (CWEX 2016). Ground-water trading in Taiyuan did not use reservoirs (TY181129). Therefore, we calibrated this condition as 1 for Yuncheng and 0 for Taiyuan in Shanxi.
Case(s)	Changji	
province	Xinjiang	
Pilot status	0	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0 because Xinjiang was never mentioned as a pilot province.
Private tradable water rights	1	Changji Hui Autonomous Prefecture has finished the privatization process of water entitlements to end users where farmer associations, on behalf of farmers, are able to sell/buy water. In 2014, the local government of Changji formulated a reform plan and issued the "Initial Agricultural Water Rights Allocation and Water Quantity Payment Measures". Together with the MWR, they issued initial water rights certificates (cards) for agricultural water users and a total of 143,100 copies were issued and the distribution rate reached 100% (Li et al. 2017: 18). Therefore, we calibrate this condition as 1.
Role of the local state	0	The local government has combined water entitlement and pricing reforms with the adoption of agricultural high-efficiency water saving technology to promote the progress of agricultural water-rights trading. It has also rolled out automatic monitoring to control water usage in the irrigation districts. The transactions between farmers is carried out under the supervision of the WUA and the tradable period of water rights is one year. The role of the WUA is to standardize the operation of transactions and their tasks include appointments, transactions and income distribution. Transaction volumes that exceed 1000 m^3 are reported to water administrative department for approval (Yang and Zhu 2018: 36). The irrigation districts (or towns) that meet the requirements of agricultural irrigation water in the irrigation districts and whose water savings

		are less than 200,000 m^3 are subject to the approval of the watershed management department and payment to the watershed management department for transactions (Ibid.). We calibrate this condition as 0.
Price discovery	0.67	Price bargaining is done by the agricultural water users but it is capped by the local government according to two experts involved in water-rights trading transactions in China (BJ180323). The government repurchases water from farm households at bottom price of not less than three times the amount of water saved in the initial water rights (Li et al. 2017). In terms of irrigation agricultural trading, the price cannot exceed three times the benchmark price. According to Yang and Zhu (2018: 36), "the transaction price is determined by the market supply and demand, the principle of reasonable income, consideration of water scarcity and water-saving investment and the cost of measurement and testing facilities. Based on this, the two parties shall determine the price through consultation." Against this background, we calibrate this conditions as 0.67.
Inter-basin transfer infrastructure	0	Agricultural water trading among farmers' associations did not rely on reservoirs or other large-scale infrastructure to enable the transactions (BJ180323). In addition, academic papers associated with water-rights trading in Changji do not mention reservoirs or large-scale infrastructure (Jiang 2017; Li et al. 2017; Yang and Zhu 2018). Thus, we calibrate this condition as 0.
Case(s)	Wuwei and Zhangye	
province	Gansu	
Pilot status	0.67	The MWR issued two policy documents about pilot projects titled "Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province" (MWR 2004, No. 159) and "Notice on carrying out the pilot work on water rights" (MWR 2014, No. 222). We calibrate this condition as 0.67 because Gansu has several cities that have adopted water markets.
Private tradable water rights	1 (Wuwei, Zhangye)	Wuwei (Shiyang River), Zhangye (Heihe River) have allocated water rights to end users that are tradeable (Xu et al. 2016; Zhang 2007). Therefore, we calibrated Wuwei and Zhangye as 1.
Role of the local state	0 (Wuwei, Zhangye)	The cases of Shiyang Basin and Heihe Basin are typical examples where the local state supervises and approves the trading instead of participating directly in it (Dai et al. 2017; Liu, Peng and Zhang 2018; Xu et al. 2016). Although water prices are capped there is still flexibility because bargaining is allowed between farmers. This condition was calibrated as 0 for Wuwei and Zhangye.
Price discovery	0.67 (Wuwei, Zhangye); 0 (Baiyin, Jiuquan)	The water prices are capped for user-level trading in Wuwei and Zhangye (Liu, Peng and Zhang 2018; Xu et al. 2016). This condition was calibrated as 0.67 for Wuwei and Zhangye.
Inter-basin transfer infrastructure	0 (Wuwei, Zhangye)	Large-scale physical infrastructure such as reservoirs or inter-basin transfer project have not been present to enable trading between buyers and sellers in Wuwei (Moore 2015), and Zhangye (Zhang 2007). Interviews with two officials involved in water-rights trading in Gansu confirm that reservoirs or inter-basin transfer infrastructure has not been involved in these transactions (BJ180323). We calibrate this condition as 0.

Case(s)	Shijiazhuang	
province	Hebei	
Pilot status	0	The MWR issued two policy documents about pilot projects titled “Guidance on the pilot project of water rights conversion in the main stream of Yellow River in Inner Mongolia province and Ningxia province” (MWR 2004, No. 159) and “Notice on carrying out the pilot work on water rights” (MWR 2014, No. 222). We calibrate this condition as 0 because Hebei has not been selected as a pilot province.
Private tradable water rights	1 (Shijiazhuang)	Yuanshi county in Shijiazhuang has allowed tradable water entitlements to WUAs (BJ180323; CWEX 2019b).
Role of the local state	0 (Shijiazhuang)	Hebei province agricultural water-rights trading measures include: “Article 4: The amount of agricultural water rights transactions shall not exceed the amount stated in the water rights certificate. Article 5: Agricultural water rights transactions may take the form of independent transactions between users of agricultural water withdrawals, transactions at the county-level rural property rights transfer and trading center, entrusted farmers’ water cooperation organizations, and government buybacks. Article 6: The autonomous transaction between agricultural water-drawing households may voluntarily select the transaction object and transaction method, and the two parties may jointly implement paid or unpaid transfer. No organization or individual may interfere in their autonomous transaction” (Hebei Provincial Government 2016). Against this background, we calibrate this condition as 0, indicating that farmer associations can freely negotiate and trade water.
Price discovery	0.67 (Shijiazhuang)	Water prices are capped by the local state water agency (BJ180323).
Inter-basin transfer infrastructure	0 (Shijiazhuang)	Transactions between agricultural water users have not relied on large-scale physical infrastructure to enable trading (BJ180323).

Table 16. Elements of the market intermediaries in Victoria and China

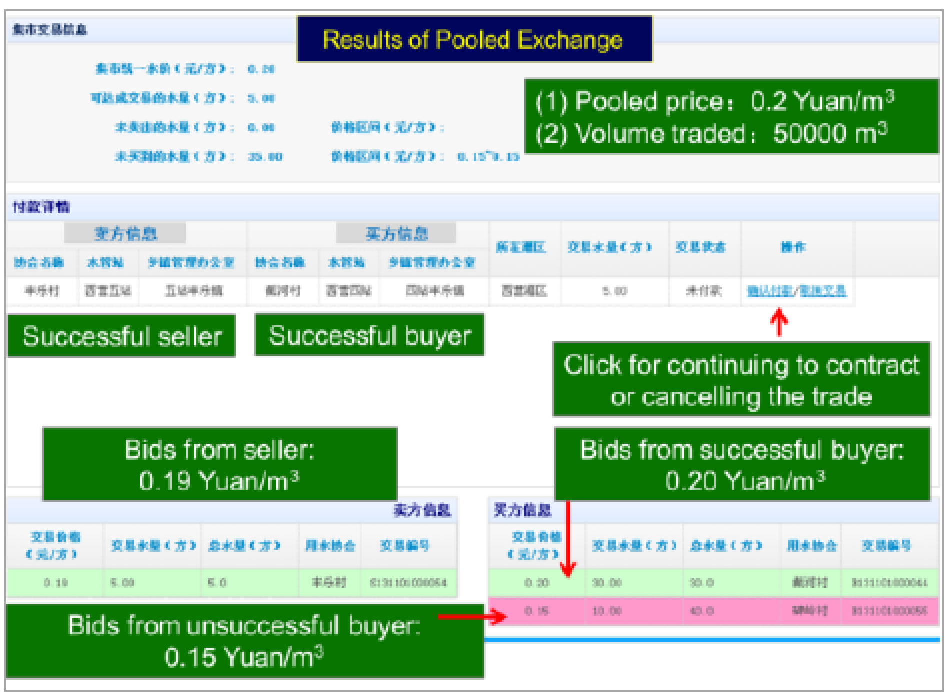
Market intermediaries	Ownership structure	Objective of the market intermediary	Time frame of trade	Function design of the online platform	Interface of the online platform
Water Partners (Aust) Ltd, Victoria, Australia.	A community owned entity governed by a board of Directors.	To facilitate access to the economic, efficient and affordable use of water to those within the irrigation community in a transparent manner.	Temporary and permanent	Operates a pooled water exchange system that matches any number of buyers and sellers of allocation water in certain trading zones at a price driven by the market. It also operates a live online trade room outside of the pooled water exchange, which enables traders to list offers to buy and sell allocation water online 24/7, resulting in the instant matching of trades.	The platform uses the electronic interface to the allocation bank account in the Victorian Water Register that provides available water balances (allocation, usage, trade in/trade out). Purchasers of water who use the pooling exchange must pay for their water purchase within seven days. Accordingly, buyers are required to pay any invoices prior to Water Partners (Aust) Ltd transferring the allocation to the buyer's allocation bank account. In addition, users who buy water via the online trade room are required to pay for their water purchase within 48 hours prior to Water Partners (Aust) Ltd transferring allocation.
Online water-trading platform in the Shiyang Basin, Gansu province.	Operated by Tsinghua University before 2015, and funded by central government.	To reallocate water among WUAs in a more flexible and timely way, and to formalize the existing informal water market.	Temporary	The functions of the platform include (1) water accounting: each user is allocated a water account in the system to record their water right, use and trading; (2) trading application: users who log into the system can submit a selling or buying bid (application); (3) application approval or rejection: the authorities will then review the application online; (4) pooled exchange: the qualified buyer and seller will be	The allocation bank account in the pooled exchange is not linked to a financial and credit system. Thus, WUAs pays for the water offline and are required to sign a paper contract with seals. Furthermore, the practice of the water-trading platform in the irrigation district requires intensive data collection of the profiles of all the WUAs, including the structure of the administration hierarchy from the irrigation management bureau to the WUA level. The water rights and the annual allocation data of each WUA, as well as the updated water use data and irrigation schemes of WUAs is provided manually by the local irrigation management bureau.

				matched according to their bids; (5) tracking the payment and update water account; (6) publishing historical trading information.	
China Water Rights Exchange Co. Ltd (CWEX).	CWEX has an initial investment of 600 million RMB with 12 investors, including enterprises owned by the MWR, China's seven river basin authorities, and the Beijing municipal government.	Bring traders together, and to establish a unified and standardized national water rights transaction system.	Temporary and permanent	CWEX publicly release water-rights trading information and solicit trading partners based on the application submitted by the trading participants. The functions include (1) trading application account: traders who log into the system can submit a trading application and choose public transaction or negotiated transfer to carry out the water rights transaction; (2) application approval or rejection: CWEX will then review the application online; (3) the exchange platform finalizes the agreement through public listing or private negotiation; (5) publishing historical trading information.	CWEX can match the bids of traders who post bids or offers for water on the exchange platform. In addition, CWEX can bring traders together and finalize the agreement through private negotiation. A financial and credit system is not linked to the CWEX platform. Thus, the payments for regional and inter-sectoral trades are finalized offline. However, payments between irrigators can be made online. Until now, the online platform cannot record the annual water allocation and water use of the user-profiles.

Sources: cwex.org.cn/; waterpool.org.au/.

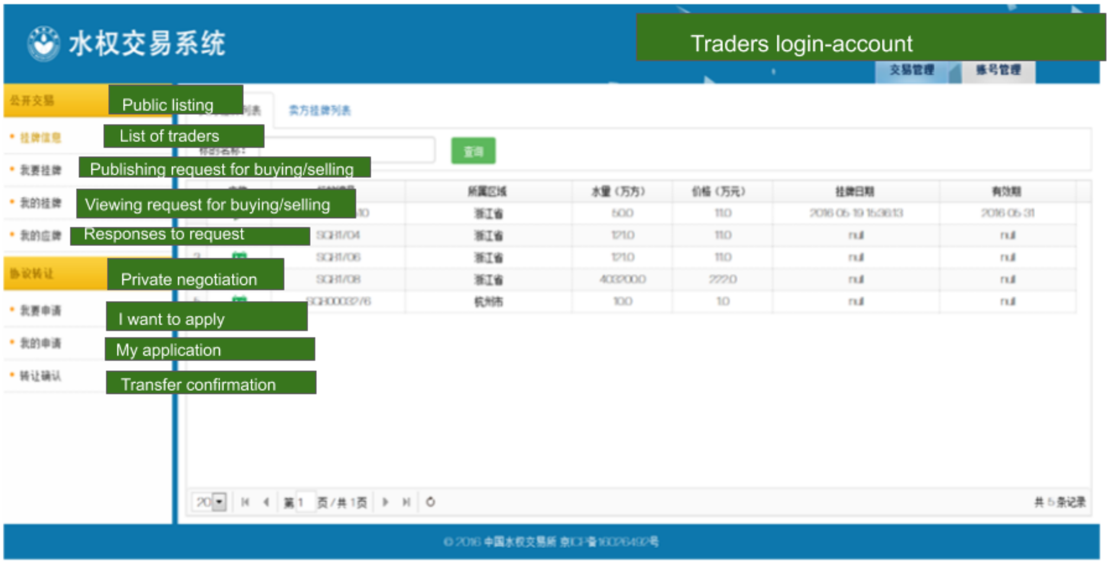
Figures 15–21. Functions and interfaces of the online trading platform in the Shiyang Basin and CWEX


Water account
location of trader
Permanent / temporary
Buy / Sell
Volume and price
Expected date for water convey if buying
Expected usage of water if buying
Submit the application


Results of Pooled Exchange
(1) Pooled price: 0.2 Yuan/m³
(2) Volume traded: 50000 m³
Successful seller
Successful buyer
Click for continuing to contract or cancelling the trade
Bids from seller: 0.19 Yuan/m³
Bids from successful buyer: 0.20 Yuan/m³
Bids from unsuccessful buyer: 0.15 Yuan/m³


中国水权交易所
CHINA WATER EXCHANGE
首页
交易大厅
交易制度
通知公告
政策法规
会员专区
新闻动态
交易案例
下载中心
关于我们
News
Login
The results of trading
不忘初心 牢记使命
成交信息


中国水权交易所
CHINA WATER EXCHANGE
Historical transactions
首页
交易大厅
交易制度
通知公告
政策法规
会员专区
新闻动态
交易案例
下载中心
关于我们
成交信息
区域水权/取水权交易
Buyer
Seller
Volume and Price
Time, date & type of transaction
项目编号 买方 卖方 成交水量（万方） 成交价格（元/方） 交易期限 成交日期 成交类型
CW191230000001 鄂尔多斯市新杭能源有限公司 杭锦旗黄河灌排服务中心 5000 0.6 25年 2019-12-30 协议转让
CW191115000001 内蒙古德晟金属制品有限公司 内蒙古河套灌区管理总局（巴彦淖尔市水务局） 1250 0.6（首付） 25年 2019-11-15 协议转让
CW191111000001 内蒙古英莱新材料有限责任公司 内蒙古河套灌区管理总局（巴彦淖尔市水务局） 75 0.6（首付） 25年 2019-11-11 协议转让
CW191029000001 内蒙古东源科技有限公司 内蒙古河套灌区管理总局（巴彦淖尔市水务局） 1000 0.6（首付） 25年 2019-10-29 协议转让
CW191021000001 内蒙古宜达化学科技有限公司 内蒙古河套灌区管理总局（巴彦淖尔市水务局） 75 0.6（首付） 25年 2019-10-21 协议转让


水权交易系统
Traders login-account
Public listing
List of traders
Publishing request for buying/selling
Viewing request for buying/selling
Responses to request
Private negotiation
I want to apply
My application
Transfer confirmation