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Environmental politics and policy adaptation in China: the case of water sector reform

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Abstract

Much of the literature on China's successful adaptation to the policy challenges posed by economic development credits two principle approaches, gradualism and local experimentation. However, the extent to which these approaches aid policy adaptation to environmental policy challenges is less well explored. This article examines how these approaches have shaped policy adaptation in water resources management by presenting data on ambitious water policy reforms that are, to our knowledge, new to the English-language scholarly literature. While gradualism and local experimentation have aided in the adoption of economic mechanisms like water pricing reform and water rights trading to regulate water use, institutional reforms have been undermined by an over-reliance on central control and direction. This phenomenon, which we call hierarchy, constrains China's ability to address diffuse, inter-jurisdictional and multi-sectoral water management challenges like nonpoint source pollution, and may inhibit its ability to address similarly complex sustainable development challenges into the future.

Keywords: China; Gradualism; Local experimentation; Sustainability; Water

Highlights

- China has implemented ambitious water pricing reforms, but their impact remains limited, especially in agriculture.
- Institutional reforms primarily emphasize inter-governmental coordination rather than stakeholder inclusion and consultation, and technocratic decision-making predominates.
- Despite innovation in constructing inter-jurisdictional water markets, they remain thinly traded with low pricing levels.

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Introduction: authoritarianism and the challenge of water resource management

How do authoritarian political systems adapt to new policy challenges? The question is especially marked in the context of China, where the continued political control of the Chinese Communist Party (CCP) is largely premised on its ability to address emerging policy challenges, notably the consequences of economic development and transformation (Nathan, 2003). To date, much of the literature on how China's political-economic system has adapted to challenges like trade liberalization and the introduction of greater market forces has emphasized a gradual and experimental approach to reform, in which various policies and approaches are tested and refined in selected local jurisdictions before being either abandoned or implemented nation-wide (Heilmann, 2008a, 2008b; Hofman & Wu, 2009). But while the focus of this research on policy adaptation has been on economic reform, environmental issues arguably present an even more apposite test case of how China's authoritarian system adapts to new policy challenges. This significance arises both from the growing salience of environmental issues as a source of popular mobilization and protest and because environmental issues present complex, inter-linked, and inter-jurisdictional policy challenges that typically require significant adaptation of institutional structures and governance processes (Christoph Steinhardt & Wu, 2016; Dai & Spires, 2018; Lam & Lo, 2019). In this article, we assess how China's political-economic system has shaped responses to a distinctive set of environmental policy challenges: managing its water resources. In doing so, we outline how the principles of gradualism and local experimentation, as well as a third principle we term hierarchy, have shaped policy adaptation. We assert that while gradualism and local experimentation have generally facilitated policy adaptation in the use of economic mechanisms to regulate water use, they have constrained China's ability to adapt to more complex and diffuse management challenges such as pollution and ecosystem protection.

Our focus on water policy stems from its often-under-appreciated significance in Chinese politics. Water resource management, including flood control, water supply, and irrigation, has long been viewed as a core state function in China, and it has continued to be a central preoccupation for governance and administration under the People's Republic (Phillip Ball, 2017; Moore, 2019). But even set in this context, water ranks among the government's highest policy priorities. In 2011, the No. 1 Policy Document, intended to outline the CCP's most important policy priorities for the coming year, proclaimed that 'Water is the origin of life, the essence of production and the basis of ecology. Water conservancy and flood control are instrumental to human survival, economic development, and social advancement … To promote steady and rapid long-term economic development, boost social harmony and stability … we must be determined to … achieve sustainable use of water resources' (U.S. Department of Agriculture, 2011). During the 19th CCP Congress held in October 2017, Chinese President Xi Jinping further re-affirmed the importance of addressing issues like water pollution (Hu, 2017). Furthermore, apart from its conceptual value to the study of Chinese political economy, China's experience with water policy reform also bears lessons for other developing countries confronting similar water resource management challenges (Woodhouse & Muller, 2017).

China's severe water resource challenges, which include growing industrial and urban water demand (see Figure 1), acute water pollution, and social displacement arising from dam-building, have received widespread popular and scholarly attention (Mertha, 2008; Moore, 2014a, 2014b; Wilmsen, 2016). Less well known, however, are the ambitious reforms that China has undertaken to address these challenges, several of which are, to our knowledge, unmatched in scale and scope in any other developing country. The 2011 No. 1 Document established several high-level goals for the water sector, including three

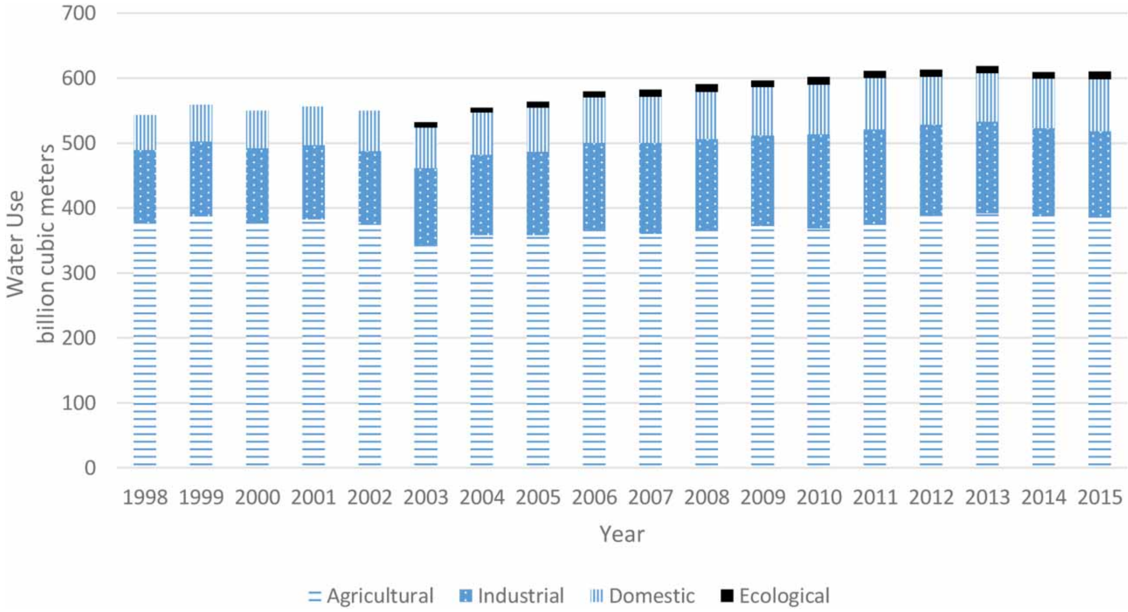

Fig. 1. Changes in sectoral water use in China, 1998–2015. *Source*: World Bank 2018.

'red line' targets limiting total water use, establishing minimum water use efficiency metrics, and mandating certain water quality standards at the national and provincial levels (see Box 1 and Figure 2). In 2012, guidelines were issued to support implementing a '*Most stringent water resources management system*' to achieve the *Three Red Lines* targets coupled with a responsibility and performance system. A more detailed work plan was prepared to implement these systems in 2014, framing the recent reforms described in the remainder of this article (World Bank, 2018). The scope and scale of these reforms represent an important test case of adaptive policymaking in authoritarian political systems.

Box 1. The Three Red Lines

The *Three Red Lines* as given in the No. 1 Central Government Document on '*Accelerating Reform and Development for the Water Sector*' are as follows:

1. **Water quantity**: By 2030, total water use must not exceed 700 billion m^3;
2. **Water use efficiency**: By 2030, industries will reduce their water use per US$1,600 (CNY 10,000) of industrial added value to 40 m^3. In addition, by 2030, irrigation efficiency must exceed 60%;
3. **Water quality**: By 2030, 95% of water function zones must comply with water quality standards. In addition, by 2030 all sources of drinking water will meet set standards for both rural and urban areas and all water function zones will comply with water quality standards.

Compliance with the Three Red Lines is to be ensured through a detailed reporting system whereby local officials must submit regular updates to higher-level officials, and verified through regular inspections and audits by central government officials.

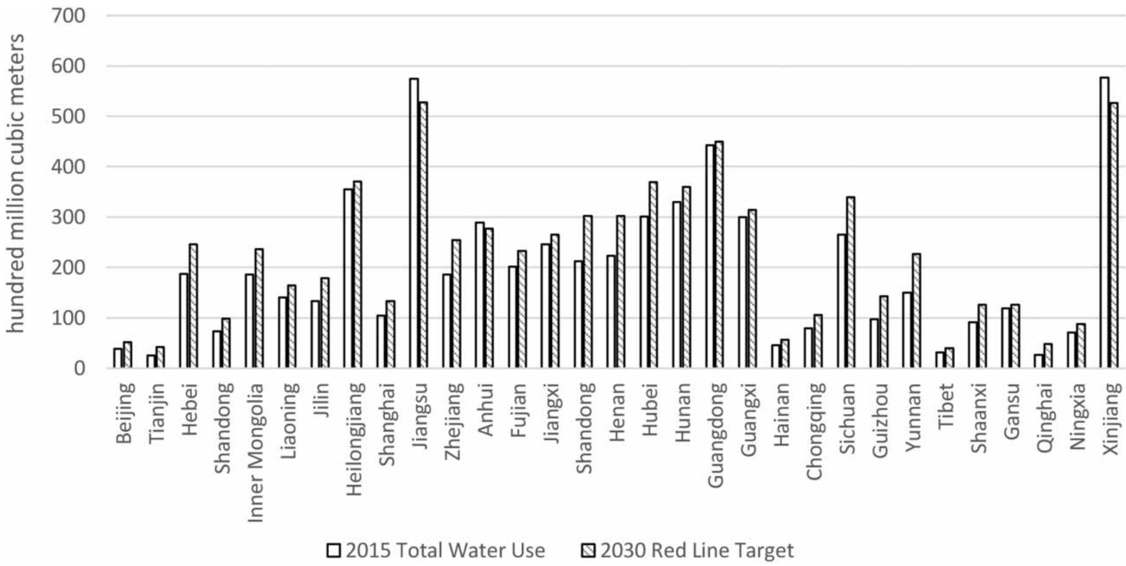

Fig. 2. 2015 Total water use and future red line water quantity targets by province. *Source*: World Bank 2018.

Accordingly, the primary objective of this article is to examine whether the well-described principles of gradualism and local experimentation can explain the evolution of China's recent water policy reforms. In doing so, this article draws on a wide range of Chinese-language source material prepared for the China Water Governance Study, a collaborative research project undertaken by the World Bank and the Development Research Center of the State Council. This project involved almost fifty researchers and involved extensive primary-source data collection from official sources, remote sensing platforms, and other sources, as well as computable general-equilibrium modeling. Some data presented here, including on agricultural water tariff reform and water rights trades brokered by the China Water Exchange are, to our knowledge, new to the English-language literature (World Bank, 2018). We focus on three key reforms identified in the course of the China Water Governance Study. The first and second, water pricing and water rights trading, are economic in nature and are intended to optimize water use, while the third, institution-building and reform, is intended to strengthen the framework for water governance in China. First, a series of water pricing reforms has been undertaken to promote water conservation and enhance the financial sustainability of water utilities, service providers, and water infrastructure operators. Second, reforms to water rights designation and allocation have introduced the concept of tradable water use and quality allowances that aim to reduce the cost of complying with total regional water quantity caps and water quality standards introduced as part of the *Three Red Lines* policy. Third and finally, a set of institutional reforms have been advanced to promote better coordination between various government ministries and agencies responsible for water resource management.

The remainder of this article explores each of these reforms in turn. The first describes water pricing reforms in both the domestic and agricultural sectors, emphasizing limited progress achieved in the second. The second section turns to water rights trading, a promising approach that has produced an important innovation in the form of the China Water Exchange, but whose overall progress has stalled. In the third section, we turn to the River Chief system as an example of hierarchical decision-making that appears poised to address some, but not all, of China's remaining water resource challenges, especially with respect to water quality and flood management. On the basis of these empirical sections, we conclude that while the principles of gradualism and local experimentation have generally aided policy adaptation in water use reform, the prevalence of hierarchical governance and decision-making severely constrains adaptation to diffuse water management challenges.

Before proceeding to an examination of these reforms, we first describe the three principles that explain adaptive policymaking in China, both with respect to water and other policy areas. The first, gradualism, refers to an incremental approach to policymaking and reform in which the effect of small modifications is carefully tested and observed. Based on these effects, policy is frequently tweaked until something approaching the desired outcome is obtained. Gradualism has been credited with helping China to avoid the calamitous social and economic effects of the 'Big Bang' approach to market liberalization followed by other developing economies, most notably the states of the former Soviet Union (Naughton, 1995; Brunnermeier *et al.*, 2017). However, gradualism has also been linked to sub-optimal policy outcomes, especially in the environmental arena. Taxes on coal have been progressively increased, for example, but remain too low to drive a full-scale shift toward less carbon-intensive forms of power generation (Garcia, 2011). As we describe below, gradualism has exerted a similar approach on economic water policy reforms, producing a more sophisticated water pricing structure but one that is likely still too low to achieve full cost recovery or sustainable resource management objectives.

Closely related to the principle of gradualism is that of local experimentation. The local experimentation principle holds that important nation-wide policies and reforms should be 'road-tested' in selected pilot locales before being implemented more broadly. In addition, these locales are often given wide latitude to choose different modalities of policy implementation. This approach provides senior policy-makers the ability to see how proposed policies perform across China's diverse regions and identify optimal implementation strategies. However, local experimentation also inherently produces widespread variation in policy outcomes, and sometimes leads reforms to stall before they can be deployed nation-wide (Chung, 2011; Teets & Hurst, 2015; Heilmann, 2018). We proceed to describe how this appears to be the case with water rights trading, where a seven-province pilot program stalled after its initial implementation in the middle of the last decade.

But while gradualism and local experimentation have aided the deployment of market-based solutions to China's water resource management challenges, a third principle, hierarchy, has severely inhibited the adoption of institutional water governance reforms. The principle of hierarchy holds that while policy implementation may be devolved and decentralized, policymaking is the near-exclusive prerogative of the central government and CCP leadership. At the same time, each level of governance is accountable to superior levels up to the CCP Central Committee. While deeply rooted in Chinese political tradition, the principle of hierarchy has exerted greater influence on policymaking in recent decades, as extensive administrative and fiscal decentralization in the 1980 and 1990s has been largely reversed (Lieberthal & Oksenberg, 1990; Liu *et al.*, 2018). Hierarchy is manifested in a number of vertical control mechanisms, such as the *kaohe* cadre evaluation system and the *bianzhi* appointment control process, that attempt to ensure that local officials faithfully pursue centrally-formulated policy priorities, even as they are given wide latitude in their approach to doing so. We find that hierarchy has exerted a significant, and largely deleterious, effect on China's water resource management policy. This is specifically because water policy fundamentally entails inter-sectoral and inter-jurisdictional cooperation. The principle of hierarchy is, to a very large extent, inimical to both (Moore, 2014a, 2014b). It is hierarchy, more so than gradualism and local experimentation, that has both shaped and constrained the ability of China's political-economic system to adapt to emerging water resource management policy challenges.

Innovation and incrementalism: the qualified success of water pricing reforms

Water price reform has gained increasing favor among water managers, particularly for urban water uses, for two reasons. First, water tariffs generate much of the capital for operating and maintaining the urban water infrastructure needed to meet growing demand in many parts of the world (Moore, 2018). Second, as water demand grows from an increasing number of sectors, water pricing becomes an important driver of efficient use. There are many potential tariff structures to support these objectives. However, in most parts of the world water prices are too low to recoup the full cost of producing and delivering water to end users, or to induce water conservation (Pinto & Marques, 2015). Beginning in the 1980s, water prices in China were gradually increased for most urban residents, helping to limit increases in urban water use despite rapid urbanization. A 2017 study found, for example, that price increases for urban water users implemented in 2002–2009 were successful in reducing water demand by a modest but still significant 5% (Zhang *et al.*, 2017). However, prices for agricultural water users, who account for over two-thirds of China's total water use, remain too low to achieve cost recovery or to promote water conservation measures (Webber *et al.*, 2008).

Water pricing in China takes a number of forms, most of which are geared towards financing water infrastructure. User water resource fees (*shuiziyuanfei*) are levied to cover capital, operation, and maintenance costs associated with water supply and delivery. Wastewater treatment fees (*wushuichulifei*), meanwhile, support capital, operation, and maintenance costs associated with wastewater treatment plants. Water resource taxes (*shuiziyuanshui*), on the other hand, are intended to capture environmental externalities associated with particular water uses and are often levied on groundwater withdrawals. Reform of these pricing mechanisms has aspired in part to utilize them to encourage greater water conservation. The basic principle of conservation pricing has existed since promulgation of China's landmark 2002 Water Law, and since at least 2008 water use has been subject to payment of fees that should at least in part reflect local water availability. Serious attempts to implement conservation pricing date only to around 2013 however, when new regulations issued to support the *Three Red Lines* policy acknowledged the need to more strongly encourage water conservation. These regulations encouraged local governments, which are primarily responsible for setting water prices, to differentiate between water use sourced from ground and surface sources as well as for 'luxury' uses such as golf course irrigation (World Bank, 2018). Subsequently, local experimentation has driven water pricing reforms throughout China.

In response to these regulations, many of China's larger cities have adopted pricing structures that differentiate between both quantity and type of water use, with the overall objective of reducing total demand while avoiding large price increases for most users (see Table 1). Taiyuan, Shanxi Province, was one of the first cities to institute a tiered pricing structure that charged users a progressively higher tariff in order to encourage water conservation. At the same time, higher tariff rates were established for uses judged to generate higher economic value. Similar water price reforms have gradually been implemented elsewhere. By 2010, 37 cities and counties in 18 provinces had introduced a preferential price for reclaimed water, for example (World Bank, 2018). Relatively few localities have since replicated Taiyuan's structural price reforms, however, with Beijing being the primary example (see Table 1).

Table 1. Water pricing rates and structure in Taiyuan and Beijing (RMB/m^3).

Pricing category/prices (RMB/m^3)	Taiyuan, Shanxi (2008)	Beijing Municipality (2017)
Residential	Tier 1: 2.3 Tier 2: 4.6 Tier 3: 6.9	Tier 1: 2.07 Tier 2: 4.07 Tier 3: 6.07
Administrative/State-Owned	2.7	Urban: 9.5 Rural: 9
Industrial	3.4	Urban: 9.5 Rural: 9
Service	4.6	Urban: 9.5 Rural: 9
Special Use	48	160

Beijing's adoption of the Taiyuan model reflects an important attribute of local experimentation: the ability to incorporate local innovations. In adopting the Taiyuan model, Beijing added separate categories for urban and rural water users, reflecting the added political sensitivity in the capital region of imposing higher water tariffs on comparatively poor farmers. However, even with the adoption of block water tariffs, total urban water prices remain relatively low by global standards. Even Beijing's 'special use' water tariff, the highest we are aware of in China, equates to only about US$23 per cubic meter – by comparison, Singapore's maximum urban water tariff is approximately US$43 per cubic meter (Singapore Public Utilities Board, 2018)[1].

Local experimentation has also played an important role in using pricing mechanisms to promote more sustainable water use. In 2016, China launched a noteworthy pilot scheme in Hebei Province to replace water resource fees with a single water resource tax based on the quantity of water used, and with a higher rate for groundwater to discourage overuse of the province's already-depleted aquifers. Surface water taxes were set at 0.4 RMB/m^3 (US$0.06), while groundwater taxes were set at a significantly higher rate of 1.5 RMB/m^3 (US$0.22). While Hebei's approach focuses on water quantity, in October 2017 Beijing announced that beginning in 2018, a tax of 1.4–14 RMB (US$0.2–2.1) would be levied on water pollutants nationwide, rather than leaving such rates to the discretion of local authorities (World Bank, 2018). Unlike the Taiyuan and Beijing block tariff structures, these taxes aim to specifically capture externalities associated with unsustainable water use, and apply equally to both agricultural as well as urban water users.

Local experimentation has been less pronounced, and less successful, in the agricultural sector, which accounts for the great majority of China's total water use. The 2002 Water Law attempted to codify the principle of cost recovery for major water projects, stipulating that water supply providers should directly receive water fees collected by local governments and administrative units (World Bank, 2018). However, agricultural water supply remains heavily subsidized by the state, chiefly through revenue transfers from the central and provincial to local governments. For the most part, agricultural water prices remain far below cost recovery levels, and must be increased if fiscal sustainability objectives are to be met. According to a 2010 survey of 414 large-scale irrigation districts, the cost of agricultural water supply was roughly 1.18 RMB/m^3 (US$0.17), but the maximum water tariff charged to users

[1] Foreign currency – USD conversions calculated as of December 2019.

was just 0.35 RMB/m^3 (US$0.05). In most areas, tariffs are substantially lower than even this minimal level. Nationally, by comparison, typical agricultural bulk water supply prices are roughly 0.0611 RMB/m^3 (US$0.009) (World Bank, 2018).

Further indication of the slow pace of agricultural water price reform is provided in Table 2, which displays agricultural water tariff data from several irrigation districts in the Tarim River Basin in Xinjiang, which has been the site of a long-running, gradual agricultural water price reform effort. This effort involves a three-phase price reform that began in 2016 and which is expected to extend into 2020. Despite the impending end date of the reform program, in only a few cases have prices even begun to approach cost recovery levels. The situation is similar in Ningxia, where despite an effort to charge farmers a higher rate for above-quota water use, prices remain far below cost recovery levels (World Bank, 2018). China's deliberately gradual approach to the implementation of water price reform in the agricultural sector has therefore so far not meaningfully increased prices for agricultural water users, raising considerable doubts concerning their efficacy in either reducing water use or in achieving full cost recovery for water supply infrastructure capital expenditure, operation, and maintenance.

Local-pilot limbo: experimentation and stalled reform in water rights trading

Along with the challenges of financing water infrastructure and promoting more efficient use, economic development also imposes the need to dynamically allocate typically limited water resources among multiple uses, including agriculture and industry. This imperative poses a significant challenge in terms of policy adaptation, because most countries lack explicit mechanisms to re-allocate water between different sectoral uses. When faced with this challenge, many water resource specialists advocate the use of an approach known as water rights trading (WRT). WRT has been instituted with considerable success in regions like the Murray-Darling River Basin in Australia (Quentin Grafton *et al*., 2011). China has experimented with WRT since the early 2000s as a means of limiting total water use in water-scarce regions. As in the case of water pricing, WRT reform has emphasized local experimentation and gradualism. In the case of WRT, however, this combination has failed to establish locally-appropriate models for development, and policy experimentation appears to have stalled (Moore, 2015).

Table 2. Irrigation water tariffs in Xinjiang (RMB/m^3).

Region/Irrigation District	Water supply cost (2010)	Phase 1 water price reform (2016)	Phase 2 water price reform (2018)
Kaidouhe	0.0405	0.0324	0.0405
Sundonghe	0.0932	0.0746	0.0932
Akedonghe 1	0.0168	0.0118	0.0143
Akedonghe 2	0.0168	0.0084	n/a
Akedonghe 3	0.0168	0.005	n/a
Akedonghe 4	0.0168	0.0118	0.0143
Akedonghe 5	0.0328	0.023	0.0279
Kashgar	0.0149	0.0131	0.0153
Hetian	0.0076	0.0053	0.0065

Source: World Bank 2018.

The deployment of WRT in China has certainly been gradual, having unfolded over the past two decades. In 2002, after being designated as the site of China's first water-saving society pilot project, Inner Mongolia established a 'water ticket trading' system between two irrigation districts, although the effort was soon abandoned. Shanxi Province introduced an important innovation several years later by extending tradeable agricultural water use entitlements, called 'water rights usage certificates' (*shuiquan shiyong zheng*) to the household level. However, this effort was also abandoned because of low trading volumes. In 2003, Ningxia and Inner Mongolia established the first inter-provincial water transfer pilot project, which created a mechanism for irrigation districts to invest in water conservation projects, such as lining canals to reduce seepage from irrigation canals, and then sell the 'saved' water to industrial enterprises in order to meet overall usage caps. As of 2012, the pilot project had completed 39 such transfers. A further important step was taken in 2007, when Ningxia mandated that all new industrial enterprises purchase water rights from existing rights-holders, thereby effectively capping localized water use and creating a market for tradable water rights. Xinjiang adopted a similar approach for its Turpan Municipality in 2011, as a result of which local industry has purchased 47.5 million cubic meters of water from agricultural water users (World Bank, 2018).

The principle of local experimentation has been more deliberately applied to WRT since 2014, when the Ministry of Water Resources established seven provincial water rights pilot projects. These pilot projects attempted to create a foundation for fully-functioning WRT in each province by setting water use caps, allocating usage rights to existing water users, and creating a trading mechanism. Progress along these lines has nonetheless been considerably slower than anticipated. To date, of the seven provinces only Ningxia, Gansu, Jiangxi and Hubei have begun allocating usage rights – the core function of any WRT mechanism. Even in other regions, outcomes have varied widely. In Jiangxi, a 25-year contract was concluded to transfer some 62 million cubic meters from Shankouyan Reservoir to a nearby urban economic development zone, at a total cost of 2.55 million RMB (US$366,150) per year. In other provinces, such as Jiangsu, basin-level caps have yet to be finalized. A final implementation challenge has been inter-jurisdictional trading. Contrary to original expectations and objectives, the province-level nature of the WRT pilot program has led officials to concentrate on encouraging trading within their jurisdictions, rather than between them (World Bank, 2018).

Interestingly, a complementary pilot program that relies far less on local initiative has in general progressed more quickly. This effort, intended primarily to cover agricultural water use, differs from other attempts to adhere to the principle of local experimentation in water resource management policy reform in two important ways. First, it is, unlike most such reforms, an inter-governmental initiative involving the Ministry of Water Resources, the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Agriculture. Second, unlike most such reforms, and notably unlike the provincial WRT pilot program, the inter-ministerial program allocated water rights directly to individual farmers and water users rather than to counties, townships, and other jurisdictional administrative units. The program designated 80 counties as experimental units in which all water users would be assigned rights entitlements. Of these, 39 counties distributed water rights to individual farmers, and 41 allocated them to water users' organizations (World Bank, 2018). The relative success of this program compared with the provincial WRT pilot suggests that the principle of local experimentation does not always produce optimal outcomes in terms of water resource management policy, especially when such experimentation relies principally on the discretion of local officials as opposed to more centralized, but still inter-sectoral, coordination.

Indeed, perhaps the most promising outcome of WRT policy reform has been the creation of a centralized, nation-wide organization to promote water trades and transfers across jurisdictional boundaries. The China Water Exchange, a state-owned entity founded in 2016, represents a promising innovation to expand WRT below the jurisdictional level. China Water Exchange was established with an initial investment of 600 million RMB (US$186 million) with 12 investors and sponsors, including enterprises owned by the Ministry of Water Resources, China's seven river basin authorities, and the Beijing Municipal Government. This unique ownership structure helps to give the Exchange unusual national reach and promises to increase trading volumes – a key feature of successful water markets. The China Water Exchange is intended to promote water rights transfers by identifying potential trades, serving as a resource for entities interested in engaging in transfers, and helping broker transfers between water users. The company has developed a number of standards to promote WRT in the form of eight guidelines covering fees, trading protocols, awareness-raising, and risk management, all of which have the potential to support continued expansion of water rights trading throughout China. The Exchange had brokered 11 water trades as of March 2017 (see Table 3). Some of these trades have been conducted jointly with provincial-level exchanges, most notably in Inner Mongolia (World Bank, 2018).

The promise of the centrally-coordinated China Water Exchange model relative to the local experimentation approach is suggested by the fact that the Exchange model has in fact been adopted by the very provinces that were originally supposed to lead reform efforts. A few jurisdictions, like Inner Mongolia, have launched their own water rights exchanges, which act as clients to the China Water Exchange itself. In other cases, river basin authorities have sought Exchange advice on facilitating trades within their areas of responsibility. Finally, at least one provincial government, that of Shandong, has expressed interest in joining the Exchange as a full shareholder (World Bank, 2018).

The promise of the China Water Exchange to further develop water quantity trading in China despite stalled provincial-level WRT programs can be contrasted with a largely failed effort to develop water quality trading through local experimentation. Water quality applies the same principle of rights allocation and trading as WRT but does so to limit pollution discharges rather than water use. Trading pollutant permits has been allowed in China since the late 1980s, and a pilot program was initiated in the Tai Lake basin in the mid-2000s. Growing enthusiasm for market-oriented policy tools has led to the promulgation of new regulations intended to provide a stronger basis for similar forms of water quality trading. Most notably, in 2014, the State Council issued its *Guiding Opinions on Further Piloting the Paid Use of Trading Emission Permits*, followed by the *Implementation Scheme for Pollutant Emission Permit Control* which was issued in 2016, and which explicitly permit the creation of markets in tradeable pollutant emissions permits in pilot localities. However, just as with province-level water quantity trading, the outcome of this local-pilot approach has been disappointing. As of 2013, total transacted allowances in water quality markets were 175,600 tons of chemical oxygen demand, 0.01 million tons of total phosphorous, and 0.16 million tons in ammonia nitrogen (World Bank, 2018). Relative to the scale of such pollution nationwide, these trading volumes are miniscule. Moreover, no comparable mechanism to the China Water Exchange has been created to attempt to facilitate water quality trading across large areas, or to increase the availability of financing for water pollution control technology.

As described above, the China Water Exchange has been more successful in increasing the volume of water quantity trades. Even so, it underscores just how constrained the development of WRT in China has been. First, such trades are disproportionately concentrated in a few jurisdictions such as Inner Mongolia and Beijing. Second, trading parties are predominantly administrative units rather than enterprises. This is reflected in the preponderance of trades brokered by the China Water Exchange that are 'agreed

Table 3. Water rights transactions brokered by the China Water Exchange as of March 2017.

Buyer	Seller	Quantity of water traded (m^3)	Source of water traded	Trade price (RMB/m^3)	Trade duration (years)	Trade type
Xinzheng People's Government (Henan)	Nanyang Water Conservancy Bureau (Henan)	240 million	South-North Water Transfer	0.74	3	Agreed trade
Songxin Chemical Company (Inner Mongolia)	Inner Mongolia Autonomous Region Water Rights Trading Center Company	20 million	Irrigation District Water Savings	0.6	25	Public trade
Jingnengshuangxin Electric Generating Company (Inner Mongolia)	Inner Mongolia Autonomous Region Water Rights Trading Center Company	5 million	Irrigation District Water Savings	0.6	25	Public trade
Niaohaishenwu Coal Chemical Technology Company	Inner Mongolia Autonomous Region Water Rights Trading Center Company	1.25 billion	Irrigation District Water Savings	0.6	25	Public trade
Alxa Prefecture Luanjinghuai Demonstration Area Water Affairs Company	Inner Mongolia Autonomous Region Water Rights Trading Center Company	2.5 million	Irrigation District Water Savings	0.6	25	Public trade
Shanxi Zhongshehuapushozao Company	Shanxi Yunchengkuiquan Irrigation District	90,000	Irrigation District Water Savings	1.2	5	Agreed transfer
Beijing Baihebao Reservoir	Hebei Zhangjiakou City Yunzhou Reservoir	1.3 million	Reservoir	0.06–0.35	1	Agreed transfer
Beijing Gongting Reservoir	Hebei Zhangjiakou City Faxie Reservoir	5.741 million	Reservoir	0.294	1	Agreed transfer
Xinmi City Water Affairs Bureau (Henan)	Pingdingshan City Water Conservancy Bureau (Henan)	2.4 million	South-North Water Transfer Project	0.87	3	Agreed transfer
Ningxia Jingnengzhongning Power Plant	Zhongning State-Owned Capital Transfer Company	3.285 million	County agricultural water savings	0.931	15	Agreed transfer

Source: World Bank 2018.

trades' (*xieyi jiaoyi*), meaning that they stem from inter-governmental agreements between administrative units. Company-to-company transactions, usually referred to as 'public trades' (*gongkai jiaoyi*), remain comparatively rare. Third, most trades are facilitated through irrigation district water savings, most often through lining canals to prevent seepage, after which the 'saved' water is transferred to industry. Fourth, prices remain quite low, and are highest in transactions involving the South-North Water Transfer Project. Fifth, and most strikingly given the China Water Exchange's mandate to broker trades nationwide, trades are overwhelmingly conducted within single province-level units (World Bank, 2018).

The constrained scope of inter-jurisdictional water rights trading speaks to the larger failure of China's political-economic system to adapt to perhaps the most fundamental of water resource management policy challenges: the need to catalyze inter-jurisdictional collective action necessary to address issues like pollution and flooding. This constraint arises primarily from the influence of a third central principle to policy adaptation in China, namely hierarchy. This principle in turn finds its clearest expression in having impeded institutional reforms to water resource management in China.

The straitjacket of hierarchy: limits to institutional reform and inter-jurisdictional collective action in China

A final adaptive challenge that water resource management poses for political-economic systems is that of inter-sectoral and inter-jurisdictional collective action. Broadly speaking, the literature on water governance emphasizes the need for institutions that are capable of meeting 'complex-adaptive' environmental challenges. Such challenges, which include controlling diffuse sources of pollution such as agriculture pesticides and fertilizers and protecting diverse ecosystems including riparian and aquatic species, are not easily accommodated within hierarchical institutional frameworks. Instead, they require considerable flexibility, and extensive cooperation across several domains, including sectors, jurisdictions, and between public and private actors (Schlager & Blomquist, 2008; Ostrom, 2010; Negendra & Ostrom, 2012). In the case of China, previous attempts to catalyze such collective action relied principally on river basin water conservancy commissions (*liuyu shuili weiyuanhui*). However, because the commissions were set up as adjuncts (*paichu jigou*) of the central Ministry of Water Resources, they for the most part proved ineffective at addressing issues like inter-provincial pollution and water quantity disputes (Moore, 2014a, 2014b; Shen, 2014). In response to these substandard outcomes, China has in recent years adopted a number of sweeping institutional water management reforms.

These institutional reforms are intended to respond to two well-documented pathologies in China's approach to water resource management. First, local officials frequently avoided compliance with water pollution regulations and abstraction limitations, often because of an unwillingness to impose costs on enterprises within their jurisdictions. Second, few incentives existed to promote cooperation between neighboring administrative units along shared waterways to address issues like inter-jurisdictional water pollution or aquatic ecosystem protection (Peng, 2009; Shen, 2009; Moore, 2014a, 2014b). Because both of these weaknesses reflect underlying features in China's political-economic system, including a hierarchical approach to governance and an incentive structure that broadly favors economic development over environmental protection, only ambitious reforms could hope to correct them. Indeed, China's two signature institutional reforms to water resource management since 2012, the *Three Red Lines* and River Chief systems (the latter of which is described below), attempt to address central-local and inter-jurisdictional challenges, respectively. Yet despite their scale, China's recent institutional reforms reinforce rather than alter its hierarchical approach to water resource management. It is doubtful this approach can successfully accommodate a proliferation of new actors and stakeholders in water governance, especially private enterprises and water users not directly connected to the state.

The single most important element of China's current water governance system is the Most Stringent System for Water Resource Management, otherwise known as the *Three Red Lines*. As described in the Introduction, the core of this system consists of targets that limit total national water use, specify minimum standards for water use efficiency, and establish clear limits on pollutant loads. This system is in turn fundamentally hierarchical in that it relies on disaggregating national targets to provincial and local levels and is enforced by a comprehensive monitoring and evaluation system established in 2014 that measures progress on several key indicators: total water quantity use; industrial water productivity; agricultural water use efficiency; and water quality. In 2016, two additional indicators were added: domestic water use productivity and total pollutant load concentrations. In keeping with a hierarchical approach to governance, these targets are then disaggregated by province and local jurisdiction level according to a detailed process based on input from the jurisdictions themselves, which are then reviewed and modified as necessary by the Ministry of Water Resources (MWR). Accordingly, the Red Line targets are shaped by political and economic as well as hydrological and ecological considerations – a reality reflected in the fact that only a few provinces are expected to reduce water use in absolute terms under the Red Line water quantity caps (see Figure 2). MWR responsible for validating and enforcing compliance by local officials with these targets, reinforcing this hierarchical management approach (World Bank, 2018).

The target-setting process further reinforces a vertically-integrated system that links central policies all the way down to individual water users and enterprises. In setting total water use targets for each jurisdiction, factors to be considered include local water resource availability, existing and planned infrastructure projects such as the South-North Water Transfer Project, national economic and social development plans, and local development plans that have been approved by the central government. Water use is to be controlled through the existing withdrawal permit system and economic instruments (e.g. prices, fees, and taxes) to encourage water conservation. Water efficiency target-setting, meanwhile, is conducted at the enterprise or production unit level. A water use quota based on the total water quantity usage limit is assigned to each production unit, which is then used as the basis for setting efficiency targets. Water use efficiency targets are meant to be implemented chiefly through a reward and punishment system that provides either recognition or financial penalties for production units depending on their adherence with the policy. Water pollution targets are set on a 'zone' basis, meaning that they specify total pollutant loads for different waterways or water bodies, depending on whether they are 'zoned' for source water protection, environmental protection, industrial, or other water uses. Compliance with these zones are enforced by local officials using pollution discharge permits and fees, providing yet another means to extend the reach of China's water governance system to the very lowest levels. However, compliance with some Red Line targets, especially water quality indicators, has been uneven – a fact reflected in the development of an alternative institutional structure, the River Chief system (World Bank, 2018).

While the *Three Red Lines* system attempts to remedy gaps in enforcement of and compliance with water use and quality regulations, it does not explicitly address the second primary weakness in China's existing water resource management system, namely its poor track record with respect to inter-jurisdictional cooperation. In December 2016, the Chinese government attempted to address this issue by creating a new system of 'river chiefs' (*hezhang*) for the country's major lakes and waterways. The river chief system effectively makes the leaders of each province, city, county, and township responsible for core water management functions, supported by a dedicated office at the county level and above. Under this approach, a single official, typically the chief CCP executive is each municipality, county, and province, is held responsible for the proper management of each stretch or section of every major lake and waterway in his or her jurisdiction (Chien & Hong, 2018). In Wuxi, Jiangsu, for example, the Party Secretary of the municipal CCP was appointed River Chief (Huanbaobu, 2009). These officials are then held responsible for meeting environmental protection and water quality targets in their designated areas, even if they are subsequently rotated to another jurisdiction (Xu, 2017). The primary purpose of the river chief system is intended to strengthen enforcement and accountability concerning key water policy measures including water use control, water quality protection, and restoration of degraded waterways. The river chiefs are expected to ensure that officials of various departments under their control work together to achieve key water policy objectives (Xinhua, 2017). Despite the wide range of tasks assigned to river chiefs, it is clear that water quality is a special area of emphasis. A revision of the 2008 *Water Pollution Prevention and Control Law*, scheduled to take effect in January 2018, codifies the responsibility of river chiefs to supervise water quality, enforce pollution regulations, and oversee ecological restoration efforts (China Water Risk, 2017).

The recent advent of the River Chief system makes it difficult to assess its progress so far. However, what is clear is that it does not address a third major weakness in the institutional structure for water governance in China, namely the inclusion of non-governmental stakeholders in decision-making. A consistent theme that runs throughout much of the global literature on water governance and water resource management concerns the importance of an inclusive and participatory approach that brings together both governmental and non-governmental stakeholders, including water users. This approach, the bulk of the literature asserts, is necessary to produce legitimate, sustainable, and well-informed decisions on often contentious issues regarding water use and management. Provisions related to stakeholder participation accordingly play a prominent role in legislation like the European Union Water Framework Directive and U.S. Clean Water Act (Priscoli, 2004; Pahl-Wostl *et al.*, 2007; Carr *et al.*, 2011). In China, non-governmental stakeholders have historically played a much less significant role in water governance than in other countries, in part because the country's authoritarian system constrains their participation by design, and in part because collective agricultural units, state-owned enterprises, and municipally-owned utilities accounted for the vast majority of water use (World Bank, 2018). In recent years, however, the Chinese state's pursuit of a 'decisive move to the market' has made the role of non-governmental enterprises in water governance a pressing question (World Bank, 2018). Continued adherence to the principle of hierarchy in water governance reform, however, so far appears inimical to this longer-term imperative.

Conclusion: environmental politics and policy adaptation in China

China's leaders have made clear that they view reform of its water sector as a core component of its overall development strategy. As this article has attempted to highlight, recent attempts to reform water resources management and governance have followed the well-known principles of gradualism and local experimentation. However, a careful examination of these reforms reveals that while gradualism and experimentation characterize attempts to reform the use of economic mechanisms, namely water pricing and rights trading, a third principle, hierarchy, characterizes institutional reforms. Moreover, while gradualism and experimentation have led to local innovation in water pricing policies, they appear to have stymied water rights trading. The adherence of institutional reform to a centralized, regulatory approach, finally, acts to severely limit China's ability to tackle complex-adaptive water resource issues, especially pollution and ecosystem protection. With these observations in mind, some tentative conclusions may be drawn with respect to how China's authoritarian system adapts to new policy challenges.

The principles of gradualism, local experimentation, and hierarchy have several advantages. When employed in concert, they provide for policy learning, diffusion, and innovation at the local level without surrendering centralized control over decision-making. This combination in turn imbues China's political-economic system with considerable adaptive capacity. Historical experience has proven it to be well-suited to many of the demands of macro-economic reform. When it comes to addressing complex environmental challenges, however, we suggest that the advantages are less compelling, and that to the contrary the principles of gradualism, experimentation, and hierarchy have constrained China's ability to adapt to certain water resource management challenges. Gradualism has produced water prices that remain too low to promote sustainable use, local experimentation has stalled the deployment of water rights trading schemes, and hierarchy has undermined the ability of institutional reform to address increasingly dire pollution issues. Moreover, despite the pluralization of actors and interests in China's water sector, there are few avenues for non-governmental stakeholders to participate in decision-making. Elsewhere, however, successful adaptation to water management challenges, especially ecological protection, has depended critically on the involvement of these stakeholders. Models like the Adaptive Working Groups active in the Colorado River Basin and France's Water Agencies may present helpful models for institutional reform in China's water sector (World Bank, 2018).

Another lingering implication of these conclusions is that, in China at least, centralization may produce better environmental outcomes than a more decentralized approach. This tentative conclusion flies in the face of the bulk of the environmental governance literature, which emphasizes the principle of subsidiarity (Moore, 2018). In the particular case of China, however, the perverse incentives that often lead local officials to prioritize provincial interests and objectives over broader ones may explain this seeming paradox. In the existence of this incentive structure, centrally-organized collective action may be most likely to facilitate adaptation to environmental and other emerging policy challenges. The example of the county-level water price reform pilot program suggests, for example, that centrally-led and -coordinated approaches to environmental governance that attempt to incorporate and reconcile diverse stakeholder interests may be more effective than either decentralized implementation or central state fiat. We suggest that China's water managers seek lessons from this example in formulating future reforms to adapt to evolving water resource management challenges.

Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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