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Growing water scarcities: Responses of India and China

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Abstract

In this article, I explore why China has surged ahead of India in irrigation and water management and in dealing with water scarcities. I offer a comparison of the two countries' policies and investment strategies using a political economy context.

KEYWORDS

China, India, irrigation, technological change, water management, water scarcity

JEL CLASSIFICATION

O57; P48; Q01; Q25; Q28; Q55

In China and India, one of the key challenges to food security is the growing competition for water between agriculture and urban sectors. The countries started with similar initial conditions but have followed different paths to water management with very different outcomes. India was ahead initially, with the world's largest surface irrigation system that it inherited at the end of colonialism. China and India now have similar areas under irrigation, after rapid expansions of irrigated lands in both. They have other factors in common, but their policies and outcomes have been very different. Bardhan, a longtime scholar of development policies of the two countries has argued that compared to India and other developing countries, China has special positive features of career incentives promoting growth at the local level, the ability to take long-term decisions relatively quickly, and a unique blend of political centralization and decentralization of economic power and responsibility, which is conducive to central guidance and local business development (Bardhan, 2020).

Yet, Bardhan is not sanguine about the weaknesses in the Chinese system, particularly the lack of sufficient downward—as opposed to upward—accountability, and the absence of an institutionalized system of scrutiny and challenge from below. The overall organizational system is prone to overreaction in times of crisis, and thus, only weakly resilient, compared to systems where information flows from below are less controlled or choked. Yet, he contends that authoritarianism is neither necessary nor sufficient to explain some of the distinctive features of Chinese governance, both positive and negative—just as some of the recently observed dysfunctionality of governance in the United States or India is not inherent in their democratic process (Bardhan, 2012, 2020).

In a similar, nonideological vein, Ostrom outlined rules for the management of a common pool resource, such as water or forests, which suffers from 'the tragedy of the commons' (Ostrom, 1990, p. 2). She argued that the fact that individual, rational strategies lead to collectively irrational outcomes challenges a fundamental faith that rational actions lead to rational, collective outcomes. She explains the phenomenon of tragedy of commons in terms of a free rider problem, where some principles of good governance can help address the problem, particularly, collectively designed and collectively enforceable rules.

We examine these propositions in the context of water management policies of the two countries, where demand for water has risen sharply. The increased demand for water reflects the growing populations of the two countries. China and India had similar populations—1.43 billion and 1.37 billion, respectively—in 2019 (UN, 2019, p. 12). As of 2017, China supported 18.4% of the world's population, with only 8.5% of the world's cultivated land (in 2016) and 5.2% of the world's water resources (in 2014). India supported 17.8% of the world's population in 2017 with only 10.6% of the world's cultivated land (in 2016) but had merely 3.5% of the world's water resources (in 2014). India's population has been growing fast and will surpass China's in 2027. Furthermore, India has a higher share of population dependent on agriculture (43%) than does China (18%), and India's water resources and surface area are two-thirds of China's (FAO, 2020; FAO, 2019; ILO, 2019; UN, 2019).

Five different responses of China and India to resource management for water and irrigation reflect the differences in their political contexts. First, China has had a relatively more holistic, overarching national strategy, which it is able to form and implement relatively more effectively due to the unique blend of centralization and decentralization with incentive structures, as described by Bardhan (2012, 2020). India's seemingly piecemeal strategy toward water and irrigation is more an outcome of its decentralized democracy, with responsibilities for water management assigned to the state level and below, albeit with relatively weak central incentives for good performance. Second, the levels and types of investments being made by the two countries are widely different. China has relied on surface irrigation. India, once enjoying the largest surface irrigation system in the world, has increasingly turned to groundwater. Third, China has made greater use of new technologies, ranging from wider use of remote-sensing technology (RS) for estimating water resources and their monitoring and control. Fourth, and relatedly, governance and institutions are very different in the two countries, ranging in China from a national constitution that provides for state ownership of water to more effective local participation, responsibility, and accountability through the water users' associations, and farmers' groups to control water consumption in agriculture and use water more productively. Here, Ostrom's principles of governance (Ostrom, 1990), including how individual rational actions can lead to collective irrational outcomes, become handy. Finally, policies toward water caps, pricing, and subsidies are deployed differently to achieve their policy goals. Few such comparative studies exist that explain why China has done better than India (Nickum & Mollinga, 2016).

FREQUENTLY MADE RECOMMENDATIONS TO IMPROVE WATER AND IRRIGATION MANAGEMENT

Previous water studies have suggested the need to (1) increase investment to increase water supply; (2) limit water use in agriculture by allocating water more efficiently through water rights, regulations and quotas, pricing, trading, and subsidy reform; and (3) improve crop productivity per unit of water. Rosegrant (2019) added two additional suggestions: the need to improve water governance through transparent, accountable, efficient, responsive, sustainable, and geographically contextualized institutions; and change diets to reduce demand for water-intensive crops and livestock. Other studies have also stressed dietary changes to reduce water demand (for example, EAT–Lancet Commission, 2019; FAO, 2014). Some studies have also noted the increasing cost of expanding surface irrigation, excessive water losses, dilapidated irrigation systems, slow increase in crop yields, and planetary boundaries (Fischer et al., 2014).

Rosegrant et al. (2002) described three possible future global water resources scenarios: (1) *business as usual* (if recent past and current trends for water investments, water prices, and management were broadly maintained); (2) *water crisis* (following a deterioration of current trends and policies in the water sector); or (3) *sustainable water use* (with improvements in a wide range of water sector policies and trends).

Based on nearly a 50-year record of policies in each country and the World Bank's experience in irrigation lending and advice over more than 50 years, I conclude that China is ahead in addressing sustainability issues, compared to India, which has faced recurring water crises. The World Bank's experience is valuable, because it is the world's largest lender for irrigation and drainage, committing US$65 billion from 1947–2018 for 956 projects in 105 countries (World Bank, 2019b).

RESPONSES OF CHINA AND INDIA TO WATER SECURITY

A comparison of the current status of the irrigation management of China and India is a useful start. The two are among the top 10 countries in area irrigated, each with rapid growth in irrigated areas, reaching nearly 70 million hectares (ha) from 1992 to 2016 (Figure 1), and each with similar percentages of global areas equipped for irrigation—22% and 21%, respectively. Their sources of irrigation growth, however, are very different, with China's heavy reliance on surface water irrigation and India's growing use of groundwater irrigation. Irrigated agriculture accounts for 75% of grains and 95% of cash crops produced in China. Sixty percent of all cropped areas in India are rainfed.

In China, the “area equipped for full control irrigation” (a measure of the Food and Agriculture Organization of the United Nations [FAO]) was 62.9 million ha in 2006, including 43.5 million ha equipped for irrigation by surface water (69.2%) and 19.4 ha equipped for irrigation by groundwater (30.8%). In India, the area equipped for full control irrigation was similar, 61.9 million ha in 2001, but differing in type, with 22.5 million ha (36.3%) equipped for irrigation by surface water and 39.4 million ha (63.7%) equipped for irrigation by groundwater (Table 1).

Response 1: Holistic overarching vs. piecemeal strategy toward water and irrigation

China's evolving “whole systems” approach

Within its whole system approach, China deals with water rights separately from land rights—India does not. It systematically tracks water use related to cropping patterns, using measures such as evapotranspiration (ET). It has built the capacity of community organizations

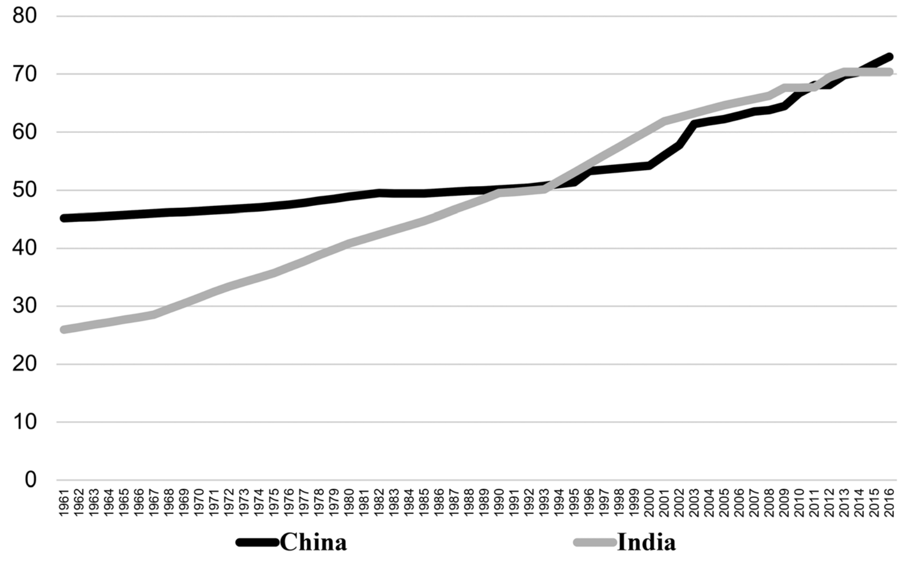

FIGURE 1 Total land area equipped for irrigation by China and India (million ha) (1961–2016).
Source: Based on data from FAOSTAT (2020), http://www.fao.org/faostat/en/#data

to self-monitor water use. It has tied incentives to water use. It has created markets for new water-saving crops, with farmers encouraged to abandon old, water-guzzling cropping patterns.

China's 2002 Water Law reflects the current legislative environment and the new administrative landscape, including new ministries announced in the 2018 reforms (Xie et al., 2009). Approaches to enforcement of existing pollution legislation are being expanded. Legislative adjustments encourage public–private partnerships (PPPs) in water management, an area in which China is already a leader, and critical for mobilizing financing to support water management. As part of its overarching policy, China has adopted three "Red Lines," with clear goals and targets:

1. *Water Quantity*: By 2030, total water use must not exceed 700 billion m^3.
2. *Water Use Efficiency*: By 2030, industries will reduce water use per US$1600 (RMB 10,912) of industrial value added to 40 m^3. By 2030, irrigation efficiency must exceed 60%. Irrigation caps are also declared. By placing a number on irrigation efficiency, China is aiming to increase the ratio of beneficial water consumption to water use, starting at the plant level and beyond, beginning the shift toward consumption-based water accounting.
3. *Water Quality*: By 2030, 95% of water function zones must comply with water quality standards. All sources of drinking water will meet set standards, both rural and urban, and all water functions/zones will comply with water quality standards.[1]

In the pursuit of these objectives, China's "whole-system" solution is intended to benefit farmers, water managers, and sensitive ecosystems, that is, a triple win. It is based on effective mechanisms and tools for budgeting, allocating, and control over water consumption, as measured by ET (Cho, 2018). Implementation of the whole-systems approach can be seen in China's Turpan Model, which addresses all five response elements in the principal argument of this article and distinguishes China's responses from India's.

TABLE 1 Water and irrigation: Sources and uses: China versus India

Indicators	China	India
Renewable Water Resources (RWR)		
Long-term average annual precipitation		
• Depth (mm/year)	645	1083
• Volume (km^3/year)	6192	3560
Long-term Average Annual RWR		
• Internal (IRWR) (km^3/year)	2813	1446
• External (ERWR) (km^3/year)	27.32	464.9
• Total Actual (TRWR) (km^3/year)	2840	1911
• Dependency ratio (%)	0.96	30.52
• TRWR per capita (m^3/year)	2018 (year 2014)	1458 (year 2014)
Dam		
• Total dam capacity (km^3)	829.8 (year 2013)	224 (year 2005)
• Total number large dams with a height over 15 meters (as registered at International Commission on Large Dams)	23,841[a] 9215[b] _	5100[a] 6785[b] 5264[c]
Water Withdrawal (China's data reported here for the year 2015 and India's data for the year 2010)		
Total water withdrawal (km^3)	598.1	761
Total water withdrawal per inhabitant (m^3/year)	425	630
By Sector		
• Agricultural (irrigation + livestock) (km^3)	385.2 (64.4% of total withdrawal)	688 (90.4% of total withdrawal)
• Municipal (km^3)	79.4 (13.3% of total withdrawal)	56 (7.4% of total withdrawal)
• Industrial (km^3)	133.5 (22.3% of total withdrawal)	17 (2.2% of total withdrawal)
By Source		
• Surface water withdrawal (km^3)	484.9 (81.1% of total withdrawal)	396.5 (52.1% of total withdrawal)
• Groundwater withdrawal (km^3)	106.9 (17.8% of total withdraw)	251 (32.9% of total withdrawal)
Total freshwater withdrawal (km^3)	594.2	647.5
Desalinated water produced (km^3)	0.0109 (year 2008)	0.0006
Direct use of treated municipal wastewater (km^3)	3.86 (year 2013)	—
Direct use of agricultural drainage water (km^3)	—	113.5
Pressure on Water Resources		
Total freshwater withdrawal as % of TRWR	20.92	33.88

(Continues)

TABLE 1 (Continued)

Indicators	China	India
Agricultural water withdrawal as % of TRWR	13.56	36
Area Equipped for Irrigation		
Total land area equipped for irrigation (million ha)	73 (year 2016)	70.4 (year 2016)
• as % of cultivated area	51.5 (year 2013)	41.5 (year 2013)
Area actually irrigated (million ha)	58.5 (year 2013)	66.1 (year 2013)
• as % of area equipped for irrigation	83.7 (year 2013)	93.9 (year 2013)
Full control irrigation (million ha)	69.9 (year 2013)	70.4 (year 2013)
• surface irrigation (million ha)	59.3 (year 2006)	61.9 (year 2004)
• sprinkler irrigation (million ha)	2.8 (year 2006)	1.5 (year 2004)
• localized irrigation (million ha)	0.8 (year 2006)	0.6 (year 2004)
Source of Irrigation Water on Area Equipped for Full Control Irrigation		
• surface water (million ha)	43.6 (69.2% of the total area equipped for full control irrigation) (year 2006)	22.5 (36.3% of the total area equipped for full control irrigation) (year 2001)
• groundwater (million ha)	19.4 (30.8% of the total area equipped for full control irrigation) (year 2006)	39.4 (63.7% of the total area equipped for full control irrigation) (year 2001)

Source: FAO AQUASTAT (2019) (see http://www.fao.org/aquastat/en/); International Commission on Large Dams (ICOLD) (Mulligan et al., 2020).
[a]Based on International Commission on Large Dams (ICOLD) database;
[b]Based on Global Georeferenced Database of Dams (GOODD) database;
[c]Based on Central Water Commission.

Turpan Prefecture, in far western China, is one of China's poorest and most arid regions, facing growing population and increasing water demand, together with chronic and worsening groundwater overdraft by low-income farmers. Previous large-scale efforts to conserve water there, counterintuitively, led to an overall increase in water consumption at the basin level due to the "Jevons effect." The Jevons effect occurs when increased efficiency in the use of a water resource (for example, due to technological progress or government policy) is offset by an increased rate of consumption, following increased demand for the resource (Perry & Steduto, 2017).[2]

Rapid expansion of irrigated land (from around 60,000 ha in the 1970s to 80,000 ha in 2000) had already greatly increased pressure on the prefecture's groundwater reserves, threatening the viability of its agricultural sector, which accounts for some 70% of employment. A water-saving program, based on installing modern irrigation technologies (such as drip irrigation, sprinklers, canal lining, and low-pressure pipelines) to save up to 80% of irrigated water had led to an increase in irrigated area by 33%—from 80,000 to 107,000 ha—from 2000 to 2008 in Turpan Prefecture. Expansion of irrigated land area, or production intensification was taking place, because prevailing definitions of water rights entitle farmers to withdraw a certain volume of water from the common conveyance channel; and any "savings" (that is, reduced seepage) that farmers realize from increased efficiency does not reduce the withdrawal right.

Instead, it is in the farmers' economic interest to further *reuse* saved water through expanded production.

Based on a pilot experiment introduced under a World Bank project, China began applying irrigation and agronomic interventions for real water savings at the farm level, as well as at the basin level, using RS, water budgeting at all levels, and reducing actual ET under the basin-wide consumption cap, translated down into farm-level water budgets and caps. This is part of a larger global trend since 2005. Satellite RS is seen as a low-cost and scalable solution to fill widespread gaps in monitoring of irrigation water use in both developed and developing countries, bypassing the technical, socioeconomic, and political challenges that, to date, have constrained in situ metering. Yet, trade-offs exist between accuracy and costs associated with different water use accounting approaches (Foster et al., 2020). Optimizing irrigation and agronomic practices raised water use productivity ($/m^3) with improved crop and irrigation practices and was recommended by agricultural R&D staff (planting, irrigation schedules, greenhouses, etc.). A major innovation of this project was to demonstrate to the government, and to reach agreement, that the only way to reduce real water consumption and reduce groundwater overpumping in Turpan basin was to take some irrigated land out of production, combined with many other innovations (World Bank, 2010, 2017). Having shown the approach to be successful on a pilot basis, the government withdrew less productive lands from cultivation in the entire basin while making use of RS to assess water use; providing alternative, water-saving, but high-value cropping patterns (such as watermelon and grapes, in place of cotton and maize); and ensuring market access to farmers' new products (for details, see IEG, 2017; World Bank, 2017).

India's piecemeal approach

Unlike China's state-controlled water resources, in India, agriculture, water, and forests are constitutionally defined as the responsibilities of its 28 states and union territories. Land and water rights are ill-defined, posing challenges in implementing policies. India has lacked an umbrella framework to regulate freshwater in all its dimensions. The water law framework is characterized by the coexistence of a number of different principles, rules, and acts adopted over many decades. These include common law principles and irrigation acts from the colonial period, more recent regulation of water quality, and the judicial recognition of a human right to water. Different state and central legal interventions and other principles are sometimes inconsistent. For example, claims that landowners have over groundwater under common law principles may be incompatible with a legal framework based on the human right to water, with the need to allocate water preferentially for domestic use and provide water to all (Cullet, 2007).

Water policies in India consist of a series of bills, programs, and partnerships, without holistic objectives or strategies to achieve them. An Indian government publication noted reforms proposed in recent years in India:

1. *Basin-Level Governance*: The consolidation of several river authorities into the central Ministry of Water Resources, to enable better decision-making for surface water projects and allocation.
2. *Groundwater Bill*: The drafting and discussion of a model groundwater bill that defines groundwater as being held "in trust" by the government and specifies a decentralized structure for its governance.
3. *Innovative Irrigation*: The renewed focus on micro-irrigation adoption by farmers in the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) to enable efficient on-farm water use.

4. *Global Partnerships*: The formalization of a partnership with Israel, the world leader in water governance and conservation, to leverage Israeli experience and knowledge for water conservation in India (Niti Aayog, 2018).

These and other policies are works in progress; a record of weak project implementation, (see in next section) contributes to India's slower structural transformation than China's, with less population leaving agriculture than in China (Lele & Goswami, 2020; World Bank, 2014).

Response 2: Investments in irrigation infrastructure

Investments in infrastructure contribute to higher productivity and more stable agricultural and overall economic performance. Historically, annual investments in irrigation and water are substantially higher in China than in India, as shown in Figure 3a,b, (roughly, US$104 billion), in 2017 for investments in the water sector: construction of water-saving and water-supply projects, improvement of flood control, rural water development, and soil and water conservation (World Bank, 2018), compared to only US$60.3 billion in India during the Twelfth Five Year Plan (2012–2017). Moreover, there is abundant evidence of a stronger implementation record in China, compared to India[3] (Figure 2). The World Bank's (2018) "Watershed" report on China showed increased rates of completion, relative to fund allocations, over time. Evidence of India's slow implementation is discussed later in this article.

China's surge in investments

The Chinese experience with irrigation infrastructure investment suggests that investment levels are integrally related to governance and institutions, resulting in stronger implementation, and explains why reasons for China's better irrigation and water management performance are complex. From 2011–2015, China invested more than 2 trillion RMB (US$304 billion) in water projects, 2.9 times that of the period of Eleventh Five Year Plan of China (704 billion RMB, or US$105 billion). The investment in 2016 is 610 billion RMB (US$91 billion) (Ministry of Water Resources, 2017) (Figure 3a).

Over the last 60 years, China has built a tremendous amount of water-related infrastructure: a total of 413,679 km of river dikes and 98,002 reservoirs, accounting for more than 800 billion m^3 in storage; flood control structures built in all major river basins; 5887 rural water supply projects to provide services to 812 million people; and hydropower capacity of 341,000 MW (World Bank, 2018). China has 23,841 large dams (i.e., dams with a height of over 15 m) to store water (Table 1). The South–North project entails redirecting part of the Yangtze River flow to Northern China (Verma et al., 2009). China's lined canals are of varying quality, but, on the whole, have had higher conveyance of water to farms than has India's due to use of better technology for canal lining. Similar data for India are presented in Table 1.

India's uneven infrastructure investments

The indicative outlays for India's Water Resources sector (irrigation, flood management, and command area development) in its Twelfth Five Year Plan was proposed to be about 422,012

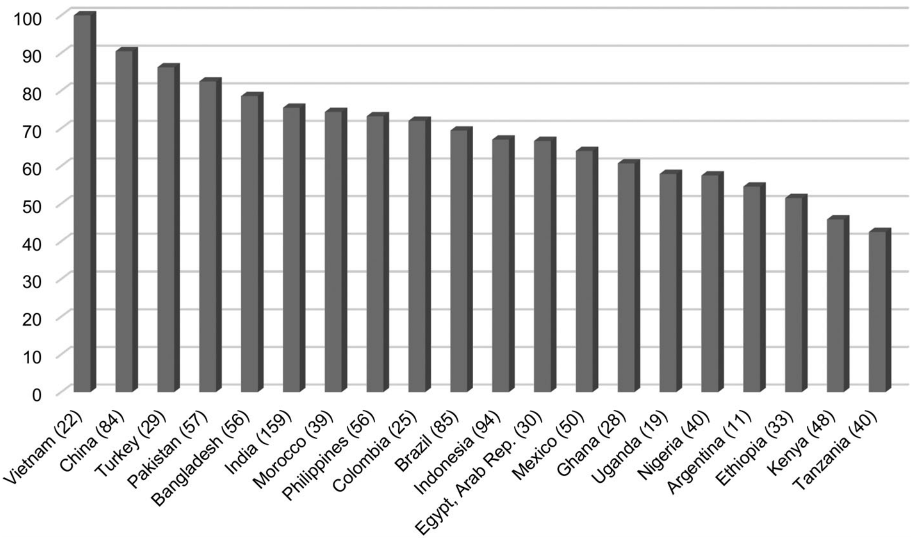

FIGURE 2 Share of outcomes in the satisfactory range (%) of the Agriculture and Rural Development projects in the top 20 recipient countries by IBRD–IDA Commitments to the Agriculture, Fishing and Forestry sector [Exit FY1972–2017] (Total 1005 ARD projects evaluated by IEG in the top 20 recipient countries). Note: () shows number of evaluated projects. Source: Based on the data from https://finances.worldbank.org/Other/IEG-World-Bank-Project-Performance-Ratings/rq9d-pctf

crore (US$60.3 billion) over five years (Figure 2b). The realization of this outlay, however, was dependent upon the resource position of the states and their priority to the sector (GOI, 2013). National-level data on irrigation investments in India have become less easily available since the replacement of the National Planning Commission in 2015, which had resource allocation responsibilities, with the National Institute for Transforming India (NITI) Aayog, which is an advisory think tank. The 28 states publish their own data.

At its independence in 1947, India inherited the world's largest public sector canal irrigation system of 22 million ha in the larger British India (including Pakistan and Bangladesh).[4] Policy focus remained on surface irrigation to achieve food security (GOI, 2011). India initially used bricks and labor-intensive methods to line its canals, so the seepage was high. This fact, combined with delays in the completion of canals, led farmers to invest in groundwater, a phenomenon much like Northern China. Small-scale tank irrigation had prevailed to meet food needs prior to colonization, which expanded surface irrigation to integrate India and promote exports (Shah, 2013). To get water to farmers' fields, by increasing agricultural credit and subsidies to purchase pumps, India now has over 25 million tube wells, two-thirds of which were built since 1990, with their expansion continuing uncontrolled. What is beneficial to individual farmers, however, is not necessarily environmentally sustainable at the macro level.

India's 5100 large dams for water storage are one-fourth the number of China's (Table 1). FAO and the International Commission on Large Dams maintain data on dams—a most comprehensive, recent, geo-referenced Global Database of Dams to date, containing more than 38,000 dams as well as their associated catchments. They show vast differences in dam estimates between the two countries (Mulligan et al., 2020).

The Twelfth Five Year Plan's water chapter lists several negative factors about dams: controversies associated with resettlement, closed basins, saline groundwater intrusion, aggravated water pollution, and other environmental consequences (GOI, 2013). The National River

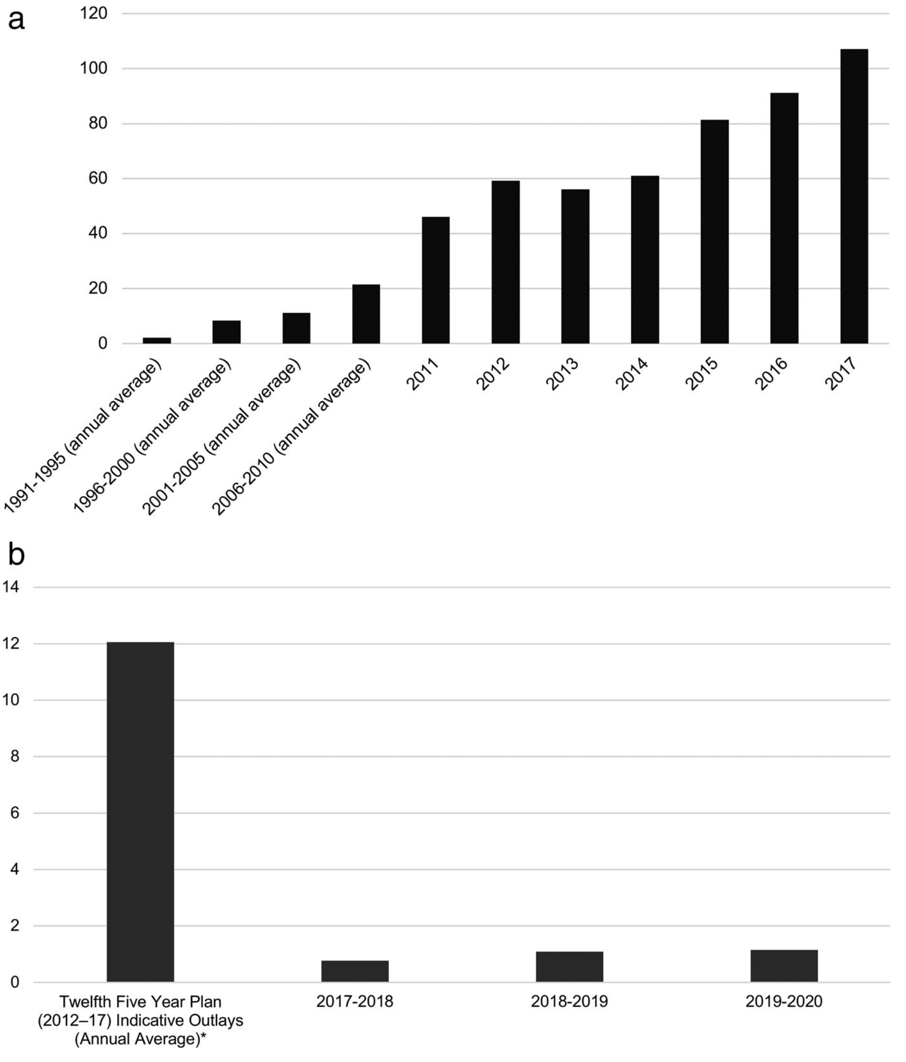

FIGURE 3 (a) China's total investment in water resources development (1991–2017) (US$ billion). Note: 1 US$ = 6.7 RMB. Source: Jiang (2013); Ministry of Water Resources (2017); World Bank (2018). (b) 12th Five Year Plan (2012–2017) indicative outlays to the Water Resources Sector (irrigation, flood management, and command area development) and total budget allocated by Ministry of Water Resources, River Development and Ganga Rejuvenation (2017–2018 to 2019–2020) (US$ billion). Note: 1 US$ = 70 INR. * According to the Twelfth Five Year Plan (2012–2017) Report: "The realisation of this outlay is dependent upon the resource position of the States and their priority to the sector" (GOI, 2013, p. 180). So, we do not know whether this materialized. The reporting on investments can certainly be improved. Source: GOI (2013), 2018b, 2019)

Linking Project is such an example of gridlock surrounding water projects (Amarasinghe & Srinivasulu, 2009). Such social opposition and ecological concerns have affected India's project performance more than China's. Seventy-five percent of the 159 ARD projects financed by the World Bank (including 57 irrigation and drainage projects), from 1972 to 2017, were rated marginally satisfactory or better (Figure 2). The slower implementation record of surface irrigation projects in India is further elaborated by Mukherjee in a complementary paper in this issue.

Capping water use is also more of a challenge in India. A recent World Bank-funded project, the Rajasthan Agricultural Competitiveness Project (RACP), has objectives similar to Turpan as a water conservation project. It has increased per ha productivity by 26%, reducing overall agricultural water use, and increasing market access for participating farmers. The project has achieved significant farmer mobilization, organizing them into more than 8100 multitask groups and 21 Farmer Producer Companies. Farmers are collectively investing US$25 million through Cluster plans to implement farm-level investments to meet the project objectives—however, unlike in China, as previously reported here, without directly addressing the consequences of the Jevon's effect in containing irrigation expansion (World Bank, 2019a).

There is a clear trade-off between short- and long-term sustainability of water use. Diversifying consumption out of rice and wheat produced in Northwestern India would reduce demand for water. Shifting food production to Eastern India, to poor states like Bihar, would address India's food security while increasing employment and incomes and assuring sustainability of water use in North-Western India. However, slow progress in Eastern India in the development of electricity and infrastructure connecting production areas to markets, as well as inadequate banking networks and institutions, have arrested growth of production and productivity, as reported in India's 2017–2018 Economic Survey (GOI, 2018a). Kshirsagar and Gautam (2013) also showed econometrically the strong relationship between infrastructure and productivity (World Bank, 2014).

Response 3: Use of technology and extent of surface vs. groundwater irrigation

RS, combined with land use and weather data, helps to accurately monitor water use. RS provides high-resolution monitoring of basin-wide land use and crop growth on a continuous basis against allocated use. Its use is more extensive in China than India.

China moves ahead with technology

At the local level, China's use of RS is found at ET management centers, with trained staff and monitoring platforms that farming communities can operate, to support basin-level decision-making. China's stronger record of implementation of surface irrigation projects helps control groundwater use, as shown earlier by the ratings of World Bank-funded irrigation projects by the Bank's Independent Evaluation Group. The growth in groundwater use, mostly through private investment, is a result of the synergetic relationship between the implementation of surface irrigation and groundwater development, a phenomenon which has been brought under control in China. With more investment funds, faster implementation, and use of better irrigation technology, China's surface irrigation is larger and its irrigation infrastructure is in stronger shape than India's. Despite these achievements, China is still facing acute challenges with respect to water quantity and water quality (World Bank, 2018, 2019b).

India's groundwater anarchy

India has been slower than China to adopt new technologies such as RS to improve monitoring of its water usage. State and central governments have been reluctant to make data from RS widely and publicly available. Wider use of the technology could minimize the controversies over the best types of irrigation in India (Shah, 2009). India went through phases of irrigation expansion followed by stagnation. The area under surface irrigation increased steadily from 1981 to the peak of 17.3 million ha by 1991–1992, but since then, surface irrigation has fluctuated between 17 million and 14 million ha, despite the government investing US$2.7 billion annually in surface irrigation (Chand, 2018; Chand & Sharan, 2018). By 2014–2015, surface irrigation was 16 million ha. Despite policy orientation toward surface irrigation, India's groundwater overdraft is the highest in the world, providing two-thirds of all irrigation and 80% of all drinking water, according to India's Twelfth Five Year Plan, and described by India's well-known water analyst, Tushaar Shah et al. (2009), in his book, as the challenge of "Taming India's [groundwater] Anarchy": a growing water demand of millions of farmers, depleting water tables, and deteriorating water quality. To deal with the challenge, India separated power lines for agriculture and nonagricultural uses, to enable access to reliable and affordable electricity. Shah has argued this approach has reduced application of water in agriculture and increased water tables (Shah, 2009). Democracy has also raised complex issues of trade-offs between "water haves" and "water have-nots"—often referred to as scavengers, depriving those with lack of access to credit to dig even deeper wells. Also, critics argue that the rise in groundwater tables may have resulted from three successive years of good rainfall, following three years of drought, rather than by improved water management. There is evidence that actual use of power in the irrigation sector has increased (Kumar & Perry, 2018). Recent analysis suggests that aquifer depletion may be worse in the "improved" areas than elsewhere (Chindarkar & Grafton, 2019).

As groundwater development has come into play with a critical role in supporting smallholder agriculture in most of India, proponents of groundwater development argue that agriculture would not be as dynamic without it Whereas large public irrigation projects are driven by hydrologic opportunity and rely on public sector bureaucracy, "groundwater development is democratic, providing irrigation wherever people are" (Shah, 2007, p. 18). Farmers are fully in control as owners and managers for small areas (1–15 ha); the cost of investing is low and manageable for small farmers with access to savings or bank finance. Groundwater irrigation can be implemented quickly; it uses motor pumps or lay-flat motor pumps for either groundwater or surface water; and it provides year-round, on-demand irrigation. Further, groundwater irrigation enables intensification and diversification of agriculture, which has been important in preventing famines recurrent in the canal areas where farmers switched to cash crops like cotton, and before that, opium. Indeed, they argue, groundwater has turned South Asia from an endemic food importer to a major exporter of food.

These and other water practices are viewed as alarming by water experts. Hoekstra (2003) and Mekonnen and Hoekstra (2016) have noted that, through rice exports, India has become the world's largest exporter of virtual water. Concepts like "virtual water" are not widely understood by policymakers. With growth of solar energy, groundwater investments are likely to grow, particularly if subsidized credit is available to invest in pumps. Such pilot schemes are underway in several parts of India, and out of concern about unchecked groundwater exploitation, farm households are also being encouraged to sell power to public utilities "as a crop," in long-term contracts with utilities willing to engage in such guaranteed purchases (Shah et al., 2016; Tushaar et al., 2017; Verma et al., 2019). While a good market-based idea in principle, it is not widely practiced. Utility companies are reluctant to take on a large number of small farmers as clients. Many companies are in financial trouble and reluctant to offer utility rates that would outbid returns to farming. Proponents argue that giving farmers access to solar panels and a guaranteed power market could lead them out of agriculture. The pilot effort has acquired national policy attention, but whether solar power generation by millions of small farmers is scalable and sustainable, at the same time, is unclear so far.

Response 4: Governance and institutions: From national constitutions to local participation

Differences in governance between China's centralized communist government and India's decentralized democratic structure have significant impacts on water management. Elinor Ostrom's eight common pool resource design conditions for collective action were rarely met in local governance of irrigation, as governance evolved organically over a long time period, often out of necessity (Ostrom, 1990). Shah (2018) explained how community participation worked in practice. Level 1 collective action involves simply paying fees; Level 2 involves actively controlling and managing water distribution, without necessarily owning parts or the whole system, often referred to as Irrigation Management Transfer (IMT); and Level 3 entails exclusion or controlling water use collectively. Controlling free riding is difficult and requires Level 3 collective action in managing aquifers shared by numerous users, but it is relatively easy in managing piped irrigation service from a collectively owned tube well or a canal distributary managed by a Water Users Association (WUA), where monitoring and exclusion are easier.

Participatory Irrigation Management (PIM) and Irrigation Management Transfer (IMT) arrangements were largely externally driven in the 1980s, by a concern about the fiscal constraints faced by governments in the period of structural adjustment. World Bank evaluations note their limited success in the world (Parker, 2010). With few exceptions, such as the sugar cooperatives in Maharashtra, India's WUAs, though large in number, lack capacity—one reason the government has promoted producer organizations, using the Companies Act (2013), to reorganize in achieving vertical integration. They are relatively new and are not organized around water use.

China's governance from the top down

The Constitution of the People's Republic of China specifies that, with minor exceptions, water resources are the property of the state, and therefore, subject to near total regulation. The State Council exercises ownership of major water resources on the state's behalf. Water in the ponds of rural collective economic organizations and in reservoirs constructed and managed by them is used by those organizations. When water conflicts cannot be resolved at the local level in China, higher levels of provincial or national government can intervene, because water is not a private resource. Water rights can be assigned, measured, monitored, and *changed* through public policy.

In response to budgetary shortages faced by developing countries following a period of structural reforms, in the early 1990s, the World Bank promoted participatory water management, leaving the responsibility for operations and maintenance of irrigation systems to farmers' groups. Although the overall record of PIM has been mixed at best, China embraced the approach and has tried to make it its own.

The first WUAs were established in China in 1995, growing to more than 50,000 by 2008. By 2020, they were expected to reach 80% of total irrigated area (Lin, 2002, 2003). A World Bank paper on PIM in China points to several successes at scale, benefiting from principles and guidelines developed under a Department for International Development (DFID)-funded project in China (Lin, 2003). In terms of planning for the future, WUAs are increasingly seen as vehicles to implement the Chinese water reforms and efficiency targets for 2020 and 2030, and in meeting the goal of bringing 18 million ha under water use efficiency by 2030. Efficiency, defined as the percentage of water used by the plant, was stated to be 0.53, up from 0.44 in 2004, and is expected to reach 0.6 by 2030, as compared to developed countries with efficiencies equal to 0.7–0.8. How credible these figures are is unclear. It remains to be seen if these goals will be achieved, but WUAs and other farmers' organizations are important to the China's larger holistic approach.

In Turpan, 43 WUAs were established and empowered to engage in on-the-ground water management and to be responsible for ongoing operations and maintenance of water systems. Along the lines suggested by Bardhan (2012, 2020), WUAs have clear responsibilities for monitoring and enforcing water withdrawals and are given financial and technical capacities to effectively implement their responsibilities. Thus, China's state-led approach to WUAs is different from Shah's (2013) typology of a framework of collective action at the farmer level in India. Although China's WUAs perform many of these functions, they have not evolved organically from the bottom up. Rather, they seem to have been built on the long history of community action. The World Bank, UK's DFID, and the Chinese government have actively promoted WUAs. China has used the resultant social capital that it creates as an instrument to improve water management. A combination of regulation, rulemaking, enforcement, and capacity building is carried out with the help of party officials at multiple levels. China has been unique in creating favorable conditions for promoting PIM, and IMT to local bodies has been seriously attempted. Elsewhere, such high-level, collective action has proved hard to sustain. It is tempting to explain this phenomenon in terms of China's centralized system. Since the Cultural Revolution, China has had a single political party, absence of a class system, and a long history of collective action at the village level, while Indian society remains fragmented by caste, class, and political parties.

India's governance in a decentralized democracy

Water governance works in a larger context of governance. Unlike China's unitary top-down system, India is a multiparty democracy with 200 major and minor political parties—in contrast to the immediate post-independence India, when the Congress Party was the ruling party at the center and in many states for several decades. Multiparty coalitions currently run state governments, often competing with the governing party (or a coalition) at the center to win the next election. Thus, the center's already weak constitutional power over states with regard to agriculture, forests, and water has declined even further, becoming more diffused. India's periodic elections provide political legitimacy, but recent research suggests that voters do not hold politicians accountable for development outcomes and rarely reward them for services delivered, such as roads built (Goyal, 2019). Promises made to get elected are soon forgotten. Indian experts also note that it is difficult to hold any one agency or individual accountable for results in the absence of clear responsibilities and accountability. More political economy research is needed to test these observations.

Not surprisingly, given the number of voices, water conflicts are increasing at all levels in India. Given the responsibility of states for water, agriculture, and forestry, the central government mediates interstate disputes, through water commissions, boards, and courts. Parliament and legislative assemblies at the state level, the Ministry of Water Resources and its various commissions and boards, the judiciary, media, civil society, and academia all play roles, albeit with very different degrees of power and access to information. A landowner in India also "owns" the water under his holding; India has not attempted regulation of groundwater where informal water markets prevail, but these markets often deprive the poor of access to water. Hence, the groundwater bill, holding water "in trust" by the government, and the bill's implementation will be crucial. Highlighting a determination to address institutional barriers to effective environmental and resource governance, recent reforms include the establishment of the Ministry of Ecology and Environment (MEE) and the Ministry of Natural Resources (MNR), along with consolidation and optimization of responsibilities within the Ministry of Water Resources (MWR) and other related ministries. It is too early to know how these reforms will work.

The weak central state has been implicated directly in India's gap between the irrigation potential created and utilized. Chand and Sharan (2018) reported, for the first time, the poor implementation in the irrigation sector; this gap has been part of a long-standing dialogue between the World Bank and India since the 1970s. In tune with the earlier World Bank observations, Chand and Sharan noted that, typically, it has taken 30–40 years to complete major irrigation schemes, compared to the 15–20 years normally expected, and 10–20 years to complete medium-sized irrigation schemes, compared to 5–10 years expected, owing to the reported "chaotic state of affairs" in the irrigation sector in all states. The gap between the irrigation potential created and irrigation potential utilized was 25% in the early 1990s, increasing to 36% in 2004–2006, then dropping to 21% during 2007–2012. The record for different states varied, but the overall record is one of lack of investment in last-mile irrigation channels to take water to farms, resulting in a simultaneous increase in groundwater exploitation. Implementation deteriorated in all states to varying degrees (Chand & Sharan, 2018).

Factors underlying India's water crisis have been widely analyzed. Mihir Shah (2013, p. 40) identified a shift of 12 paradigms: among others, of command and control approaches, bureaucratic governance, the "unidisciplinary" (engineering) bureaucracy, and the absence of a hydrological perspective. Earlier studies had reached many of the same conclusions. Water raises complex issues of command and control, in which there are externalities, beyond private use, as in the case of groundwater. Separately, a report of the Planning Commission's Working Group on Major and Medium Irrigation and Command Area Development for the Twelfth Five Year Plan (the Mihir Shah Committee), proposed fundamental changes in India's principles, approaches, and strategies for its water management (GOI, 2011; Shah, 2013). India's 2012 water policy was meant to address these issues.

Others have reinforced the governance concerns (Himanshu, 2018), but not all the solutions that the Mihir Shah Committee proposed for restructuring of the Central Water Commission and Central Ground Water Board of India are widely shared (Kumar et al., 2016). Critics argue that the nonperformance of state governments, which have responsibility for water management, are at the heart of the problem. Problems emanate from the lack of incentive to perform due to the inherent problems with institutional design, lack of transparency, and accountability in the functioning of these agencies (Kumar et al., 2016). It is unclear if the replacement of the Planning Commission by an advisory, strategic think tank (Niti Aayog) in January 2015 has improved implementation. Under the principle of a cooperative and competitive federalism that India has adopted, the power to allocate federal funds is now vested in the Finance Ministry, rather than the Planning Commission, but absence of accountability of the states to the use of federal resources remains a challenge.

Reinforcing the need for a strong political strategy despite the country's decentralization, India's leading national defense expert, Brahma Chellaney, venturing into water wars, predicted: "Water has emerged as a source of increasing competition and underlying discord between many Asian states striving for greater economic growth.... Water scarcity is set to become Asia's defining crisis by mid-century" (Chellaney, 2011, p. 1). Briscoe (2010) raised the risk of the Indus Waters Treaty between India and Pakistan, first signed in 1960, coming apart.

Reform 5: Water caps, pricing, and subsidies

Water productivity, a broader concept, allows for measurement at multiple scales (Giordano et al., 2017; also, Molden et al., 2007, in the specific case of China's two basins). Without capping water use at a higher level, increase in water use efficiency at the farm level will typically increase consumptive demand for water across farms and make capping water consumption more difficult, regardless of whether efficiency is viewed physically, that is, increasing the ratio of water beneficially consumed to water delivered, or economically, that is, increasing value-added per unit of water delivered (Perry & Steduto, 2017).

China: Conservation policies of the central state

Water pricing and pricing of services are often deployed in China with allocation of water on a volumetric basis and caps on water allocation, as a means of (1) achieving targets for reducing water use; (2) multisectoral allocation of water to provinces and local authorities; (3) measurement of water requirements on a crop-by-crop basis; (4) reduction of water caps in agriculture over time; and (5) rapid expansion of water-saving technologies, including the use of ET as a recommended measure of water use (World Bank, 2019b).

Volumetric allocations (typically administered by WUAs) and pricing were new in China in 2000, but both are widely practiced in many of the 22 irrigation and water projects for which project performance audits were completed by the World Bank. There is no one-size-fits-all approach. A number of complexities in measurement, allocation of volumes, and different methods of pricing practiced in China are described in the World Bank (2011) report on "Water Pricing and Water Users Association Sustainability." However, there is a long way to go to achieve reforms. In an empirical analysis of the impacts of irrigation pricing reforms in China, in contrast to the Turpan and other Xinjiang projects, Liao et al. (2007) noted low farmer involvement in irrigation decision-making. Lack of involvement leads to the farmers' low level of understanding as to what fees were due, for what purpose, and thus, how fees were related to water use and overall irrigation system financing, a problem sometimes exacerbated by the imposition of unofficial fees. The analysis showed that while current irrigation prices may be low relative to water supply costs, they are high relative to farmers' returns. Additional price increases would lead to a decline in production and income, outcomes that oppose current government policies to reduce the disparity between rural and urban incomes and to maintain something approaching national food self-sufficiency. The authors' results led to recommendations for the future of irrigation pricing reform for water use efficiency and cost recovery in China. These included more investment in irrigation infrastructure; greater interaction between surface and groundwater pricing, so costly surface water does not increase groundwater exploitation; and generally, the need for increased involvement of farmers in organizational and management decisions and the need for income transfers to farmers. Water prices remained low in China in 2010, ranging from RMB 0.01 to 0.35 per m^3. Substantial water pricing reforms have been underway, but the record has been mixed at best (Wang et al., 2020).

How widely and how well the current policies and such recommendations for future reform are applied, and with what impacts on water conservation, farmers' incomes, and sustainability of investments are known only on a very limited basis. In his visit to China in 2002–2003, Tushaar Shah noted that China was already experimenting with many alternative ways of water delivery, beyond the PIM and IMT that the World Bank and other donors were promoting. He described those outside of China as having been largely unsuccessful (Shah, 2007).

A key element of the Turpan strategy was setting a basin-wide, sustainable, scientifically determined cap on water consumption (China's water caps at the farm level have done away with the Jevon's effect) by conducting water balance/budget analysis, using multistakeholder decision-making to annually define prioritized water consumption in the basin, and allocating water use targets to farmers with permits issued (that is, an expected ET per farmer, converted to withdrawal volume) and revised annually as irrigation efficiency improves. Thus, in Turpan, farmers' water withdrawal permits were revised, based upon water target consumption allocations of the basin-wide, sustainable water cap. To enforce permits and discourage overuse, Turpan introduced a two-tier block tariff system. If actual withdrawals are below their targets, farmers pay low water charges. If farmers exceed targets, they pay higher water resource fees. A key difference between the Chinese Turpan Project and India's Rajasthan project (and other projects in India) is that China is promoting a "whole-system" solution, including caps on water use across sectors.

India's policies without enforcement

India is following some similar measures as China, but without imposing, enforcing, or monitoring adherence to caps on water usage and without water pricing as part of positive or negative incentives. The government has long encouraged groundwater expansion, more recently, through subsidies provided to farmers for electricity and credit for tube well use. India subsidizes water use through power subsidies, which are often seen as a strong political imperative, difficult to overcome, and without water charges. By providing assured power supply for a defined number of hours, India *expects* less wasteful use of water than when power supply is more erratic (Shah, 2007; Shah et al., 2009).

Aided by subsidies to power and credit for tube wells, much of the groundwater overdraft over large areas has been in Western India, with little incentive to control power use. The "Gujarat Miracle" is an experiment separating power supply to agriculture from household supply, making eight hours of predictable power supply available to farmers for nighttime irrigation, along with monitoring of power usage. It has brought groundwater overuse under control. Groundwater tables have increased, and several Indian states have adopted the policy of separating power lines for domestic and farming use (Chindarkar & Grafton, 2019; Kumar & Perry, 2018; Shah et al., 2009).

Critics of these policies assert that India has already exceeded its limits on groundwater exploitation, and water policies and subsidies have enabled more people to remain in agriculture than is sustainable (Perry, 2018). They argue that India must impose caps on agricultural water use, and small unviable farms must be abandoned, policies which China pursued in Turpan and elsewhere. Unless the population dependent on agriculture declines and farms are consolidated into efficient units, agricultural productivity (and agricultural incomes) will not increase. To the contrary, policy initiatives are designed to use more water in agriculture and provide incentives for the populations to remain in agriculture.

The rebound effect in India has been reinforced by the subsidies for farmers, based on widespread popular belief that drip irrigation saves water. This may be because drip irrigation takes water directly to crops, reducing water loss during its conveyance, but increase in crop production also means a commensurate increase in ET, a phenomenon rarely understood by nonexperts. China and India have actively promoted drip irrigation to preserve groundwater and increase resilience to climate change—while the likely impact is the opposite. Indian farmers receive substantial subsidies to invest in drip irrigation. They increase cropping intensity and establish greenhouses to introduce high-value, short duration crops (for example, red chiles in Rajasthan), exacerbating groundwater overdraft (Birkenholtz, 2017).

Drip irrigation increases farmer incomes through diversification and increasing the area that can be irrigated per unit of water delivered to the farm. Only better-off farmers can afford to introduce drip irrigation. The Indian government had no regulation to control abstraction of water. Basin-level water accounting and monitoring is needed (Birkenholtz, 2017; Grafton et al., 2018). Water accounting is being introduced in some state governments, such as Karnataka (Government of Karnataka, 2018; Shawky, 2018; World Bank, 2016). Reviewers of this work suggest that it is difficult to convince farmers and policymakers of Jevon's effect in India (personal communication, Raj Paroda, former Director General of the Indian Council of Agricultural Research (ICAR); Shalinder Kumar, scientist in the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), January 21, 2019; Ellen Hanak, January 22, 2019).

CONCLUSION

China's holistic, overarching approach should be part of the cross-country experience that policymakers in India and elsewhere review with interest. Evidence from 22 World Bank projects and other studies suggests that China has been moving toward conservation, by capping agricultural water use and making its use more productive and remunerative. We demonstrated that China is ahead of India on responding to water scarcity. India needs to create a much wider awareness of its impending water shortages, particularly, given India's decentralized democracy, so as to create a strong groundswell for improved water governance. With less top-down and more participatory governance, with clear responsibilities and accountabilities, and in the absence of coercive means to achieve change in water management, more grassroot demand and accountability is necessary. Greater use of technology such as Geographic Information System (GIS) mapping for routine water accounting, monitoring, and stronger planning and implementation is needed to be ready for future impending crises.

How India shifts from subsidies to incentives for water conservation remains a big political challenge. Referring to the estimates of the external 2030 International Water Resources Group (2009), India's Twelfth Five-Year Plan acknowledged that, if the current pattern of demand continues, about half of the demand for water will be unmet by 2030. It called for a paradigm shift. Niti Aayog's Composite Water Management Index (CWMI2018), published to enable effective water management in Indian states, also made headlines: “India is suffering from the worst water crisis in its history and millions of lives and livelihoods are under threat.... The crisis is only going to get worse" (Niti Aayog, 2018, p. 15). The new trend is investment by several states within the government, forming their own policies and making their own investments. The balance of investments in surface and groundwater irrigation remains a future challenge, a rich subject for analysts concerned with sustainability. Meeting multiple demands on water and agriculture represents a great challenge, especially in water "battleground" countries. With multiple objectives, there must be specific policy instruments to achieve specific objectives (Tinbergen, 1978). The focus on the water–food–energy nexus has tended to overlook specifics and trade-offs in the short and long runs.

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ENDNOTES

[1] The focus of the paper is limited to agricultural water consumption, and not water quality or industrial water use issues, although these issues deserve similar comparative studies.

[2] Taylor and Zilberman (2017) observed Jevon's paradox in the case of the diffusion of drip irrigation in California, as did Birkenholtz (2017) and Grafton et al. (2018) in the case of drip irrigation in India. Xinjiang Turpan basin was facing a similar problem at the time of project appraisal (World Bank, 2010).

[3] Among the 20 top recipients of World Bank (IBRD + IDA) assistance to Agriculture, Fishing and Forestry (AFF) sector—for which the World Bank evaluated a total of 1005 Agricultural and Rural Development (ARD) projects, which exited during 1972 and 2017—China was one of the best performers in overall ratings, as well as the country with the largest number (12 out of 84 rated projects, including 22 irrigation and drainage projects) rated as highly satisfactory projects. India's record, which was stellar in the 1960s and 1970s, has declined over time. It has had only one highly satisfactory project out of 159 rated projects. China's share of project outcomes in the satisfactory range was 90.5% compared to India's 75.5% (Lele et al., 2021).

[4] The canals were built to ensure a reliable supply of poppy exports to China, which had been the cause of frequent famines during colonial India.

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