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Chinese Agricultural Water Resource Utilisation in the 21st Century

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Abstract

With increasing industrialisation and urbanisation, more and more of China's scarce water resources are being transferred from low-value agricultural use to high-value industrial and domestic uses. The challenge now facing decision makers is how to resolve the conflict between increasing food demand and decreasing water supply without undermining the growth of cities and the industrial sector. Along with water shortages, water use inefficiencies are apparent. An analysis of some causes of these inefficiencies is provided. They include attenuated property rights, artificially low water prices, lack of user participation in irrigation district management, fragmented government management, and lack of a compensating mechanism between upstream and downstream users. It is concluded, against the background of a transitional economy, that the lack of economic incentives in the allocation of water is the principal reason why shortage and waste coexist in Chinese irrigated agriculture. Owing to failures in both markets and governments, it is argued that water resources should be allocated through a quasi-market.

Keywords: Water Resources, Property Rights, Market Allocation

1. Chinese Water Resources

1.1 Water supply

China is geographically large yet relatively poor in terms of water resources per capita. The total volume of water runoff in China is 2,711 million mega litres (mML) per annum. The per capita water run-off per annum is 2.151 ML. This is less than one-quarter of the world average (see Table 1).

Table 1 International water availability

Country	Annual run-off (m ML)	Population (b)	Run-off per capita (ML)	Arable land (m ha)	Run-off per ha arable land (ML/ha)
Brazil	6950	0.149	46.808	32.3	215.17
Former USSR	5460	0.28	19.521	226.7	24.111
Canada	2901	0.028	103.607	43.6	66.536
China	2711	1.26	2.151	97.3	27.867
Indonesia	2530	0.183	13.825	14.2	178.169
USA	2478	0.25	9.912	189.3	13.09
India	2085	0.85	2.464	164.7	12.662
Japan	547	0.124	4.411	4.33	126.328
World	46,800	5.294	8.84	1326.0	35.294
China/world	6%	21%	24.3%	7.3%	79.0%

Source: Chen Jiaqi and Wang Hao, 1996. *A General Analysis of Water Resource in China*, The Water Conservancy Press, China: 80.

Northern China is especially water poor, with an average 0.75 ML of runoff available per capita per annum. Water availability in the Hai-Luan River Basin is particularly low at 0.355 ML per capita per annum. Availability in the Huai and Huang River Basins is higher, but still below the internationally accepted definition of water scarcity of one ML per capita per annum (World Bank 2001).

Since 1949, 4.6 million water supply projects have been constructed across China. This has allowed the utilization rate of water resources to reach 20 per cent of available runoff. The water storage capacity of supply works has increased from 100 million ML in 1949 to 560 million ML in 2000 (China, People's Republic 1997).

The Chinese population is expected to reach 1.6 billion by the middle of the 21st century. At that point, the amount of run-off per capita per annum will be reduced to 1.75 ML. According to The Ninth Five Year Plan and 2010 Program of Chinese Water Conservancy Development, China's water storage capability will continue to be extended by 120 million ML until 2010. The total water storage capacity then will stand at around 620-650 million ML.

1.2 Increasing water demand

According to the White Paper on Population in China (2000), China's population (excluding the population of the Hong Kong and Macao Special Administrative Regions and Taiwan Province) reached 1.26 billion by the end of 1999. Based on the current per capita demand for water, Deng and He (1997) predict that a water supply deficit of 100 million ML will exist by 2010 and this will widen by 2030, when it will reach 230 million ML. Furthermore, the World Bank predicts that the urbanization rate will increase to around 40 per cent by 2015 from the current rate of 36 per cent (The World Bank 2001). In addition, as income per capita grows, Chinese people are shifting their food preferences toward less grain and more meat (Li Xiaoyun *et al.* 1997). Both factors will tend to boost the per capita demand for water.

As a response to changes in consumer tastes since the mid-1980s, Chinese farmers have rapidly expanded the area used for commercial crops. For example, the area in China used for vegetables increased threefold, and that for orchards fourfold over the period 1982-1998 (Tagalder Technology

Corporation 2000). Farmers adjust the pattern of cultivation to meet market demand and improve the quality of farm produce. This means increased demand for water.

Table 2 Water use in China

Year	Indicator	Agricultural	Industry	Urban	Total	Water use per person per year (ML)
1949	Withdrawal (mML)	100.1	2.4	0.6	103.1	0.187
	Share (%)	97.1	2.3	0.6	100	
1959	Withdrawal (mML)	193.8	9.6	1.4	204.8	0.316
	Share (%)	94.6	4.7	0.7	100	
1965	Withdrawal (mML)	254.5	18.1	1.8	274.4	0.378
	Share (%)	92.7	6.6	0.7	100	
1980	Withdrawal (mML)	391.2	45.7	6.8	443.7	0.450
	Share (%)	88.2	10.3	1.5	100	
1993	Withdrawal (mML)	405.5	90.6	23.7	519.8	0.443
	Share (%)	78.0	17.4	4.5	100	
1997	Withdrawal (mML)	419.7	112.1	24.8	556.6	0.458
	Share (%)	75.4	20.2	4.5	100	
1998	Withdrawal (mML)	405.5	112.6	25.4	543.5	0.435
	Share (%)	74.6	20.7	4.7	100	
1999	Withdrawal (mML)	416.4	115.9	26.8	559.1	0.440
	Share (%)	74.5	20.7	4.8	100	
2000	Withdrawal (mML)	307.6	113.7	28.5	549.8	0.423
	Share (%)	74.1	20.7	5.2	100	

Source: the Ministry of Water Resources (1999, 2000). *Bulletin of Water Resources*, China.

As shown in Table 2, agricultural activities (including crop farming, livestock raising, drinking water and other uses in rural areas) consumed about 307.6 m ML in 2000. This accounted for 74.1 per cent of the total water use. Irrigated land accounted for 50 per cent of the total cultivated area and consumed over 95 per cent of the agricultural water use. Although the demand for water arising from intensified industrial and human needs is increasing, the extent of irrigation demand has not grown in recent years. Agriculture, however, is still the main water user.

1.3 Unevenly distributed water resources

There are striking differences in the allocation of water resources across the regions and provinces of China. With regard to the geography of water, there are two Chinas. The humid south includes the Yangtze River and has a population of 700 million. The arid north includes the Yellow, Liao, Hai, and Huai Rivers, and supports 550 million people. However, whilst 81 per cent of Chinese water resources are in the southern part of the country, the largest part of the arable land, 64 per cent, is in the north. As a result, the amount of water per hectare of cropland in the north is only one-eighth that in the south. Furthermore, the northeast of China accounts for 26 per cent of the total population of China, but it receives only 20 per cent of the total water resource. The distribution of groundwater is similarly skewed. Average groundwater resources in the south are more than four times greater than in the north. This naturally uneven spatial distribution of water resources constitutes a challenge to the sustainable economic and social development in China.

Natural precipitation is also unevenly distributed over time. There are significant seasonal variations in rainfall among the different areas of China as well as from year to year. About 70 per cent of precipitation falls in the ‘high-water’ season from June to September. Rainstorms and floods are common in that season. The ratio of maximum to minimum annual runoff on a yearly basis is 2 to 3:1 for the Yangtze and Zhujiang Rivers in the south, 4:1 for the Yellow River and 15 to 20:1 for the Huaihe and Haihe Rivers in the north (Li xiaoyun et al. 1997). Dramatic shifts in annual and monthly precipitation cause floods and droughts (see Table 3).

Table 3. Losses caused by drought

Years	The area affected by drought (ha)	The area of cropland damaged (ha)	The loss of grain (kg)
1950s	1160	370.3	434,900
1960s	2164.4	1002.5	931,100
1970s	2612.2	745.4	924,900
1980s	2456.2	1176.2	1,921,900
1990s	2431.2	1176.2	1,956,900

Source: The Commission of Splendid Development of Water Conservancy, 2000. The Splendid Development of Water Conservancy in China in 50 years: 45.

1.4 Environmental problems arising from water development

The deterioration of riverine environments is an issue of concern in many countries around the world, including China. For instance, the Yellow River first appeared to stop flowing in 1978. Subsequently, flow ceased each year from 1985 up until 1997. The accumulated period of zero flow is now 226 days (Ministry of Water Resources 2000). Although it is perhaps the most visible manifestation of water scarcity in China, the drying-up of the Yellow River is only one of many such signs.

Overexploitation of water in Chinese arid areas is profoundly changing hydrological conditions in northern China. The supply deficits in surface water resources have led to intensified use of the groundwater beyond the 'safe yield', where recharge balances withdrawals. Hence the water table has fallen under both rural and urban areas. Other consequences have included land subsidence and salt-water intrusion in coastal areas. Overextraction of ground water has become a serious problem in a number of cities including Nanjing, Taiyuan, Shijiazhuang, and Xi'an. Groundwater depletion is most problematic in coastal cities, including Dalian, Qingdao, Yantai and Beihai, where saltwater intrusion is on the rise. Soil erosion and wetland degradation related to water use are also occurring (World Resources Institute 1998-1999).

All of China's water bodies are polluted to various degrees of severity. Serious pollution has been documented in seven of the country's major watersheds: Huai, Hai, Liao, Songhua, Chang, Zhu and Huang. More than 90 per cent of urban water supply sources are polluted to varying extents. In the upstream and middle reach areas of rivers, the water conservation capacity has been reduced because of vegetation clearing (World Resources Institute 1998-1999).

2. Implications for Chinese Agriculture

2.1 Heavy dependence of agriculture on irrigation

China's agricultural land is small in area relative to its population. However, the most limiting current constraint to agricultural production in China is water rather than land. This is particularly the case given the uneven distribution of water between the north, which is drought prone, and the south, which is frequently threatened by flooding. Irrigation provides supplementary water for agriculture where rainfall is not sufficient for the needs of crops. It is crucial for the survival of China's agriculture, because 81 per cent of China's arable land is in north China, where natural rainfall does not match the needs of crops in quantity, nor in time. Large parts of the existing agricultural areas in the north cannot be cultivated to their full potential due to insufficient rainfall. An example is the Huanghe, Huaihe and Haihe River plain, which is considered to have the greatest potential for agricultural development due to its vast area of arable land and relatively low current yields. This area covers about 10 per cent of China's territory but has less than two per cent of the nation's water resources. The gap between water supply and potential demand is equivalent to about three-quarters of the annual rainfall. This, therefore, results in the heavy dependence of agriculture on irrigation.

2.2 The direction of irrigated agriculture in China

Feeding China's population is a continuing major challenge for the Chinese Government. 'It is a matter of mounting concern, not just to agricultural officials but increasingly to national leaders and security advisers, to know more precisely what happens to land productivity as the supply of irrigation water plummets' (Brown 1998: 2). In China, 70 per cent of the grain harvest comes from irrigated land. One way to secure food supply into the future is through increased production from irrigated arable land. After the foundation of the new China, the Central Government has aimed to increase irrigated agriculture production. This has proceeded in four stages (see Table 4):

- 1949~1975: irrigated land expanded quickly, increasing by 30.19 m ha in 26 years (1.16 m ha per year);
- 1975~1982: irrigated land expanded more slowly, increasing by 2.54 m ha in 7 years (0.363m ha per year);
- 1982~1988: irrigated land contracted slowly, decreasing by 0.75 m ha in 6 years (0.12 m ha per year);
- 1988~1997: irrigated land expanded slowly, increasing by 4.36 m ha in 9 years (0.48 m ha per year).

Table 4. Area of irrigation in China

Year	Cultivated land (m ha)	Area of irrigation (m ha)	Ratio of irrigation to cultivated land (%)
1949	97.88	15.93	16.3
1952	107.92	19.34	17.9
1957	111.83	25.00	22.4
1962	102.90	28.70	27.9
1965	103.59	32.04	30.9
1975	99.71	46.12	46.3
1978	99.39	48.05	48.3
1979	99.50	48.32	48.6
1982	98.61	48.66	49.4
1983	98.36	48.55	49.4
1984	97.85	48.40	49.5
1985	96.85	47.93	49.5
1986	96.23	47.87	49.7
1987	95.89	47.97	50.0
1988	95.72	47.91	50.1
1989	95.66	48.34	50.5
1990	95.67	48.39	50.6
1991	95.65	48.95	51.2
1992	95.43	49.46	51.8
1993	95.10	49.84	52.4
1994	94.91	49.94	52.6
1995	94.97	50.41	53.1
1996	94.97	51.16	53.9
1997	94.97	52.27	55.0

Source: *The Yearbook of Statistics*, Water Conservancy Press, China.

As a growing open economy, China can import more food to support its people. However, according to Brown et al. (1998), China's water shortages will threaten world food security. Differences in living and dietary patterns between China and developed countries cast doubts on these predictions, but they do provide a warning to the Chinese Government that food security is a major issue. From the perspective of Chinese decision makers, maintaining food security means attaining high food self-sufficiency for China. This is because importing even a small share of China's grain consumption would constitute a large proportion of the world export market. For example, in 1995 when there was a severe drought in China, the grain deficit in China reached an unprecedented level of 20 m tonnes in that year. The 20 m tonnes of grain imported in 1995 covered only four per cent of China's grain consumption, but accounted for 10 per cent of world grain trade (Tagalder Technology Corporation 2000). In this case, Chinese authorities feared the economic risk of increased grain prices and/or the political risk of a large scale embargo on the grain trade. Hence, irrigated agriculture has played, and will continue to play, a crucial role in the support of the policy of food self-sufficiency in China.

With the development of a market-oriented economy in China, the market mechanism can be expected to play an increasing role in the allocation of resources. Because of the difference in value derived from industrial, agricultural, and domestic water use, more and more water resources will be transferred from low-value agricultural use to high-value use in the future. The challenge now facing the Chinese economy is how to resolve the conflict between increasing food demand and decreasing water supply without undermining the growth of cities and the industrial sector. Irrigated agriculture faces two kinds of pressures: increasing demands for agricultural products and decreasing water supply for agriculture.

Although Chinese agriculture depends heavily on irrigation, due to the big difference in value between different users, continuously decreased water supply for agriculture is the main constraining factor. As Brown *et al.* noted:

> Of course, those farmers' ability to provide food enough for their nation is constrained by a range of factors in addition to water - by the construction of roads over once-productive farmland, by erosion of soil, by diminishing benefits of fertilizer, and by a shrinking backlog of the technology used to raise land productivity. But it is the swelling diversion of irrigation water, combined with heavy losses to aquifer depletion, that has emerged as the most imminent threat to China's food security (1998: 2).

3. Problems in Chinese Agricultural Water Utilization

In order to alleviate the water supply deficit in irrigated agriculture, the Chinese Government has adopted many technological advances and policy instruments to increase the productivity of irrigation water. The Chinese Government has instituted the China Water Conserving Development Program for Irrigation Agriculture, drawn up the technology standards suitable for national conditions for various water-conserving irrigation projects, and formulated a plan for the construction of large-scale water-conserving irrigation demonstrations at the national level. After decades of development of water-conserving technology, Chinese irrigated agriculture has a strong technological base. However, there are many crucial problems in Chinese agricultural water use.

3.1 Inefficiency

Whilst the water supply deficit for Chinese agriculture has been increasing over time, water use efficiency is still poor. At present, the average efficiency of the canal water delivery system is 30 to 40 per cent, compared with a rate of 70 to 90 per cent in most developed countries. In 1995 the use rate in China was one-eighth of the rate in the United States of America in 1990, and four per cent of the rate in Israel in 1989. Mean grain output per ML of water is 850 kg, less than half of that in some developed countries. By contrast, it is 2320 kg per ML in Israel (Liu and He 1996). The poor condition of water-supply facilities and infrastructure also leads to waste in domestic water use. In other words, inefficiency of water withdrawal is making the Chinese water deficit even more serious.

3.2 Water pollution

China has suffered seriously from water and soil loss (Ministry of Agriculture 1997). Croplands are increasingly affected by pollution, mostly arising from industrial discharges of contaminated wastewater or through pollution of irrigation water. Less than 20 per cent of wastewater is treated before being discharged into rivers and lakes. So far, about 2.6 m ha of land has been taken out of agricultural production as a result of wastewater pollution and the amount of grain foregone is estimated at five to 10 m tonnes. Almost seven m. ha. of irrigated farmland has been affected by salinisation and alkalinisation as a result of irrigation without adequate drainage, or the application of insufficient water to flush salts through the soil and into the drainage system (Li Xiaoyun *et al.* 1997).

Table 5. Total amount of wastewater in China 1991-2000

Year	The total amount of wastewater (m ML)	Industrial wastewater (m ML)	Residential wastewater (m ML)

1991	33.6	23.6	10.0
1992	36.7	23.3	13.4
1993	35.6	22.0	13.6
1994	36.5	21.6	14.9
1995	39.0	23.0	16.0
2000	62.0	40.9	21.1

Source: the Ministry of Water Resources (1999, 2000). *Bulletin of Water Resources*, China.

Agriculture is a primary and important source of pollution. Agricultural pollution is predominantly non-point due to fertiliser runoff, pesticide runoff, and discharges from intensive animal production enterprises. According to the World Bank (2001), total fertiliser consumption in China increased by more than 500 per cent between 1980 and 1998, by which time it amounted to about 41 m tonnes per annum. Nearly 70 per cent of the total nutrient load flowing into Dianchi Lake in Yunnan Province is derived from agricultural runoff. About 75 per cent of total phosphate and 60 per cent of total nitrogen is derived from agricultural non-point sources (World Bank 2001).

4. Causes of Inefficient Chinese Agricultural Water Utilization

4.1 Attenuated property rights over water

'Property rights form an open-ended bundle of rights to possess, to use, to benefit from and to dispose of valuable and scarce assets' (Kasper 1998: 63). According to the newly revised Water Law (2002), all water resources in China belong to the state. In the absence of an integrated management organisation, the Water Conservancy Department, the Department of Construction and the Environment Department co-owned the control rights of the water resource on behalf of the State before 1997. As a result, water has effectively been an open access resource. The result has been inefficiency in water use.

In the absence of well-defined property rights, disputes over water use have become more frequent. In an attempt to improve water resource use efficiency, the Central Government implemented a licence permit system in 1994. The presence of many small, fragmented farms makes it costly to measure the amount of water used by a farmer. These high transaction costs make it difficult for the licence permit system to be implemented in agriculture. Hence, the water resource in rural areas remains an open access resource.

4.2 Low water prices

Historically, the price for water has been held at an artificially low level by the Government. In October 1965, the method of use and collection of water fees was promulgated by the State Council. This was the first system for water fee collection in China. The price for water at that time was set at US$0.36 to US$1.20 /ML for industry, and US$ 0.24 to US$ 0.60 /ML for residents. Provincial governments determined the water fees for agricultural users and they were nearly free of charge. The price of water was set without regard for the costs of supply. Hence, the Chinese Government subsidised the use of water. The heavy financial burden of subsidies forced the government to enact a new method for the accounting, collection and management of the water fee in 1985. Under this new method, water fees were accounted on the basis of cost. Where the price of water for agriculture was concerned, the price of water for food crops should cover the cost of supply, and the price for industrial crops was beyond the cost of supply.

In 1992, the State Council attempted to establish a new management method for the price of water. This new method involved the decentralisation of water pricing, the use of incremental pricing for extra water, and the introduction of a two-part tariff for water. Because of many difficulties in practice, the reform was not introduced. However, it pushed forward the reform process for water prices considerably. Since then, water fees have been called water prices. This was not mere semantics: it signalled the start of water being treated as an economic good.

In 1999, the price of water supplied by water conservancy projects were US$ 3.26 /ML on average, US$ 9.67 /ML for industry, US$ 6.65 ML for residents, and US$ 3.26 /ML for agriculture. The water price for agriculture incorporated only the operation cost of water conservancy projects. It did not include labour cost, depreciation and management expenses. The water used by agriculture was therefore subsidized. More problematic is that the subsidies were paid directly to the enterprise supplying the water resource, not to farmers. The beneficiaries of the subsidies were the supply authorities not the farmers. Furthermore, the water revenues were not collected by the supply enterprises themselves, but by local Counties or town administrations on behalf of the enterprises. The water price was thus regarded as a fee for administration, not the price of an economic good.

In sum, the problems of pricing agricultural water use are threefold. Firstly, the water price does not reflect the true economic cost of supply causing inefficiencies in use patterns. Secondly, there are too many stages in the process of water price collection and hence too many opportunities for free riding and rent seeking on the part of local administrators. Thirdly, the prevailing pattern of subsidies exerts a heavy burden on government

4.3 Lack of property rights over water supply infrastructure

Historically, many of the large irrigation schemes constructed in the 1950s and 1960s were designed hastily, constructed to low standards, and built with poor quality materials and equipment. Many were not completed or currently lack distribution and drainage networks at the tertiary and farm level currently. Most systems require major upgrading, rehabilitation and completion.

Under the Home Responsibility System, farmers hold relatively independent land use rights. However, the rights over the water supply system have been held by the State. The physical infrastructure thus had the characteristics of an open access resource. However, the management responsibility for the water supply infrastructure in the irrigation districts (ID) is now being transferred to water users associations (WUAs). The objective of this reform is to establish financially autonomous enterprises and self-governing WUAs. However, due to the poor quality of the infrastructure, the WUAs are unwilling to take over the responsibility for its management. Furthermore, the authorities that have been responsible for the infrastructure are unwilling to give up their monopolistic position.

4.4 Fragmented government management

Before 1997, the Ministry of Water Resources (MWR) was responsible for overall water resources planning and management, major water supply infrastructure and large hydropower generation. The Ministry of Construction was responsible for wastewater treatment investment, and the National Environmental Protection Agency was responsible for wastewater legislation and discharge compliance monitoring. Since 1998, the Ministry of Construction has turned over most control rights to the surface water to the MWR. This has made the MWR more completely responsible for the allocation of water resources.

To realise comprehensive control over the overall quantity, quality and ecology of water resources, the State has been developing plans of management for water resources based on watersheds. River Basin Committees, such as the Huanghe Water Conservancy Committee and the Yangtze Water Conservancy Committee have been established. However, due to the lack of supporting legislation and enforcement, all these committees have only partial control over the rights to water resources.

4.5 Lack of compensating mechanisms

For a long time, there was no compensating payment for the inter-regional and intra-regional redistribution of the water resource. Artificially low prices for irrigated agricultural products and a heavily subsidized price for water have inevitably resulted in overuse of water resources. The open access nature of water has resulted in overuse by upstream users. Downstream users are unwilling to pay for the opportunity cost caused by the reduction of upstream water use. Upstream and downstream users have been in conflict. Research carried out on farmers' behaviour in IDs has shown that the water used by upstream users is not the highest available value use (Han 2000). A trading mechanism between upstream and downstream users could therefore lead to improved social welfare.

5. Challenges to Future Agricultural Water Use - the Establishment of a Quasi-market for Water

Shortage and waste coexists in Chinese agricultural water utilization. An increase in agricultural water use efficiency is a necessary condition not only for future agricultural development, but also for Chinese social and economic development. Against the background of a transitional economy, the lack of economic incentives is the fundamental cause of inefficient Chinese agricultural water utilisation. Continuing macroeconomic reform in China will require further market development at the micro level. Sources of growing non-agricultural demand will push for increasingly open water markets, farmers will continue to lobby for easily transferable water rights and the general climate of decentralisation favours the continued development of water markets.

5.1 Market failures in the allocation of water resources

Markets are institutions that exist to facilitate exchange. They exist in order to reduce the cost of carrying out exchange transactions. Under the conditions of complete information and perfect competition, markets will achieve first-best allocations. Markets can only function well under the following preconditions (Johansson 2000 p9):

- Institutional arrangements establish water rights that are excludable, transferable and separable from land rights;
- A flexible infrastructure can transfer quantities of water;
- Third party effects (externalities) are internalised by the system; and,
- Equity concerns, such as future and social goals, are addressed.

A situation where the market does not result in an efficient allocation of resources is the core of market failure. There are three basic reasons for market failure. First, individuals may not have sufficient control of a commodity or resource to undertake the necessary exchange. Second, high transaction and information costs can erode the advantages of trade. Finally, the individuals involved in trade may be unable to negotiate and agree upon the terms of mutually advantageous exchange.

Crase *et al.* (2000) outlined five basic factors hindering the development of the permanent water market: poorly defined rights to access and use the resource, variability of supply, infrastructure obstacles, excessive transaction and transfer costs, and hoarding behaviour and speculation.

More especially, the nature of monopoly power and presence of public goods results in market failures in the allocation of water resources. The production of water resources has some characteristics of a natural monopoly: that is, average costs decrease as more units are produced. Some water services are public goods in that once they are produced, no one can be excluded from benefiting from their availability. All these factors may lead to market inefficiencies.

5.2 Government failures in the allocation of water resources

Ever since Marshall and Pigou it has been argued that externalities constitute a *prima facie* case for government intervention in a market economy (Coase 1988). This Pigouvian tradition is criticised because ‘it fails to disclose the factors which determine whether governmental intervention is desirable, and of what kind, and it ignores other possible courses of action’ (Coase 1988: 24).

Hence, public intervention has problems of its own. These include misallocated project investments, overextended government agencies, inadequate service delivery to the poor, neglect of water quality and environmental concerns, and the underpricing of water resources. The government faces the same problems as the market: incomplete information and high externalities resulting from incomplete information. The central water authority often lacks complete information on water supply, demand, and consumption. For example, whenever irrigation water is priced by some public agency, problems related to incomplete information arise. The user has complete information on his/her marginal water value and amount of water used, but some of this information is private and unavailable to the State.

Meanwhile, government regulation confronts administrative costs: including the costs of investigation and administration. Sometimes the costs are sufficiently high that the expected gains from governmental intervention are less than the costs involved. 'Under public management the dominant incentive to comply is coercion: that is, setting regulations and using sanctions for those who break them. But this type of incentive is only effective if the State detects infractions and imposes penalties. In many cases the state lacks the local information and ability to penalize, e.g. for breaking water delivery structures or for excessive water withdrawals' (Dinar *et al.* 2001: 6). In particular, the existence of externalities does not imply that there is a *prima facie* case for governmental intervention. Whether government intervention is desirable depends on the costs relative to the expected gains.

5.3 The establishment of a quasi-market for water resources

Because of market failures and government failures, the operation of a simple market or the control by government may not allocate water resources efficiently: 'What one can observe in the world, however, is that neither the state nor the market is uniformly successful in enabling individuals to sustain long-term, productive use of natural resource systems. Further, communities of individuals have relied on institutions resembling neither the state nor the market to govern some resource systems with reasonable degrees of success over long periods of time' (Ostrom 1991: 1).

The aim of economic policy is to ensure that resource allocation conforms to social objectives, notably efficiency and equity considerations. While economic efficiency is concerned with the amount of wealth that can be generated by a given resource base, equity deals with the distribution of the total wealth among the sectors and individuals of society. While there are many reasons why markets fail, at the heart of the issue is poorly defined property rights. Hence, a key role for governments in natural resource management is to provide a secure, transparent system of property rights. 'In the development of water markets, the government is responsible for creating a supportive institutional environment----government intervention is often necessary to define and enforce water rights in order for the successful functioning of water markets. Government assists in monitoring and regulating externalities and third-party effects of irrigation'(Johansson 2000: 17).

Achieving this role faces many challenges. First, water resources are non-fungible resources for human existence. Second, there are many uses for water, drinking and domestic purposes, irrigation, fishing and navigation, hydropower generation, flood management, recreation, tourism and preservation of uses. The purposes are often in conflict and the satisfaction of one obstructs the fulfilment of the other. Meanwhile, there are some characteristics of water resource development that lead to public intervention. They are large capital investment and monopoly pricing. Besides these, 'there are a number of legislative or administrative caveats at the local level which complicate the operation of the water market. These limitations are largely designed to reflect environmental, physical and operational constraints but have developed on an ad hoc basis' (Crase *et al.* 2000: 299-321). Furthermore, some of the environmental benefits provided by water, for instance, the instream biodiversity protection, have public good characteristics, which means that property rights cannot be defined. Hence the government's role may extend beyond the defining, or enforcing of property rights. The market for water, especially in an economy in transition, can thus best be seen as a quasi-market.

5.3.1 The present institutional settings

A well defined system of rights that are monitored and enforced is a prerequisite for efficient water use: 'It is evident that, for their operation, markets such as those that exist today require more than the provision of physical facilities in which buying and selling can take place, they also require the establishment of legal rules governing the rights and duties of those carrying out transactions in these facilities' (Coase 1988: 10).

This applies for both individual and collective decision making. The system therefore involves not just the legal framework but also the policy environment and administrative arrangements. Institutional arrangements governing the water sector are undergoing changes worldwide. The Chinese Government has been attaching great importance to the reform of the laws and regulations concerned with water resources. The MWR began work in the 1970s on water pollution monitoring. More importantly, the Act on Water Pollution Prevention of the People's Republic of China, enacted in May 1984, provided the legal basis for water environmental protection.

In 1988, the first law on water resources, the Water Law of The People’s Republic of China, was formulated ‘for the purpose of rational development, utilization and protection of water resources, control of water disasters, fully deriving the comprehensive benefits of water resources and meeting the needs of national economic development and the livelihood of the people’ (Water Law, Article 1 1988). Considering water as people’s property, the law distinguishes the management and allocation rights of the State from the usage rights of the people. It advocates a water permits system and full cost recovery, stipulates the river basin as the basic management unit, and mandates the formulation of national, regional, and sectoral water plans (Saleth and Dinar 2000: 175-199).

The Chinese Government has also intensified legislation and law enforcement relating to water resource utilization and environmental protection. In July 1991, the National People's Congress approved the Water and Soil Conservation Act of the People's Republic of China. In 1993, regulations related to the law on water and soil conservation were put into effect. A comprehensive system of administrative agencies for water and soil conservation ranging from the central to local authorities was established.

In 1997, China created the Law of Flood Control, promulgated a national policy on Pollution Control, and passed the Aquatic Protection legislation. Meanwhile, the State Water Industry Policy was declared. ‘It is unique for a socialist country as it allows the entry of private investors into the water sector and also requires all public water projects to operate on commercial lines’ (Saleth and Dinar 2000: 175-199).

The Water Law passed in 1988 not only strengthened water administration with the formalisation of coordination and conflict resolution mechanisms, but also led to a fundamental change in water policy. ‘While water planning and development functions as well as legislative and regulatory powers are with the national governments, the actual management and maintenance functions are with the lower level governments’(Saleth and Dinar 2000). Most agencies dealing with water resources have only sectoral responsibility (for example, to deal with irrigation or drinking water or industry or environment). It should be recognised that any sector-related policy affects the relationship between the particular sector and other sectors, so the policy framework acknowledges the interactions among various elements comprising the water catchment area, incorporating cross-sectoral and environmental consideration into the design of investment programs in different sectors. The coordination of sectoral policies and responsibilities is a precondition to ensuring the sustainability of natural resources.

5.3.2 Establishing non-attenuated property rights

It is a precondition of a quasi-market for water that non-attenuated property rights be established. Market transactions are the exchange of rights pertaining to goods and services. What is bought and sold consists of a bundle of rights. ‘If rights to perform certain actions can be bought and sold, they will tend to be acquired by those for whom they are most valuable either for production or enjoyment. In this process, rights will be acquired, subdivided, and combined, so as to allow those actions to be carried out which bring about that outcome which has the greatest value on the market’ (Coase 1988:12). This assures that the market will be predictable, stable, and certain. Meanwhile, through the establishment of non-attenuated property rights, the relationships between government, consumer, and producer will be clearly defined.

The current institutional settings in China remain focused on State based regulations enforced by administrative agencies. For a quasi market for water to emerge, attention must be given to the establishment, definition, monitoring and enforcement of property rights vested in either the individual or tightly defined collective unit.

5.3.3 Establishing a market

The market mechanism involves the interaction of buyers and sellers to set the price of the good or service being exchanged. The fundamental role of prices is to help allocate scarce resources among competing uses and users. A water market, in which well-defined non-attenuated rights are exchanged could result in improved water use efficiency. Such a market would need to reflect environmental and social costs in water prices or in the economic analyses for water supply investments to ensure the efficient allocation between competing uses for scarce water resources.

Volumetric pricing for irrigation water is a key component of a water market based on well-defined property rights. This requires information on the volume of water used by each user or some other way to infer a measurement of water consumption. Transaction costs associated with volumetric pricing are relatively high and require monitoring of use. When water flow is reasonably constant, implicit volumetric pricing is possible by charging for time of delivery. If volume of water delivered by the water source per hour varies throughout the cropping season, then the efficient price per water unit will vary by crop and by season. This requires sophisticated monitoring technology.

Non-volumetric methods may be used when the transaction costs associated with volumetric pricing preclude its use. There are several such pricing methods: output prices, input pricing, or area pricing. Area pricing is very popular in China. Under this pricing mechanism, users are charged for water used per irrigated area, often depending on crop choice, extent of crop irrigated, irrigation method, and season. This method is easy to implement and administer and is best suited to continuous flow irrigation. It may however be unable to send clear signals to farmers regarding water scarcity and may be subject to manipulation.

An efficient allocation of water resources is that which maximises the total net benefit able to be generated under the existing technologies and available quantities of those resources. In other words, efficient water allocation should be regarded as the equalisation of marginal benefits from the use of the resource across different sectors of the economy. The allocation of water resources should not only take into account efficiency but also equity. Equity of water allocation is concerned with the ‘fairness’ of the economics. The ‘fairness’ of water allocation across economically disparate groups in a society or across time may not be compatible with efficiency objectives. How to coordinate the conflict between efficiency objectives and equity objectives is a critical problem faced by policy makers.

5.3.4 Fostering the market

A market involves the exchange of goods and services between producers and consumers. For a long time, the suppliers of water to users were economic organizations controlled by the Chinese Government. They supplied water to farmers at a subsidised price. However, the water suppliers held a monopolistic position. Water supply units achieved two kinds of benefits, the benefit from government subsidies and the benefit from their market monopoly. Meanwhile, the small and fragmented farmers had little power in the bargaining process. Establishing the WUAs in irrigated agriculture development and defining rights over infrastructure for them is a step toward redressing this situation. In the process of ID reform, the establishment of Water Supply Companies (WSCs) and WUAs is the basis of developing the water market.

WUAs are organizations managed by farmers themselves that are responsible for a wide range of management activities. In China, most of the WUAs are based on social or hydraulic boundaries and incorporate farmers in smaller organization units. Since WUAs are managed by farmers and operated with the interests of water users in mind, they tend to reduce the transaction costs of implementing water pricing, including monitoring and enforcement costs. Volumetric wholesaling is the practice by which the WSCs sell water to WUAs at points where volumetric measurement is possible. WUAs are responsible for delivering water in the branch canals and collecting fees from each user. Meanwhile, WUAs can also provide important brokering services for water trades. Of course, all these practices require strong leadership and organization, but because of the social networks, WUAs can achieve a high rate of collection of water fees. However, there are many factors affecting the viability of WUAs. Of all the factors, the establishment of property rights is crucial. Well-defined water rights give farmers incentives to participate in the operation and maintenance of water supply facilities. Those rights can be assigned to individuals or to the small, tightly knit groups of farmers.

6. Conclusion

Water shortage, deterioration of water environments, and the inequitable distribution of the water resource between different users are common throughout the world. Water issues are closely related to social, economic and ecological issues. While reform efforts differ across countries in terms of actual coverage and effectiveness, the currently observed water sector institutional changes at the international level are remarkable for their commonality of focus and direction. These include a shift from supply management to demand management, wide acceptance of privatisation and the decentralisation of control, adoption of integrated approaches to sector-wide management, and an increased focus on economic viability and physical sustainability. In China, the potential conflict between decreasing water supply and increasing demand will become more prominent in the near future. Faced with limited physical, financial, and ecological resources available to extend water supply, the Chinese government must implement a program to establish well-defined non-attenuated property rights that will allow trading in water to set prices. Water prices set in this way will ensure the cost-effective use of infrastructure and the efficient allocation of resources between those responsible for managing the water supply infrastructure and farmers undertaking irrigated agriculture. By setting up water user associations, the coordination role of the market can be permitted to function whilst excluding the pitfalls of monopoly power. The efficiency in water use that will result will enable the Chinese economy to maintain its growth in urban areas and in industrial production without jeopardising its agricultural output. With social and economic development, there remains much room for improvement in the institutional settings relevant to water resources.

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