Analyzing Alternative Policy Instruments for the Irrigation Sector

An Assessment of the Potential for Water Market Development in the Chishtian Sub-division, Pakistan

Promotor: Dr. ir. R.A. Feddes
Hoogleraar in de Bodemnatuurkunde, Agrohydrologie en Grondwaterbeheer

Co-promotoren: Dr. M.W. Rosegrant
Senior Research Fellow, International Food Policy Research Institute, Washington D.C., United States

T. Rieu, IGREF
Head, Irrigation Division, Cemagref, Montpellier, France

Pierre Strosser

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To Ian

Stellingen/Propositions

Behorend bij het proefschrift "Irrigation management strategies for improved salinity and sodicity control" door Marcel Kuper.

1. The combined use of the terms waterlogging and salinity and their qualification as a twin menace is misleading.
   Mehta (1940); Choudry (1979); Kijne and VanderVelde (1992); This thesis

2. A model representing a complex system, e.g. an irrigation system, should be evaluated for the insights it provides in the functioning of the system and in the comparative effect of policy and management interventions, and not for the accurateness of its predictions.
   This thesis

3. If one is interested in improving the performance of an irrigation system, the analysis of physical processes, assuming ideal human management, or the analysis of human behaviour, considering the physical environment as an external factor, is not sufficient. In addition, a common platform should be developed, quantifying the physical impact of human interventions.
   Strosser (1997); This thesis

4. In continuation of the economic principles related to the functioning of markets, the spatial heterogeneity of physical parameters can be considered an important asset in the management of an irrigation system, allowing a more innovative allocation of irrigation water.
   Peasant economics, Ellis (1988); This thesis

5. Archaeologists today in Mohenjodaro are fighting a similar battle that farmers were 4000 years ago in keeping soil salinity within acceptable limits.
   Mohenjodaro and the Indus civilization, Marshall (1973)

6. L'objet de la vérification d'une proposition n'est pas la proposition elle-même, mais sa valeur de vérité.
   Encyclopaedia universalis (1985); Konikow and Bredehoeft (1992)

7. C'est trop facile, de faire semblant
   Grand Jacques, Jacques Brel (1955)

8. Een proefschrift, ook één in de exacte wetenschappen, moet naast een wetenschappelijke ook een literaire waarde hebben.

9. Rugby maakt meer kapot dan drank goed kan maken
   pers. meded. J. Wijdeven (1987)

10. Θαλασσα, θαλασσα
   Anabasis, Xenophon (4[e] eeuw voor Christus)

Stellingen/Propositions

Behorend bij het proefschrift *Analyzing alternative policy instruments for the irrigation sector – An assessment of the potential for water market development in the Chishtian Sub-division, Pakistan* door Pierre Strosser

1. The notion of water scarcity is more related to financial issues than to water issues.
   This thesis

2. There is a potential for surface water market development in irrigation systems for which the interdependency in allocation between users and between time periods is reduced to a limited level.
   This thesis

3. Purchase at its very price the water you'll drink.
   Deuteronome, Chapter 2, Verse 6

4. Suggestions for improvement of irrigation system performance must take the current system as a given. For economists, this means recognizing the physical dimension of water resources in the search for better use of these resources.
   Gould (1989) ; this thesis

5. Ce qui est simple est toujours faux, ce qui ne l'est pas est inutilisable.
   P. Valery

6. To integrate disciplines leads to one discipline: but which one?
   Adapted from the English proverb: to form a couple is to become one: but which one?

7. Risk is like love: we all have a good idea of what it is, but we cannot define it precisely.
   J. Stiglitz

8. In the long term, we will all be dead.
   J.M. Keynes

9. Il vaut mieux allumer une seule et minuscule chandelle que de maudire l'obscurité.
   Chinese proverb

10. Mais voir un ami pleurer.
    J. Brel

Abstract

Strosser, P. 1997. Analyzing alternative policy instruments for the irrigation sector – An assessment of the potential for water market development in the Chishtian Sub-division, Pakistan. Ph.D. thesis, Wageningen Agricultural University, the Netherlands. 243 pp, 39 figures, 40 tables, 3 appendices.

The increasing scarcity of water and financial resources has made the economic dimension of water an important element of irrigation sector policies. Water pricing is the means traditionally used to incorporate economic issues into irrigation sector policies. More recently, water markets have been proposed as an alternative to water pricing. From a theoretical point of view, water markets are expected to lead to an efficient allocation of water among water users, as well as to improve water use economic efficiency. However, the discrepancy between theoretical requirements and the existing characteristics of the irrigation sector is significant. Therefore, the potential for water markets in managing water resources is questioned.

In Pakistan, consideration has recently been given to water markets as a means to improve the performance of irrigated agriculture. The present study investigates issues related to water markets in Pakistan using the example of the Chishtian Sub-division, an irrigation system located in the South-Punjab. Within the framework of an integrated approach that combines hydraulic, soil and economic issues, the study analyses the functioning and impact of existing surface and groundwater markets that have developed spontaneously within the tertiary units of the irrigation system. Although constraints remain on the functioning of these markets, water transactions significantly improve the flexibility in managing water resources without threatening significantly the sustainability of irrigated agriculture.

This study also discusses elements related to the technical feasibility of water markets at higher spatial scales in the irrigation system, and their potential impact on agricultural production and the physical environment. The potential for reallocation of surface water in terms of increased farm gross income is the highest within and between tertiary units. Also, the impact of reallocation on farm gross income is higher when volumes of surface water are transacted independently of the time of the year, as opposed to yearly reallocations that would affect proportionally the supply of canal water received each month. Constraints related to the existing conveyance infrastructure are not seen as a major obstacle to water transactions. Changes in the operational rules required to develop water markets at higher spatial scales, however, may represent an important constraint to water market development. Also, the absence of storage facility limit the potential for temporal reallocation of surface water, thus the overall impact of potential water markets.

The thesis concludes by emphasizing the importance of a combination of interventions to manage the irrigation sector, as well as to improve its performance in terms of agricultural production and sustainability. The need to analyze, compare and combine interventions, further stresses the relevance of an integrated approach that integrates disciplines, links decisional and bio-physical processes, and investigates the heterogeneity of these processes within the irrigation system.

Keywords: water markets, irrigation management, integrated approach, economic modeling, Pakistan

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Abbreviations and glossary of local terms

Abbreviations

CCA	Culturable Command Area
Cemagref	French research center for agricultural and environmental engineering
DPR	Delivery Performance Ratio
FAO	Food & Agriculture Organization of the United Nations
GCA	Gross Command Area
GDP	Gross Domestic Product
GIS	Geographic Information System
ICWE	International Conference on Water and the Environment, Dublin, 1992
IIMI	International Irrigation Management Institute
MAD	Mean Absolute Deviation
MVP	Marginal Value Product
NESPAK	National Engineering Services of Pakistan
OECD	Organization for Economic Cooperation and Development
PIPD	Punjab Irrigation and Power Department
PTO	Power-Take-Off tubewells
RD	Reduced Distance
SCARPs	Salinity Control And Reclamation Projects
SDO	Sub-Divisional Officer
SIC	Simulation of Irrigation Canals, hydraulic model
SWAP93	Simulation of transport processes in the Soil-Water-Air-Plant environment, hydro-dynamic model
UNCED	United Nations Conference on Environment and Development, Rio de Janeiro, 1992
WAPDA	Water and Power Development Authority, Pakistan

Glossary of local terms

Abiana	Area and crop-based water charges
Bildar	Laborer
Distributary	Secondary canal
Gur	Raw sugar
Kaccha warabandi	Flexible irrigation schedule, taking the variability in watercourse head discharges into account
Khal Barai	Time required draining the watercourse
Kharif	Summer cropping and irrigation season

Locals	Social group that settled in the study area long before the development of large scale irrigation
Mogha	Tertiary outlet
Nikkal	Time required filling the watercourse
Pakka warabandi	Irrigation schedule with turns being fixed for a specific time of the week
Rabi	Winter cropping and irrigation season
Settlers	Social groups that came in the study area at the time of the Sutlej Valley Project or at the time of the Independence in 1947
Warabandi	Roster of water turns developed for all landowners (official warabandi) or water users (agreed warabandi) along a given watercourse
Watercourse	Tertiary unit

Chapter 1

Introduction

The main objective of this introduction is to present three important elements that have been combined to form the present thesis. The first element relates to interventions and policies for the irrigation sector, and the assumption that *water markets* have an increasing role to play in the management of the irrigation sector. The second element is methodological, advocating for the need to develop a sound research framework, or *integrated approach*, to investigate the multiple dimensions of irrigation systems and their performance, and assess the potential for interventions in the irrigation sector. The third element relates to the location where most of the scenes presented in this thesis will take place, i.e. *Pakistan*, where a drastic institutional reform is currently being discussed for managing the irrigation sector.

1.1 Water scarcity and water sector policies

The history of the irrigation and water sectors in various countries shows that water sector policies are dynamic processes, often responding to changes in the physical, macro-economic, social and political environment. Although in the past policy changes took place at each country's pace, it is increasingly apparent that discussions on irrigation and water sector policies have moved from the national to the international arena and are part of a wider concern about issues and appropriate options. As will be discussed below, the failure of past policies and projects, inadequacy of existing interventions to tackle current issues of the water and irrigation sector, and increasing financial pressures on governments and economies are seen as the main causes explaining this *world-wide concern of the importance of water issues*.

In recent years, there has been a growing recognition from a large number of countries, as well as from international bodies such as the Organization for Economic Cooperation and Development (OECD, 1989), the International Bank for Reconstruction and Development (World Bank, 1993) and the Food and Agriculture Organization (FAO, 1994) of the need to move to more demand-oriented interventions that consider the economic value of water. This recognition is illustrated by the following citations:

> *Member countries develop and* ***implement effective water demand management policies*** *in all areas of water services through making greater use of: forecasting future demand for water;* ***appropriate resource pricing*** *for water services; appraisal, reassessment and transferability of*

***water rights**; **various non-price demand management** measures; and integrated administrative arrangements for demand management* (OECD, 1989)

*Past failure to recognize the **economic value of water** has led to wasteful and environmentally damaging uses of the resource* (ICWE, 1992)

*A prerequisite for **sustainable management of water as a scarce vulnerable resource** is the obligation to acknowledge in all planning and development its full costs. Planning considerations should reflect... investment, environmental protection and operating costs, as well as opportunity costs reflecting the most valuable alternative use of water... **The role of water as a social, economic and life-sustaining good** should be reflected in **demand management mechanisms**.* (UNCED, 1991)

The following paragraphs investigate the rationale that supports this wide consensus, which emphasizes the economic nature of water and promotes the integration of *demand management mechanisms* in water and irrigation sector policies. The objective here is not to identify solutions that will resolve all problems faced by the irrigation sector of any country. On the contrary, the complexity of the task of designing appropriate irrigation sector policies is fully recognized. Different objectives are specified simultaneously (for example, increasing agricultural production, restoring equity, or developing specific regions); are given different weights according to economic, cultural and political criteria; and are to be met under physical, socio-economic and political constraints that may vary in space and in time. The main thrust of the discussion presented below emphasizes the need to investigate the relationship between water scarcity and appropriate policy options.

Using the terminology developed by Randall (1981) in his analysis of the water economy, two stages can be distinguished in the development of the water economy, each requiring different interventions and policies. The first stage or *expansionary phase* is characterized by *supply-based* interventions (See Table 1.1) and the expansion of irrigation facilities, i.e. developing more area under irrigation, constructing new irrigation systems and storage facilities, and reaching a larger number of potential users. Priority is given to expansion of the irrigated area and increasing total agricultural production to respond to the needs of an increasing population and to reduce the risks of famine. Public intervention is predominant, partly due to the large investment costs involved in most of the irrigation infrastructure (natural monopoly), but also due to the social and political dimensions of water. Also, there is no structural shortage of water and water is supplied more or less free of cost to users.

The second stage, or *mature phase*, is characterized by water scarcity, with no extra supplies that can be tapped except at prohibitive costs, increasing pressure from the other sectors of the economy such as municipalities and industries, and significant environmental problems such as waterlogging, salinity and pollution. As water scarcity, both in terms of quantity and quality, increases, the irrigation economy enters into its mature phase. Supply-based interventions, such as constructing new irrigation infrastructure, that were favored during the expansionary phase are less well adapted to this phase. Supply-based approaches coupled with the failure to price water at an economic level induces short and long-term water problems: supplied at zero or low costs, water is seen by consumers as available in unlimited quantities with no incentive to use water efficiently.

Table 1.1. Supply-based versus demand-based interventions in the water sector.

Intervention	Supply-based	Demand-based
Modification of physical system	Construction Rehabilitation Changes in infrastructure	Development of new irrigation technology
Changes in management activities	Operation Maintenance Information management	Farm scheduling Information management
Changes in enabling environment	Institutional framework Legal system Budgetary policy	Water pricing, quota, water markets Legal system

To correct the imbalance between demand and supply of irrigation water, the economic value of water should be considered to influence water users' behavior. In short, there is a need to move from strictly supply-based to more *demand-based* interventions (see Table 1.1) or demand management mechanisms that become the least-cost methods to maximize benefits. With increasing water scarcity, efficient use of water and efficient allocation between users, whether within a sector or between sectors, become important objectives of water sector policies. Examples of demand-based instruments that have been widely discussed under different socio-economic and physical environments are *water pricing, quotas and water markets*. Box 1.1 presents some of the characteristics of these policy instruments. For presentation and discussion of a larger number of supply-based and demand-based interventions, see for example Bhatia et al. (1994), FAO (1994) and Winpenny (1994).

The distinction proposed by Randall (1981) between the *expansionary* and *mature* phases requires some comments. Going from the expansionary phase to the mature phase is a continuous process, with no clear separation between the two phases. According to the position of the irrigation sector within the economy, the overall economic development of the country, the physical characteristics of water supplies, and the existing infrastructure and institutional set-up, different levels of *maturity* may be expected, with only some of the problems highlighted above appearing in the water economy. Also, as new technologies develop, changes in the imbalance between supply and demand may be modified and excess supplies become again available, positioning the notion of maturity into a more dynamic context.

It is important to stress that policy choices are not limited to the decision to choose between supply-based and demand-based interventions (FAO, 1994). Whether to promote independent *projects* or integrate interventions into a general framework or *programs* is also part of the policy process (World Bank, 1993; FAO, 1994; Winpenny, 1995). Important choices should be made regarding the management mode that is going to accompany these interventions:

Box 1.1. Three examples of demand management mechanisms: Water pricing, quota and water markets (adapted from Montginoul and Strosser (1997)).

Water pricing

From a theoretical point of view, water pricing is the basic instrument that helps to distribute limited water resources to users and to determine allocation of these resources by providing appropriate signals or incentives. At the same time, water pricing is used for cost recovery purposes. Several conditions are required for water pricing to achieve allocative efficiency: demand for water being sensitive to water prices; water pricing mechanisms that are easily understood by water users; and, mechanisms stable enough over time to be in accordance with time horizons considered by farmers/water users to take their decisions. Other aspects to be considered for the establishment of water pricing include the enforcement of payments by users, the need to consider marginal cost issues and externalities, and financial issues such as the cost of implementing water pricing mechanisms and the financial autonomy of the managing agency.

Although water pricing is aimed at influencing farmers' decisions and the demand for water, demand and/or supply parameters may be considered while developing water pricing mechanisms. Objectives of demand-based pricing may be to appropriate part of the benefits made by water users, to maximize their total utility by putting users in competition, or to take into account more socio-political aspects (for example equity considerations). Supply-based water pricing considers the costs of delivering water to the crop (operation and maintenance costs, investment costs) and other (social) costs related to negative external effects and support by the society. The parameters used to develop and compute water prices, along with the water pricing structures, differ from country to country, and even from irrigation project to irrigation project. Extreme cases of water pricing structure (or water charge schedule) are flat-rate or fixed charge (whether area-based or user-based) and volume-based charge.

Quota

The main objective of the quota is to limit water use. Contrary to water pricing, quotas do not provide an incentive to water users but simply constrain their demand. A quota has an effect on the demand only if, for a given water price, the estimated demand for water would be higher than the quota imposed. Different types of quota may be proposed: quota in time, quota in volume and quota related to uses (for example type of crop). Quotas may be fixed over time or may vary according to the availability of water.

If the price elasticity of water demand is equal or close to zero, quotas are more efficient in constraining water users to save water than water pricing. If the demand is elastic with regard to prices, then economic theory shows that quota and water pricing lead to the same results in terms of water use when the demand for water is stationary. However, if increases in the demand for water are expected as a result of changes in other sectors of the economy, then quotas are the preferred option as they constrain the demand at the same level, while changes in water demand would be expected under water pricing.

Water markets

Water markets are an allocation mechanism based on an initial allocation of water rights. As a result of the confrontation between water supply and water demand, water is (re-)allocated between users at an equilibrium price established on the market. Requirements for well functioning water markets include water scarcity, well defined and transferable water rights, a large number of purchasers and sellers, no (or limited) transaction costs and the existence of an appropriate information system.

Existing water markets show a large diversity of functioning and organization. Water markets include permanent transfers of water rights, or lease of these rights and transfers of volumes of water. Water markets often function at the margin, i.e. involving only a limited portion of existing water resources. High transaction costs (as compared to the value of water and expected benefits), inadequate physical infrastructure and legal framework, or socio-political resistance are factors that explain this situation. Many difficulties arise as a result of potential externalities and third-party effects of water transactions, and lack of information to quantify these effects.

- *Decentralized or centralized management and control.* While in the past centralization has often been the first choice (especially in large irrigation systems in developing countries), the tendency in recent years has been towards decentralization of organization and decisions.

- Range of management styles polarized between *authoritarian and participatory*. Again, and as a result of the failure of past authoritarian management styles, participatory management has recently received a lot of attention in developing countries. Examples of experiences in the irrigation sector are summarized by Kloezen and Samad (1996).

- Identification of the relative importance of the *public and private sector*. The role of the public sector has always been very strong in the water sector, due to the special cultural and social value of water, its natural monopoly nature, the interdependency between users in a river basin or aquifer, and problems of externalities (World Bank, 1993; Winpenny, 1994). However, fragmented management, inefficiency of public agencies in managing water resources, and increasing financial problems of these agencies have highlighted the potential for private sector involvement in the water sector.

Finally, it is important to emphasize that consideration has to be given to the fit between demand-based instruments and the infrastructure available to support the implementation of these instruments. Thus, in most cases, the challenge remains *the identification of the right balance between water treated as an economic good and water considered as a social good, between supply-based and demand-based interventions, and between different management options or models.*

Many countries are moving towards policies that consider the economic value of water and emphasize proper incentives, pricing and regulation (Serageldin, 1993; FAO, 1994). Drastic changes in water sector and irrigation sector policies have been proposed and also implemented in numerous developing countries, often primarily as the result of financial pressure from donors and funding agencies and, secondarily, to respond to increasing water scarcity. Interestingly, however, the highest priority is often given to changes in the institutional framework and management mode (i.e. decentralization, participation, and higher private sector involvement) instead of changing incentives and implementing demand management mechanisms. The priority given to the reduction in budget deficit as compared to improving economic efficiency, along with the relative lack in popularity of these mechanisms (for example, increasing water charges) may explain this trend.

In developed countries, also, important modifications have taken place as a result of the imbalance between supply and demand, increasing competition between sectors, and water quality problems (pollution). Also, financial considerations play an important role as demonstrated by the recent reform of the water sector in the United-Kingdom. Table 1.2 presents examples of recent changes in water and irrigation sector policies in selected countries. The fact that changes have taken place under a large range of physical and socio-economic environments stresses the complexity of what is often casually defined as *water scarcity*.

Table 1.2. Recent changes in water and irrigation sector policies for selected countries (adapted from FAO (1994)).

Country	Justification for change and review of existing policies	Main thrust of policy review & reform	Final documents and action
Indonesia	Re-orientation of large public investments, with high water subsidy, deterioration of water resources infrastructure, regional supply-demand imbalance, water use changes.	De-centralized water administration based on river basins; privatization and cost-recovery; cross-sectoral analysis; regional water resources development.	Water Policy in 2nd 25-Year Plan and VIth Development Plan. Decentralized water administration.
Mexico	Growing regional imbalance between water demand and availability of water to cities and to irrigation	Promote water use efficiency; improve quality of water services through enhanced role of the private sector.	November 1992: Laws on National Waters enacted by Federal Congress.
England and Wales	1985: conflicting issues of financial management of public Water Authorities	Redraw boundary between the public and an integrated private sector. Control of a privatized water industry.	1988: Water Bill released. July 1989: Water Act enacted by Parliament.
France	Supply-demand imbalance worsened by drought	Manage water resources in an integrated and balance manner. Balance water resource development and conservation	January 1992: Laws on Waters enacted by Parliament.

In fact, as a conclusion to this section, it is important to look again at the analysis presented by Randall (1981) that emphasizes the link between water scarcity and water sector policies. Current examples of policy changes that promote demand management mechanisms in developing and, to a lesser extent, developed countries emphasize the importance of financial resources required to implement water and irrigation sector policies. In the case of the western United States, for example, Gould (1989) mentions that *the pressure for (water) reallocation is not simply a result of demand exceeding supply. Much of the pressure is financial.* The recent impetus for change in water and irrigation sector policies may be more the result of a financial crisis in the context of structural adjustment programs and reduction of budgetary deficits, than a pure water crisis. Of course, the importance of the latter is fully recognized, especially in the context of supplying basic water needs to the poorest in developing countries. But this view is supported by the simultaneous recognition in a large number of countries facing a large diversity of "water scarcity" situations, of the need for drastic changes in water and irrigation sector policies that promote demand based mechanisms.

The following section takes the example of the irrigation sector in Pakistan to illustrate what has been described so far in general terms. Some of the symptoms of the mature phase of the water economy as described by Randall (1981) are present in the irrigation sector in Pakistan, that is currently under scrutiny and pressure to undertake drastic policy and institutional reforms.

1.2 Main issues related to irrigation system management in Pakistan

The importance of the agricultural sector in the economy of Pakistan can be summarized in the following key figures: the sector accounts for 26% of the Gross Domestic Product (GDP) of the country, provides job opportunities for 55% of the labor force, and accounts for 80% of the total export earnings of the country (Strosser and Rieu, 1993). Within the agricultural sector, irrigation plays a predominant role as it provides 90% of the total agricultural production of the country, mainly within the 14.5 million hectares of the Indus Basin Irrigation System. Also, the irrigation sector plays a major role in the industrialization process of Pakistan with the production of cash crops such as cotton and sugarcane.

During the 1960s and 1970s, and similar to other countries that benefited from the technological improvements of the Green Revolution, Pakistan has been able to improve its self-sufficiency in agricultural and food product with significant increases in cropping intensities and crop yields. However, crop yields remain among the lowest in the world. Also, by the end of the 1980s, several signals suggested that the period of agricultural output growth was over, with the productivity per unit of land of the main crops becoming stagnant or even following a decreasing trend (World Bank, 1994; Bandaragoda and Firdousi, 1992).

With a population estimated at more than 130 million inhabitants today, that is expected to reach 150 million people by the end of the century and 400 million by the year 2050 (World Bank, 1994), the demand for food products is expected to continue growing. Thus, unless there are significant improvements in agricultural productivity and total production at least in the same order of magnitude as those recorded during the Green Revolution period, the imbalance between supply and demand of basic agricultural goods is expected to increase in the future and to threaten the self-sufficiency objective of Pakistan.

While the different actors involved in the management of the irrigation system may disagree on *the* main cause explaining the current low productivity level, the majority of them recognizes the problems faced by the irrigation system. Although the benefits of irrigation *per se* are fully recognized (under the semi-arid climate of Pakistan, little would grow without irrigation), the irrigation sector has become increasingly the target of criticisms and considered as the main cause for productivity problems in agriculture for the following reasons:

- *Poor performance of the public sector in supplying irrigation water to end-users.* Low conveyance efficiencies are obtained, with only 40 percent of the water diverted to the canal system reaching the root zone of the crops (John Mellor Associates, 1994)[1]. Canal water supplies are highly inequitable, variable and unreliable (Bhutta and Vander Velde, 1992; Kuper and Kijne, 1993; Ahmad et al. 1993). Public tubewells, also, have a poor operational performance, with low utilization rates and discharges lower than design (Malik and Strosser, 1994). Poor maintenance, lack of application of operational rules, no proper information system, local preference by operators that increase variability downstream, and interference by water users in

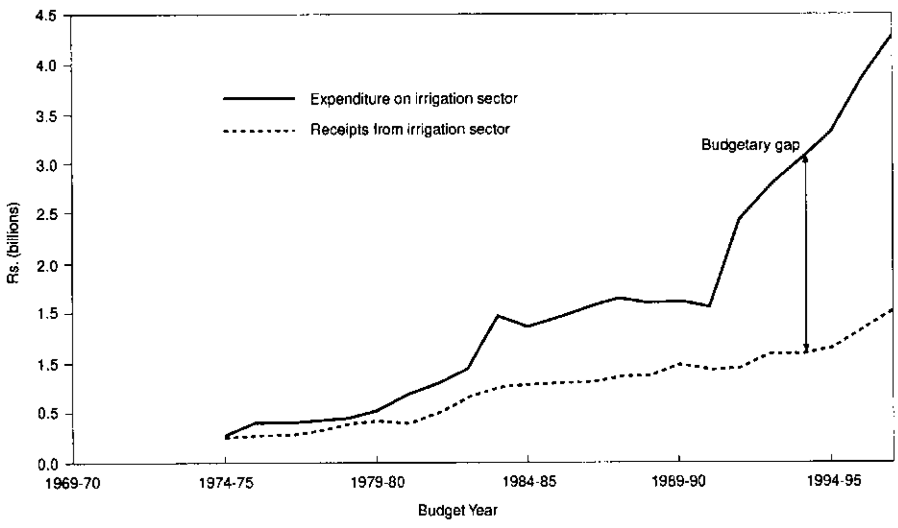
[1] In fact, low conveyance efficiencies are to be considered in the context of the overall efficiency of the Indus Basin. In areas with good quality groundwater, such losses will be reused via tubewell pumping.

the operation of the irrigation system, or lack of interest by government staff, are reasons explaining the poor performance of the public sector.

- *Severe environmental problems.* Although investments in drainage have been significant in Pakistan during the last 20 years, waterlogging still affects large tracts of land, with more than 22% of the total Gross Command Area (GCA) of the Indus Basin Irrigation System having groundwater tables within 1.5 meters of the soil surface (World Bank,1994). Also, salinity and sodicity constrain farmers and affect agricultural production, problems that may be further exacerbated by the use of poor quality groundwater (Kijne and Kuper, 1995). In areas with good groundwater quality, excessive pumping by private tubewells leads to mining of the aquifer (NESPAK, 1991).

- *Financial constraints.* Maintenance and operation of irrigation systems has been constrained by inadequate allocation of funds in the provincial budgets. The low level of funding is partly related to the existing gap between water charges collected from water users and operation and maintenance costs (influenced by the high operation and maintenance costs of public tubewells) as illustrated in Figure 1.1. However, the overall financial constraints faced by the different provinces largely explain the situation (John Mellor Associates, 1994). Inadequate financial allocation, along with the lack of appropriate methodologies to allocate these scarce financial resources optimally, and poor quality control and fraud associated with contract work (Vander Velde, 1990), has led to deferred maintenance, with negative impact on canal water supply performance.

Figure 1.1. Gap between receipt and expenditures in the irrigation sector for the period 1974 to 1996 (source: Government of Punjab, Pakistan)



There is a need to stress that some of these problems are not new in the irrigation sector in Pakistan. Dry tails, problems of maintenance, user's interference, and waterlogging and salinity, have always been part of the history of irrigation in Pakistan. For example, in 1895 already, measures were implemented to control waterlogging (Kuper, 1997). However, the negative impact of these problems could then be compensated at the macro level by the construction of new irrigation systems that constituted the major public intervention in the irrigation sector for a very long period.

1.3 The historical context to understand current policy changes in Pakistan

Looking back at history

Up to the end of the colonial period in 1947, the British administration promoted the construction of large irrigation schemes that resulted in the existing Indus Basin Irrigation System. Initial objectives of irrigation related policies included the relief of the population pressure existing in the congested districts of Central Punjab and the creation of model villages *superior in comfort and civilization to anything which had previously existed in the Punjab* (Farmer, 1974). Rapidly, the main objective of irrigation related policies became the mitigation of famines, especially after the severe famine that affected large parts of India in 1878, by spreading water resources thinly and equitably over large areas of land. Also, the establishment of a comprehensive hydraulic network and its related administration strengthened the control of the British over large areas and populations.

In irrigated areas, the British established a system of quota (still in use nowadays) to share limited canal water supplies. The quota, expressed as the combination of a duration of use at the farm level (i.e. the water turn of the *warabandi* schedule that shares canal water between users within the tertiary unit or *watercourse*) and a share of water flows (specified by the dimensions of the watercourse outlet) was enforced through social control and physical infrastructure. A limited number of control structures along the main canals were provided to minimize operational requirements. With imposed scarcity, efficient use of canal water was also expected. The British established a system of area/crop-based water charges (*abiana*) to cover mainly operation and maintenance costs and also to generate some revenue (Farmer, 1974).

Since Independence in 1947, most of the interventions in the irrigation sector have focused on water supplies to increase agricultural production, improve self-sufficiency in major food crops, and promote equity in water supplies. Major efforts were targeted towards replacing the supplies "lost" to India under the 1959 Water Treaty by building link canals to bring supplies from the Western to the Eastern part of the country, and constructing dams to increase storage capacity. However, cropping intensities increased more than irrigated areas during this period.

At the same time, further emphasis was given to mitigating the adverse effects of irrigation such as waterlogging and salinity. Large-scale Salinity Control And Reclamation Projects (SCARPs) have been implemented since the beginning of the 1960s, initially with the installation of large public tubewells that provided also extra irrigation water supplies in areas with good groundwater quality, and then with the construction of large surface drains. More recently, drainage facilities have included sub-surface (tile) drainage systems in limited areas. As will be discussed below, the end of the 1970s saw a shift in the focus of policies, with the development of the On-Farm Water Management projects aimed at reducing water losses taking place within tertiary units and farms.

The irrigation system to date: new pressures on water and financial resources

The Indus Basin Irrigation System today is the result of one century of supply-based policies. Surface water is supplied to more than 14.5 million hectares or 89,000 watercourses through an extensive network of main canals and secondary canals or *distributaries*. The system of quota and area/crop-based water charges is still in use, although discrepancies exist between official rules and rules in practice, with for example the development of localized canal water markets. The 1980s, however, have brought major changes that have stressed the inadequacy of the supply-oriented and engineering-driven interventions for projects implemented so far. In this context, two issues are seen as particularly important.

The *first issue* relates to *changes in water scarcity* that have taken place within the irrigation system. It is not clear that the quota initially imposed by the British administration played a role as the demand for irrigation water was rather minimal. During the last decade, however, the pressure on water has drastically increased, with more competition for quantity and quality of irrigation water within the irrigation sector, but also from other sectors of the economy.

- As a result of changes in the macro-economic environment, farmers have increased their cropping intensities from the original design figures of 50-70% to an average of 120% per year for the Indus Basin (John Mellor Associates, 1995). This has led to an increasing pressure on the (cheap) surface water resources, translated into a significant interference of water users into the operation of the irrigation system (Rinaudo et al., 1997a).

- As a result of inadequate canal water supplies, but also as a response to changes in the macro-economic environment, farmers have installed a large number of private tubewells to tap groundwater resources. However, current pumping rates have already led to mining of the aquifer in several canal command areas with good groundwater quality (NESPAK, 1991). In areas with poor groundwater, farmers still have installed tubewells and pumping leads to problems of salinity and sodicity (Kijne and Kuper, 1995).

- More recently, water needs by other sectors of the economy, such as industries and municipalities, are becoming more significant, although the overall quantity used by these sectors remain marginal as compared to water use by the irrigation sector, i.e. less than 5% of total water resources (World Bank, 1994). Competition over water resources between sectors has been limited to specific areas close to large cities and industrial complexes. The main issues presently at stake include competition on groundwater use (quantity), and problems of effluents and pollution of irrigation water (quality).

- There has been a recent recognition of the in-stream needs of the Indus River. Minimum discharges from the Indus to the sea are required to limit intrusion of seawater into the coastal area. However, little is known about the minimum flows required and how this would compete for surface water resources with the irrigation sector.

- Finally, the competition for surface water resources has intensified between the four Provinces, and mainly between the Sindh and the Punjab. After long negotiations, the Indus River System Authority was created in 1992 to implement the water apportionment accord that specifies surface water allocations to Provinces. However, confrontations between the Sindh and the Punjab regarding these allocations still arise periodically, mainly during periods of high water demand.

The *second issue* is linked with the level of *financial resources* available for the irrigation sector. Financial resources for the development of the irrigation sector are scarcer today than 20 years ago, both in absolute and relative terms. Several reasons explain this situation.

- Similarly to the general trend observed in the Sub-continent (Rosegrant and Svendsen, 1993), the development costs of irrigation projects per unit area today are significantly higher in absolute terms, as low-cost high-potential areas have already been developed. As a consequence, significant improvements in agricultural benefits will be required if acceptable economic returns are to be realized.

- In the context of structural adjustment programs and under pressure from international lending agencies, there is a political will to reduce subsidies to the irrigation sector. As shown by Figure 1.1, the irrigation sector has been (and still is) highly subsidized in recent years. Financial autonomy has become an important policy objective in Pakistan. The recent SCARP Transition Projects illustrate this concern. In order to eliminate the financial burden related to the high operation and maintenance costs of public tubewells, these projects aim at closing down public tubewells, selling them to farmers or group of farmers, or providing subsidies for the installation of private tubewells by individual farmers.

- The level of financial public resources available for the irrigation sector has drastically decreased in relative terms. This results from the disengagement of donors traditionally involved in the irrigation sector (the end of the US-Aid period in 1991 as a result of the Pressler amendment). The increasing importance of the total debt servicing of the country, presented in Figure 1.2 as a percentage of the Gross Domestic Product (GDP), is another element that limits the availability of financial public resources. Also, the competition from other sectors of the economy has increased: higher economic rates of return are in fact expected from investment in industrial and infrastructure development as compared to investments in the irrigation sector. Figure 1.3 illustrates the decreasing share of the agricultural sector (including irrigation) in the total annual development expenditures of the Government of Pakistan.

Figure 1.2. Total debt servicing in Pakistan for the period 1987 to 1996, expressed as a percentage of the Gross Domestic Product (GDP) of the country (Source: Government of Pakistan).

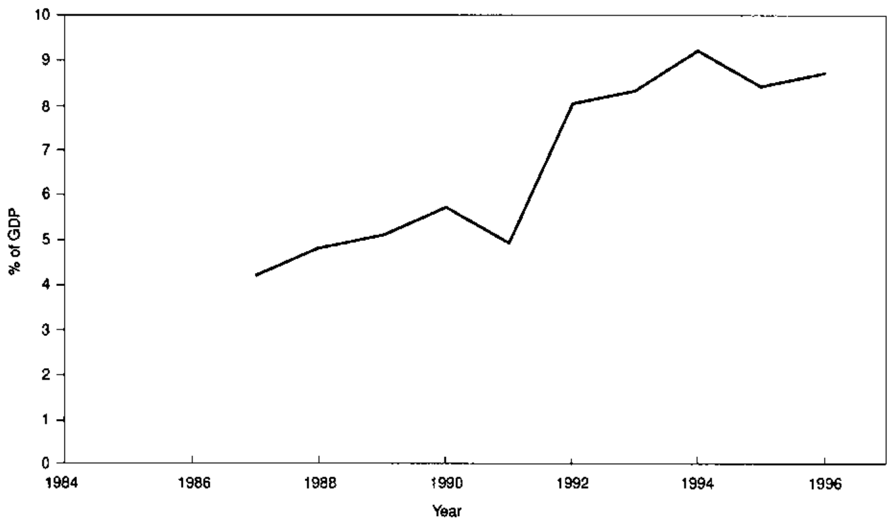
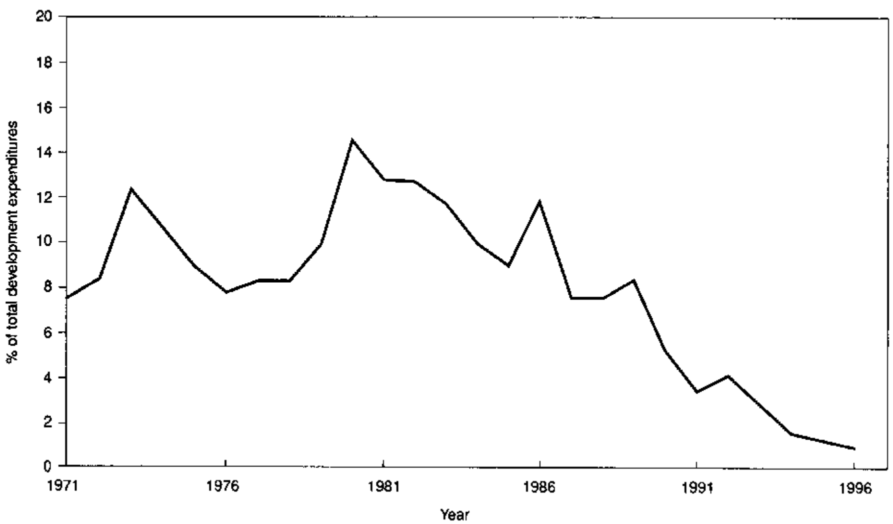


Figure 1.3. Annual development expenditures of the agricultural sector (including irrigation) in Pakistan for the period 1971 to 1996, expressed as a percentage of the total annual development expenditure of the Government of Pakistan (Source: Government of Pakistan).



With the increasing scarcity of water resources and financial resources described above, it is clear that highly expensive *supply-based engineering* approaches become less viable. This has been reinforced by the increasing recognition of the failure of past projects that did not yield the expected (lasting) benefits that were visualized, and could not solve problems in the irrigation sector (World Bank, 1994).

1.4 Proposed options for irrigation sector policy in Pakistan

In the 1980s in Pakistan, there was already recognition of the inadequacy of the purely supply-based engineering biased interventions for tackling the problems faced by the irrigation and agricultural sector. New approaches were proposed that included institutional components. Examples of such approaches include: the On-Farm Water Management Projects that promote the development of water user associations at the watercourse level (Colorado State University, 1976); the SCARP Transition Projects that aim at reducing public involvement in the groundwater sector by closing down or transferring public tubewells to water users (World Bank, 1988); or the Command Water Management Program that promoted water users' involvement in the maintenance of the irrigation system up to the distributary head (World Bank, 1996a). Also, under the pressure of donors, there have been discussions on the need to increase water charges to decrease the gap between revenues from the irrigation sector and operation and maintenance costs. Although conditional to loans for several projects, the political decision to increase water charges has been postponed. Only recently have some of the provinces decided to increase water charges.

However, despite the apparent change in philosophy that guided interventions in the irrigation sector, the engineering components only of these new approaches were successfully implemented. A typical example is the On-Farm Water Management Projects cited above, where watercourse lining (the engineering component) has been implemented in large number of watercourses while few water user associations (the institutional component) have been developed in a sustainable manner. Reasons explaining this lack of success may be related to inadequate approaches for local conditions; the absence of real needs for water user associations within the watercourse command area; the lack of local support and appropriateness of changes brought by outsiders; the meager qualified human resources (i.e. technical staff from engineering wings of government departments trained as social organizers) allocated to the implementation of these projects; and the incentives for implementation staff closely tied to construction progress rather than to institutional progress and development impact (World Bank, 1996a).

More recently, in recognition to the current problems in the irrigation sector and under pressure from international lending agencies, drastic changes in irrigation sector policies have been proposed (World Bank, 1994). These changes, in line with the worldwide recognition of the economic value of water illustrated above, included the *privatization of the irrigation sector and development of water markets* in order *to achieve financial autonomy of the sector and economic efficiency*. Several rounds of discussions were held between the major stakeholders of irrigation systems in Pakistan, i.e. government departments at the provincial and federal levels, farmer organizations, politicians and donors to discuss the proposed and highly controversial changes. The different stakeholders eventually agreed on the need to decentralize, instead of privatize, irrigation system management and to promote a participatory management mode. In short, the final proposal opted for an increasing involvement of water users and the development of financially autonomous irrigation authorities at the Provincial level and Area Water Boards at the canal command area level.

Although there has been a political decision to proceed with these changes, it is surprising to realize that very little is known regarding the details of the proposed changes and of their implementation, and their expected impact on water supply, agricultural production and sustainability of the resource base. The approach selected for implementation includes the development of selected canal command areas as pilot projects that are expected to provide information on constraints and limitations of proposed changes and lead to a successful implementation for other irrigation canal commands. It is important to note that pilot projects will impact on large areas of no less than 300,000 hectares, thus on a large number of farmers that may eventually pay for an ill-designed project or unsuitable options.

1.5 Justification of the study

Analysis of policy interventions in the irrigation sector shows that little effort is generally made to adequately appraise alternative interventions and estimate their economic impact. This aspect has been recently emphasized in a study reviewing irrigation projects funded by the World Bank that *noted a very high level of unsatisfactory planning and design in irrigation projects* (Jones, 1994). In fact, policy and project appraisal may take place too often under the conditions described more than 25 year ago by Ingram (1971) with *benefit-cost analysis* (or as a matter of fact other studies used to appraise interventions)*.... used to clothe politically desirable projects in the figleaf of economic respectability*. Often, interventions are justified theoretically, ideologically or politically, or because similar experiences have successfully taken place in other countries.

Although the political nature of policy decisions may limit the need for appraisal of new projects and policies, other causes explain the lack of comprehensive appraisal and analysis of proposed interventions in the irrigation sector. Firstly, well-specified appraisal methods that analyze and integrate the multiple facets of irrigation in an effective way are rare. Due to the *complexity of the irrigation system*, there is no simple cause-effect relationship between an intervention and its impact. It may be necessary to analyze the complexity of decisional and biophysical processes to identify and quantify the impact of a given intervention. Also, as other external interventions may take place at the same time and influence these processes, it is sometimes difficult to identify the *marginal* impact of given interventions. In some cases, methodologies may be available with researchers, but have not been operationalized to integrate constraints existing in most of the appraisal processes related to availability of time, financial resources and information.

Secondly, the appraisal process in itself is often mono-disciplinary oriented, without due consideration given to the integration of disciplines. Priority is often given to technical aspects. And environmental, social and economics issues are considered at a later stage of the appraisal process once major technical choices are made. In fact, although the need for integration between disciplines in appraisal and evaluation processes is increasingly recognized, the effective integration of economics and technical issues in these processes remains rare (Goldsmith, 1986; Srinivasulu et al., 1997; Faisal et al., 1997).

Thirdly, the appraisal process is hampered by a lack of information. Little is often known on the functioning of the existing irrigation system and good information is particularly scarce in developing countries. Pakistan provides a good illustration of information-related issues in the irrigation sector; information is scattered between institutes, is collected for different time and spatial scales, lacks accuracy, and is often outdated. The following sentence mentioned by Gould (1989) in the context of water right issues remains valid for the appraisal of new irrigation sector policies in Pakistan and stress the importance of good information on the existing situation: *suggestions for improvement must take the current system as a given. It can be improved, but it will not be replaced. This, too, is a reality, which must guide the search for better use of water resources.*

Also, information on the impact of policy interventions in other countries and irrigation systems is lacking in most of the cases. Proper monitoring and evaluation of past experiences is often inadequate. The large literature on privatization or turn-over of irrigation systems, for example, focuses on the processes and the organizational dimensions of privatization, while results showing that these experiences have effectively produced the desire benefits are lacking (Seckler, 1993). Thus, lessons from past interventions are generally insufficient to support current appraisal processes. New policies are then only justified by the existence of similar interventions in other countries or irrigation systems, and not by the effectiveness of these interventions to reach specific objectives and tackle well identified issues.

1.6 Objectives of the study

Most of the issues mentioned above explain the lack of adequate appraisal of current proposals for decentralization and water market development in Pakistan and provide the rationale for the present study. The main thrust is that further research on the functioning and constraints of the irrigation systems to date will provide necessary information and understanding of the complexity of these systems and lead to a more appropriate design of alternative policy instruments. This research requires a specific framework to analyze in an integrated manner the technical, economic and environmental dimensions of the irrigation sector, to understand the relationships between these dimensions, and to analyze tradeoffs between policy options.

In this context, the present study has two objectives:

- The **development of a methodology or *integrated approach* to assess the potential for policy interventions in the irrigation sector**.

The proposed methodology will be used to analyze irrigation systems in an integrated manner, and provide information on the impact of various interventions on irrigation system performance in terms of water supply, agricultural production and the physical environment. Also, the technical feasibility of these interventions is assessed as part of this integrated approach. The methodology has been developed jointly for the present study and for the analysis of the relationship between main system management and salinity and sodicity presented by Kuper (1997).

- The application of this methodology to one case study, the assessment of the **potential for water market development in irrigation systems in Pakistan**.

The application investigates one component of the current policy proposals in Pakistan, i.e. the development of water markets to improve economic efficiency and increase agricultural productivity and agricultural production. Of interest in this application will be the analysis of *existing water markets*. As mentioned above, informal water markets have already developed within the tertiary units of the irrigation system, but little analysis has been carried out regarding their organization, impact and constraints. Also, the *potential for water market development* at different levels of the irrigation system (between tertiary or secondary units) will be investigated.

The structure of the thesis is as follow. Based on a literature review, Chapter 2 investigates issues related to water markets. The main objective of this review is to identify important issues related to water markets, in general, that are to be addressed in the context of water market development in Pakistan. Chapter 3 presents the general methodology or integrated approach that has been developed to assess the impact of interventions in the irrigation sector on irrigation system performance. Chapter 4 presents the irrigation system selected for the application of the integrated approach to the analysis of existing and potential water markets, while Chapter 5 summarizes the elements combined into the economic component of the integrated approach.

Selected elements of the integrated approach are applied to the analysis of the functioning and impact of existing water markets, and to the analysis of the potential reallocation between tertiary and secondary units of the irrigation system. The results of both analyses are presented in Chapter 6 and Chapter 7, respectively. Based on the application of the integrated approach to the analysis of water markets, and also on results obtained in the companion study by Kuper (1997) on the link between main system management and salinity and sodicity, Chapter 8 concludes with a preliminary assessment of the added value, potential and perspective of the integrated approach.

Chapter 2

Understanding water markets: a literature review

The main objective of this chapter is to better define water markets and identify the main issues that are related to their functioning and impact, based on a review of literature. The conditions for perfectly functioning water markets are first defined, and then discussed in the context of the intrinsic characteristics of water resources. The important role given to the definition of water rights is then discussed, theoretically and in the context of existing water markets. An attempt is made to investigate the economic impact of existing and potential water markets. The final section of the chapter summarizes the main issues related to water market functioning and impact that are relevant to the analysis of existing and potential water markets in Pakistan.

2.1 Water markets from an economic theory perspective

Generalities

Markets are traditionally defined as the place or context in which buyers and sellers buy and sell goods, services and resources. The confrontation between supply and demand of a given product results in a market equilibrium price when the forces of market demand and market supply are in balance. Apart from the confrontation between supply of, and demand for, given commodities and inputs, and as highlighted by the definition given above, markets are also an institution and organization that links potential sellers and purchasers. Specific arrangements are required to obtain appropriate information and provide it to potential sellers and purchasers, to organize and implement transactions, and to control and enforce transfers of products between sellers and purchasers.

The definition used to define markets for water is similar to the ones presented above. Quoting Katz and Rosen (1994), *water markets generally refer to a group of independent voluntary decisions (transactions) by consumers and producers taking place continuously over a period of time.* From the theoretical point of view, the sale of irrigation water by a centralized agency (whether private or public) to individual customers may be seen as a water market, with the producer (the irrigation agency) and consumers (farmers) entering into a series of voluntary transfers. The particularity of this example, however, would be the monopoly power of the (single) producer. In this case, the supply curve would be mostly based on cost-related considerations that would lead to the establishment of specific prices or water charges. The demand curve depends on farmers' strategies and constraints and on the equalization of the marginal value product of, and proposed price for, water. Importantly, however, are the *independent* and *voluntary* aspects of the *transactions* that limit cases of water markets to irrigation systems where users can specify and modify their demand according to water prices and their own water requirements.

In the literature, the term water market is mostly used to describe situations where users with specific rights over water sell or lease these rights to other users, whether permanently or temporarily. Water markets can be considered in terms of the access to water or irrigation services (a quantity received for example) or in terms of transfers of water rights. The main benefits expected from water markets are an optimal allocation of available resources between users and uses, and an increased water use economic efficiency.

In the case of irrigation, the decisions to sell water or water rights are not related to marginal cost considerations, but to opportunity cost issues; irrigation water has an utility for farmers and can be alternatively used on the farm or sold on the market. Thus, the development of an irrigation water market is expected to improve the allocation of resources, while also impacting the efficiency of water use of *both* purchasers and sellers. The main advantage of water markets as compared to efficient water pricing remains their flexibility and ability to respond to temporal changes in demand from different uses by reallocating water from low-value to high-value uses. In a well-functioning market, the marginal benefit of using water is the same for all consumers and users, so that general economic welfare cannot be increased by re-allocation. This is referred to in the economic literature as the *pareto-optimum* condition

Necessary conditions for market perfection

An important issue related to markets in general, and water markets in particular, relates to the above-mentioned pareto-optimum and the notion of *market perfection.* This notion relates to the ability of markets to promote an optimal and efficient allocation of resources, not only for individual users that participate in market transactions, but also for the society as a whole. From a theoretical point of view, necessary conditions that lead to market perfection include (Brajer et al. 1989):

- A large number of sellers and purchasers, so that the action of any individual does not affect the price of the water;
- Sellers and purchasers free to participate in water transactions;
- The homogeneity of the product transacted on the market;
- Transparent and perfect information available to all potential participants in the market, unbiased and free of cost;
- A perfect mobility of resources, thus absence of transaction costs;
- The absence of externalities or third-party effects.

The characteristics of water resources themselves make the above-mentioned conditions valid in only a few very specific cases. These characteristics, described in the following paragraphs, lead to cases of *market failures* to express markets' limitations for achieving (optimal) economic efficiency. In fact, market failures are (or have been) the main justification to public interventions into the water sector.

- Water has the *nature of a public good.* The essence of a public good is that it is available to all and no one can be denied access to it (Winpenny, 1994). Investments in the water sector yield common products such as flood control, electric power, recreation and irrigation, which makes pricing and allocation decisions difficult. However, many argue that water is not bound to remain a public good (Vaux, 1986; Winpenny, 1994). In fact, inappropriate and outmoded institutions that lead to under-pricing of water and locking water into existing usage confer a public good nature to some water services that did not originally have this nature.

- There are rarely a large number of sellers and purchasers. On the supply side, decreasing return to scale for large investments often leads to situations of *natural monopoly.* Most of the irrigation managers of large irrigation systems are, in fact, in a situation of monopoly towards their customers. Similarly, tubewell owners in Pakistan may be in a situation of monopoly towards neighboring farmers that do not have choices among several sellers. On the demand side, situations of *monopsony,* with a single buyer facing a large number of potential sellers, are also frequent. This is the case, for example, for most of the water transactions taking place between the agricultural sector (large number of farmers) and the urban sector (usually one city).

- There is a high interdependency between water users. This interdependency usually leads to high *externalities* or *third-party effects* resulting from the reallocation of water resources. From the economic point of view, an externality is a divergence between private costs and social costs or between private gains and social gains. Examples of direct externalities include users sharing the flows of a common stream with some users depending on return flows of upstream users, or aquifer where each user pumping from the aquifer is affecting other users that pump in the same aquifer. In both cases, the transfer of water rights between two users may threaten the water right of other users. Indirect externalities take place when the reallocation of water resources affect sectors of the economy that do not have a direct use of water, but that are economically dependent from the actors involved in water markets.

- Water is not an homogeneous product and is characterized by a *bundle of attributes.* Apart from the quantity or volume that is usually considered in market analysis, those attributes include timing of water supplies, reliability of water received, location, and water quality. Although the different facets of water may be integrated into the definition of water rights and eventually translated into the price of water, it remains difficult to define and easily compare water rights. This, in turn, may affect the development of water transactions and also their overall efficiency. In most of the cases, however, this may be more a problem of information collection or higher transaction costs (see below) to assess existing rights, than a problem affecting market perfection in itself.

- *High transaction costs* are expected in water transfers. These costs include collecting appropriate information on existing rights and potential third-party effects, searching for transaction partners, and organizing transfers. It also includes contractual and enforcement costs, costs required to manage the physical and legal hardware to ensure that rights are transferred, and to confirm the absence of third-party effects. As a result of the numerous attributes of water, the mobility of water resources and their unreliability, and the existing legal system, large efforts are spent on collecting information related to the rights to be transacted and to potential third-party effects that may result from the transaction. Transaction costs include, also, the potential physical losses that may take place as a result of the transfer. Transaction costs are often high in absolute terms, but also in relative terms as compared to the low value of water per unit of volume resulting from the bulkiness characteristic of water.

Water rights, precondition for efficient allocation of water resources

An important part of the discussion on water markets focuses on water rights seen as the basic requirement for efficient functioning of water markets (Coase, 1960; Rosegrant and Binswanger, 1994). Coase (1960) reduces the market perfection conditions to two issues and demonstrates that market allocation will be efficient given *well-defined and non-attenuated water rights* and *no transaction costs*. Completely specified, exclusive, transferable and enforceable water rights, that combines security and flexibility (Livingston, 1995), are then a requirement for efficient allocation of water resources through market mechanisms (Brajer et al., 1989; Rosegrant and Binswanger, 1994). More practically, water rights must be defined in a readily understood and measurable way, so everyone knows what the right is and can monitor its transfer (Simpson, 1994).

Water rights may be defined as riparian water rights, appropriative water rights, or usufruct rights related to a concession or contract with a water company (Colby, 1990). Water rights may be linked to land ownership, as it is in the case of riparian water rights and most of usufruct water rights in irrigation systems. The entitlement attached to the right can be defined in terms of volume of water, share of a flow, share of a storage capacity (Dudley, 1991), or time of use for the simplest usufruct water rights. Also, different levels of priority of use may be attached to water rights. For example, appropriative water rights in California are fully defined by 5 distinct elements, i.e. the diversion entitlement, the point of diversion, the purpose of use, the location of use, and the priority date.

According to the type of water right, it may be more difficult to develop water markets. For example, the definition of riparian water rights limits the possibility of reallocation to other users. In some cases, only a component of the water right may be transacted, as illustrated by changes in location and transfers of the consumptive portion of appropriative water rights.

In a large number of situations, water rights are not properly defined and enforceable as specified above. The inherent heterogeneity in appropriative water rights may be a reason limiting water transfers, or at least increasing the information requirements and transaction costs (see below). Ill-defined water rights that do not internalize third-party effects are also problematic, as they will require complex procedures to ensure that third parties are not affected by transactions. In most of the cases, for example, information on the consumptive use portion of water rights would not instantaneously be available and would need to be collected. And water rights mostly concentrate on water quantities and neglect water quality issues, an important element to be considered in reallocation of water resources (Howe et al., 1986). Also, transactions may carry a certain level of risk, as there is no certainty attached to the output of the purchase (Frederick, 1986).

Sufficient conditions for water market functioning and improved economic efficiency

The preliminary, maybe obvious, condition for water markets to develop is water scarcity, i.e. a demand for water higher than water supply. The level of water scarcity specifies the marginal value product of water, i.e. the marginal increase in output expressed in financial or economic terms that is obtained by increasing water allocated to a user by one unit. Water transactions will develop only when differences exist between the marginal value product of water for different users or uses. And water will then be transferred from lower-valued to higher-valued uses. It is important to note that scarcity may be a temporary condition only, with different arrangements being required to develop water markets under conjectural or structural scarcity conditions.

Other necessary conditions for water markets to function include sellers and purchasers free to enter or to leave the market, and the possibility for establishing links between potential sellers and potential purchasers in terms of information and infrastructure to exchange water (Rosegrant and Binswanger, 1994). It is important to note that the infrastructure may not be a problem, as a simple infrastructure may be sufficient for water markets to function (Rosegrant et al., 1995). Also, a tradable margin that can be accommodated by the existing infrastructure may already provide the required flexibility and lead to an efficient allocation of water resources (Howe et al., 1986). In fact, the infrastructure becomes an issue when transfers between uses, or at high spatial scales, are considered (Simpson, 1992).

The fact that transactions between individuals do not consider third party effects and externalities is an important limitation for water markets to achieve overall economic efficiency. A particular (market-based) water allocation is efficient relative to another (non market-based) allocation if those who benefit from the reallocation of water are able to fully compensate those who lose water or income as a result of the transfer. Several alternatives may be proposed to limit externalities:

- To develop a legal and institutional framework to control water transactions;
- To incorporate externalities into the definition of the water right itself, as discussed in the previous section;
- To limit water transfers to the consumptive use part of the water right or user's entitlement (Rosegrant et al., 1995); and,
- To promote market-related organizations that would internalize externalities related to water reallocation taking place within the boundaries of the organization.

Although the theoretical requirements for well-functioning water markets are rarely met in reality, water markets have been reported under a large range of physical and socio-economic environments. The following section concentrates on the description of *existing* water markets, and stresses the diversity of functioning of these water markets.

2.2 A large diversity in existing water markets

The increasing interest in water markets mechanisms, whether by policy makers or researchers, is rather recent and has its origin in the 1980s as a result of the recognition of the poor performance and inadequacy of past policies to manage water scarcity (see Chapter 1), possibly accentuated in some regions and countries by recent periods with temporarily high water scarcity such as the 1987-91 drought period in the State of California. However, water markets already existed long before this more recent surge of interest. Although not very well reported in the literature, historical examples of water markets include transactions of surface water rights in traditional irrigation systems in the South of Spain (Maas and Anderson, 1978), accounts of water trading dating from the first-half of the twentieth century in irrigation systems in the western United-States (Hutchins, 1936; Anderson, 1961; Gardner and Fullerton, 1961, cited in Reidinger, 1994), or groundwater transactions reported in the State of Gujarat, India for more than 60-80 years (Shah, 1985).

Water markets within irrigation systems are probably the most common cases of water markets, although they have not been the focus of intensive research and are not often reported in the literature. The term *water markets* covers a large range of highly diverse situations and organizational arrangements. It is used to characterize varied situations such as the exchange of canal water turns between neighboring farmers in North-India (Reidinger, 1980), the transfer of water rights from the agricultural sector to the urban sector, and reallocation of water resources between countries as proposed for an efficient management of water resources in the Middle-East (Becker, 1996). More specific terms are used to distinguish some of these transactions: *water transfer* when there is a change in use or place of use (Gould, 1988); *water marketing* when prices for water are attached to the transaction (Reidinger, 1994); *water trading* for transactions that do not involve prices (Reidinger, 1994); and *water farming* to describe the sale of farm land to cities as a means to purchase groundwater rights attached to land in order to provide required water supplies to urban customers (Charney and Woodard, 1990).

The main characteristics of, and differences between, water markets are summarized in the following paragraphs. Water markets can be classified according to three important dimensions:

- *The object of the transaction*
- The definition of the product that is transacted: whether volume of water or water rights, or a specific component of the water right such as the consumptive use portion of appropriative water rights.
- The duration of the transaction: ad-hoc or seasonal transfers of volumes, temporary or permanent transfers of water rights (most of the transfers from the agricultural sector to other sectors).
- The resource considered: surface water flowing along a stream or stored in a reservoir, groundwater.

- *The actors involved in the transaction*
- Individual users, user's groups or local communities, private companies, governmental departments, or states.
- Within sectors or between sectors: In some cases, water transactions mean change in use. A large number of water transactions exist within irrigation systems and involve individual farmers or groups of farmers. However, water markets may involve changes in use as illustrated by water right transfers from the agricultural sector to municipalities or industries.

- *The organization of the transaction*
- Informal or formal water transfers: informal water transfers usually take place within irrigation systems. Formal water transfers exist when the legal system of water rights is more developed to take into account third party effects or mitigate negative effects to third parties.

- Centralized or decentralized: water transfers are mostly decentralized. And potential sellers and purchasers are put in contact directly and bear the entire transaction costs. In some cases, however, a centralized body may be involved in controlling and recording existing transactions. Such an organization plays the role of water broker that makes the link between demand and supply of water, but without a direct confrontation between suppliers and purchasers.
- Auction or bilateral negotiation: in auctions, water rights or volumes are proposed to a large number of potential purchasers and allocated to the highest bidders. Bilateral negotiation usually takes place when one single purchaser (most of the time a municipality) negotiates water purchases from individual farmers or an irrigation district.

Box 2.1 illustrates the functioning of three different types of water markets that have developed under different characteristics of the socio-economic and physical environment, namely:
- Groundwater markets in the State of Gujarat, India;
- Institutionalized water markets in Chile; and,
- The emergency 1991 Drought Water Bank in the State of California, United-State.

Also, existing and potential water markets in Pakistan are described in Chapter 6 and Chapter 7 of this thesis.

Two important conclusions can be drawn from the review of existing water markets reported in the literature. Firstly, the majority of the literature on water markets focuses on two types of water markets:
- The transactions of well-defined water rights from the agricultural sector to the urban sector that have been reported in the western states of the United-States (and also in Australia and Chile); and,
- Informal groundwater markets that take place in South-Asia and have been reported mainly in India, Bangladesh and also Pakistan.

The importance of the literature on water transactions from the agricultural sector to the urban sector may be explained by the indirect economic effects related to changes in use, with larger socio-economic and political issues being involved in such transfers. As specified by Gould (1989), *changes in use, not changes in ownership, are responsible for problems in water transfers*. This results mainly from changes in the consumptive use portion of water rights that often accompany changes in use and that lead to direct third-party effects.

Secondly, the literature mainly focuses on legal and statutory remedies to promote water markets and explain limitations in their current functioning. Little attention has been given to the existing functioning of these markets and *the role of water organizations in water transactions*. In fact, local agricultural water organizations often promote water transfers within their borders and may provide local flexibility that does not exist in the law and operational rules with reduced transaction costs. At the same time, these organizations appear to limit external transfers (Thompson, 1993).

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