Chapter 19

Economics of Irrigation Water

Muhammad Ashfaq and Javaria Nasir*

Abstract

Water stands as one of the very important factors for agriculture, industry, human life, livestock and probably for all phases of life on the earth. Consequently, it may the considered as the key element in the national economy and development. It is a natural resource that supports the agricultural productivity. Agricultural country such as Pakistan cannot think of surviving without ample water resources. Therefore, it must be used efficiently focusing all the management opportunities to minimize water losses. Thus, a working knowledge on economic aspects of irrigation water is a prerequisite for engineers, managers, policy makers and progressive farmers. Farmers in Pakistan have encountered different policies of the Government in pricing of water, such as crop based and area based putting different constraints on the farmers for its profitable use. Water productivity in Pakistan has been lower than advanced countries of the world, which must be improved for improving the economy of the country. Thus, understanding water as a public and private good, its pricing policy framework must be developed. This chapter deals with various aspects of the economics of water, historical developments of pricing of water, water productivity and principles of water pricing, particularly, in relation to the agricultural production, which would set a sound base of knowledge for students, economists, engineers and policy makers.

Keywords: Water Pricing, Market good, Water Productivity, Water Use Efficiency

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Learning Objectives

- To provide a working knowledge on economic aspects of irrigation water for engineers, managers, policy makers and progressive farmers.
- The reader may understand the dual nature of water as public and private good and its consequences for water pricing
- Understanding of the water pricing policy framework in Pakistan
- The readers may learn different approaches of economic and financial analysis for irrigation projects.

19.1 Introduction

Economics primarily deals with the allocation of scarce resources in an efficient manner. It is generally associated with the allocation of profit-making goods such as automotive, garments, or petroleum, etc. Thus, economics of water usually requires answer to the following questions:

I. What are the efficient ways of utilizing water in an efficient manner across competing uses?
II. To determine whether the allocation of water recourse is equitable and if not how we can make it both equitable and efficient?

Economics is the science of decision making so it can help policy makers make conversant choices and also ensure that water resource allocation is equitable and efficient across alternate uses. Subsequently mass trading assumes a significant part in deciding the cost of water, the structure of water markets, welfare dissection of water portions, ecological worth of water asset and appraisal of the expense profit examination of different water ventures.

Water is an extremely complex resource because of its unique characteristics. Its economic valuation is difficult because it's both public and private good. Its opportunity cost is difficult to calculate because it has multiple uses. The flaws in institutions and policies also add complexity for the water resource allocation. However, economists have evolved a great deal of literature in this context. Following are some basic concepts necessary to be understood before explaining different aspects of economics of irrigation water.

19.2 Market and Non-Market Valuation of Water

Most of the goods/agricultural products are traded in markets and they have market prices, e.g. wheat, fertilizer, seeds, chemicals, etc. Water, on the other hand, is a natural resource and its markets are not perfect or do not exist sometimes. For instance, groundwater in Pakistan has a market where farmers buy and sell water, but the price on which the water is sold does not reflect its true scarcity value. For Tubewell water only, the charged price covers its extraction cost, maintenance cost and some profit. The true price for water may be far more than the existing prices. Same is the case for canal water in Pakistan, which is sold at heavily subsidized prices that are not enough to cover even the repair and operational costs of the irrigation infrastructure. These distorted prices should be kept in mind while going into the economics of irrigation projects.

The benefits and costs of water projects may go far beyond the monetary gains only. For example, to decide on building a large water dam/reservoir, the costs do not include the construction costs only. There may be huge other costs associated with such projects like dislocation costs for moving a sizable population residing in the area, the loss of natural habitat, deforestation, etc. Likewise, the benefits of water projects may include several other benefits than just the increase in agricultural production or electricity generation. These additional costs and benefits are called social benefits. Several methods have been developed to calculate social benefits and costs of a water project.

19.3 Water as a Public and Private Good

Private goods are those which are traded in conventional markets. The Public goods are ‘enjoyed in common’ and must have two characteristics, namely, (i) Non-rivalry in consumption (ii) Non-excludability in consumption

The utilization is non-rivalry if one man's utilization of water does not rival the utilization of whatever viable individual, e.g. the air has the property of non-contention as utilization of one man does not lessen the utilization of others. Private goods do not have this property as the consumption of one person reduces the consumption of another person for the same good, e.g. consumption of wheat stored by a household. Public goods also have a property of non-excludability which means that nobody can be excluded from its consumption, e.g. consumption of air. Everybody can use it. In other words, it implies that if the goods are available for consumption to one person, these are available to all. In contrast, private goods are excludable which makes it possible to physically exclude some persons from using it as in our wheat example.

So, what this theory of public and private goods has to do with water? Water is both a public and private good. It depends on the situation when it is a public good and when it becomes a private good. Flowing water is generally a public good as everybody can use it without significantly harming the consumption of others. But water becomes a private good, e.g. when is stored by a farmer in a reservoir for irrigation. This dialog of water as one of the open goods and private goods has two imperative results, particularly if there should be an occurrence of open benevolence of water. Firstly, Public goods are supplied collectively and therefore they may be undersupplied due to the free rider problem which arises due to the selfishness of some people who think why they should pay the ‘cost’ of ‘resource’ when they can use it for free (think of water in a river as ‘resource’ and of ‘cost’ in terms of pollution costs)? Secondly, there is a valuation problem as discussed earlier. Private goods are valued for a single user through efficient market mechanism. In contrast, public goods are used by all people so value placed in them is not by all the people but only by the one who care. So, the benefits of the public goods, mostly go to a number of users while only some pay the costs. This dual nature of water poses special problems when one aims at estimating the true costs and benefits of using water, such for irrigation purposes.

19.4 Water Productivity

Water productivity index may only express a physical ratio between the yield and the water used to produce it. Yet, there is not a common agreement to use it as an indicator. It is generally defined as the ratio of crop yield harvested in kgs to the amount of water used in cubic meters (m^3) to produce that crop. We can calculate water productivity with a simple mathematical formula:

$$WP = \frac{Y\ (Kg)}{WU\ (m^3)} \qquad (1)$$

Where:

WP refers to Water Productivity,

Y refers to crop yield in Kg and

WU refers to the volume of irrigation water used in cubic meter.

Most developing and developed nations have a goal to increase the water productivity.

The other way to calculate water productivity is

$$\text{Water productivity} = \frac{GDPinconstantprices}{annualtotalwaterwithdrawal} \qquad (2)$$

Table 19.1 Water Productivity of Top Twenty Countries in the World-Country Ranking

(Constant 2000 US$ GDP per cubic meter of total freshwater withdrawal)

Rank	Country	Value	Year	Rank	Country	Value	Year
1	Singapore	914.78	2011	11	Switzerland	118.49	2011
2	Monaco	631.44	2007	12	Congo	113.97	2011
3	Luxembourg	447.06	2011	13	Finland	90.89	2011
4	Equatorial Guinea	367.36	2011	14	Israel	90.85	2011
5	Denmark	260.63	2011	15	Malta	87.17	2011
6	Antigua and Barbuda	178.83	2011	16	Brunei	76.34	2011
7	Ireland	157.42	2011	17	Kuwait	74.94	2011
8	Qatar	152.27	2011	18	Slovak Republic	68.74	2011
9	United Kingdom	136.34	2011	19	Norway	67.46	2011
10	Sweden	121.52	2011	20	Puerto Rico	67.36	2007

Source: Food and Agriculture Organization, AQUASTAT data, and World Bank and OECD GDP estimate

19.5 Water Use Efficiency (WUE)

Water use efficiency in irrigation is the ratio of the amount (volume) of irrigation water actually used by a crop to the volume of actually diverted from a source for that purpose.

$$\mathrm{WUE} = \frac{\mathrm{Vu}\ (\mathrm{m}^3)}{\mathrm{Vd}\ (\mathrm{m}^3)} \qquad (3)$$

Where:

V_u = volume of water utilized, m³

V_d = volume of water diverted or extracted from a reservoir, m³

19.6 Pricing of Irrigation Water

Water is an important economic resource and, over time, economic pressure on water resources forced countries to create a mechanism to enhance water use efficiency, especially for irrigation water.

19.6.1 History of Irrigation Water Charges in Pakistan

The practice of collecting water charges can be traced back many centuries in the sub-continent. Initially the collection of water charges was informal. Evidence of the collection of water charges from water users started from the period of Feroz Shah, an emperor of India, in the late 14th century. He levied water charges from water users of the Hansli canal. In the period of the Sikh Government in the Punjab (1763-1849), water charges were introduced on fixed rates, based on the type of crops. Water loving crops were charged one fourth of the produce while low water consumption crops were charged one tenth of the produce. The system was further improved later in 1854 by introducing a monetized system of water charges for some crops like sugarcane and cotton.

After the proper canal system building in sub-continent British introduced the productivity based charge system and first time water charges were introduced to a large canal in 1891 and then to other canals, as they became operative. In response to declining prices of farm output the charges were substantially reduced in 1934. Taxes remained compelling work 1953 and water charges were expanded by 50 percent in zones of immersion trenches. The water charges for the arrangement and plantations were likewise multiplied in 1954 in light of the fact that they supplied additional water supplies for the watering system. In 1955 all charges were again brought back to the level of 1924. In 1959 the waterways were appropriated in two gatherings, the composite duty into parts, so that rationalization and revision of water charges can be possible throughout the country. Water charges were increased many times in the period of 1959-1969, resulting in a 10 percent average increase in overall price. Enclosures and plantation were furthermore charged 3 to 4 rupees for every section of land for every year. The reconsidered water charges remain compelling work 1978 which are 14.4 rupees for every section of land. Water charges overhauled a few times from that point forward and, in 1978, arrived at 18-21 PKR for every section of land for wheat, 18-34 PKR for rice, 18-32 PKR for cotton and 18-71 PKR for sugarcane. The recovery rate was just 50 to 60 percent and was covered by government subsidies. Different forms of this charging system remained in practice till the year 2003 when in Punjab, fixed water charges based on area owned were introduced. These charges were separate for cropping seasons and head-tail differentials were also introduced. Water rates have been kept low in Pakistan since 1959 especially for food and fodder crops as compared to cash crops. It was decided as a policy to keep the water charges low for food and fodder crops to ensure food security. This policy principle has become very contentious with the passage of time as governments tried to keep the water charges low to fulfill political motives. It has been estimated in different studies that irrigation charges have only made up to 2 to 6 percent of the total cost of production of different crops and these would have to be raised considerably to have any notable effect on water demand.

19.6.2 Water Pricing Markets

Getting right prices of water is to allocate water in an efficient and sustainable way, but ways of water allocation are very responsive to physical, socioeconomic, institutional and political settings, so one should take into account all these important aspects while developing the water pricing mechanism. Rather, all exertions of water valuing for the proficient designation of water assets, there are contrasts on the methods by which we infer the water costs (Kim and Schaible, 2000). The Government has to play an important role to build a strong institutional and organizational mechanism for efficient water allocation, even if we allow the private markets and give them right to exchange water for successful operation of these private markets that depend on institutional arrangements.

19.6.3 Principles of Water Pricing

Due to increased population, changing lifestyle and dwindling water supplies, the competition for scarce resources has been increased, Therefore, it is necessary to rationalize the water use. Water is a precious resource so we should use it efficiently and equitably. Consequently, it is important to consider the efficiency and equity issues so that economic efficiency becomes compatible with social objectives.

19.6.3.1 Efficiency

We can see the economic point of view of water resource allocation in different sectors as portfolio of investment projects. Considering this precious water resource as capital and with efficient allocation, one can get the maximum profit by equating marginal benefits of all sectors and utilize water until these marginal benefits are equal for all sectors. In the transient for productive designation, it acknowledges most extreme net profits over variable cost and bring about to minor net profits balance from all divisions asset utilization likewise augment social welfare (Dinar et al., 1997). In the long term we also consider the fixed cost optimal utilization. First, the best efficient is an allocation that maximizes net benefits in the absence of distortionary constraints or taxes. Second, the best efficient is that maximization which considers under distortionary constraints (informational, political, or institutional) or taxes (Tsur and Dinar, 1997)

19.6.3.2 Equity

The issue of impartial allotment concerned with reasonable portion over all financial gatherings into the general public and may not perfect with investment proficiency (Seagraves and Easter, 1983; Dinar and Subramanian, 1997). At present, the pricing mechanism of water resource may not be effective in redistribution of income (Tsur and Dinar, 1995), however, this may be because of some political and government's enthusiasm to build the accessibility of water for specific segments or residents. It is important to give water procurement at sponsored rate or receive diverse estimating component to record for different pay level to meet the objective of value (Dinar et al., 1997).

19.6.3.3 Theory

Water imparted some regular properties of both renewable and non-renewable assets. The surface water has the issue of reallocation of renewable supply around contending clients if the capacity is not accessible. Anyhow ground exhausts with the current withdrawal if the revive rate is in fitting; due to this reason the asset distribution is exceptionally imperative to think about. Allocative proficiency of watering system water might be computed by likening minimal profits of a unit of water to the peripheral expense of supplying that unit of water. Because many distortionary constraints associated with irrigation water practically it is difficult to achieve Allocative efficiency. Considerable attention has been given to these constraints along with efficiency and equity issues. Both partial equilibrium and general equilibrium have been used to evaluate the irrigation projects. Partial equilibrium analysis considers on one irrigation unit, keeping all other things constant while general equilibrium analysis determine the economy wide effects of policy by considering all other sectors in the analysis. Know we start with general society benevolence of water procurement and notice a few flights into the writing of second-best theories.

19.6.3.4 Public Goods

Water is often a public good weather we consider water from underground sources or surface sources of water. As we know water is a scarce resource and we have finite water resources that must be shared between different sectors, user and regions. The difficulty of overutilization of these open products alluded as the "**tragedy of the commons**". This happens when a few clients overlook the impact of their movements on alternate clients of asset and on the asset also, and all clients simply pursue their redirections toward oneself. Economist advocates the definition of private water rights and establishment of water markets to devise the proper user rights which are efficient, equitable and also protect the resource from depletion. For example, tube-well irrigation has now become cheaper due to technology and now it is considered as a private good, even for small scale farmers. However, for exhaustible, non-renewable or uncertain resources privatization is difficult.

19.6.3.5 Implementation Costs

Appropriate institutions are required for proper implementation of the pricing methods, such as a central water agency, but these entail costs. The physical, political and institutional environment is manifest in the form of transaction costs. Implementation cost may also render some pricing methods unreasonable and also shrink the list from which to select. It is not a trivial task to value these constraints under various pricing methods and we have no general rules that can be applied in a given situation. Administration costs, which are easy to value and estimate implementation cost, also include such things as compliance costs, which can be quite extensive. Complex pricing scheme which is also efficient may be constrained by the informational and administrative costs needed for implementation in various parts of the world due to complex farming systems.

Tsur and Dinar (1997) found that the effects of implementation costs on the performance of different pricing methods are significant in the sense that small changes in costs can change the order of optimality of those methods. While these remarks may be uncomplicated, very little experiential proof or methodology exists for evaluation of the practical limitations of various implementation costs.

19.6.3.6 Incomplete Information

If there is a situation that water user has complete information about the marginal value of water, but a part of information is confidential and unavailable to the water authority then othercosts rise. In this situation, rational individuals may use their private information to precede their own interests, but water authority has to put more efforts or monitoring and enforcement at society's expense. The text refers to this as asymmetric information and moral hazard. The persistent case of unmetered water and the occurrence of pricing mechanisms on an area basis demonstrate this aspect of incomplete information in a good manner. Here, an authority will often remedy to the use of per unit area pricing due to the high costs of implementation of metering system. Because the authority does not have complete information on the value and use of the irrigation water, farmers might have an incentive to under-report actual usage of water if priced volumetrically.

19.6.3.7 Scarcity

A pricing mechanism can be used in many ways to address scarce water supplies. We can implement high marginal cost prices during seasonal shortages, to ration all of the water and to recover fixed costs during peak demand. To address scarcity, many informal allocation systems have been introduced in the nonexistence of prices or prescribed markets. For many years, these long-established, mutual measures have often operated successfully, but these are not efficient or equitable: for example, the subaki system in Bali, the warabandi system in Pakistan and India, and the entornador-entornador system in Cape Verde. Imparts instead of volumes of water might be dispensed to unique homesteads when streams are questionable, and proficient designations could be accomplished if these shares are tradable. To balance the budget of water authority, we have another mechanism of introducing the fixed charge to cover scarcity costs. The productivity of minimal expense evaluation might be reached out in this way for short-run (utilizing a two-part tax system). In Egypt, this strategy is utilized. Yearly Pigouvian duty can likewise be utilized to handle shortage; it additionally stays away from distortionary influences or other burdened structures and is accordingly equipped for accomplishing long-run proficiency. Decision of water source and watering system framework is additionally identified with unverifiable and this will eventually influence the cost of water. By method for productivity and value criteria Small and Rimal (1996) assessed water shortage impacts on watering system framework execution in Asia. They note that ideal transport methods to record for shortage may decrease financial proficiency and value insignificantly. Thusly, Zilberman (1997) creates an ideal water evaluation, distribution, and transport framework over space to catch diverse upstream and downstream motivations.

19.6.3.8 Other Distortionary Constraints

It is troublesome to accomplish first-best portions because of numerous other distortionary requirements; we talk about a percentage of the institutional and political demands in later areas. Be that as it may, we ought to say that diminishing comes back to-scale and externalities are additionally considered in attaining productive and impartial water designations before we turn to the act of evaluating and assigning water. There are externalities to nature's domain (contamination) or to other vested parties (outsider impacts) connected with water assignment. Economists have customarily upheld the utilization of assessments to address these externalities. On the other hand, the potential for this relies on upon the way of the watering system framework.

The irrigation projects at large scale exhibits increasing return to water production technology and give rise to natural monopoly. The cost of treatment of water and the per unit delivery cost declines the delivered volume of water increases. Negligible expense will be dependably lower than normal cost so peripheral expense estimating won't take care of the full expense. We can recuperate the full cost (variable and settled expense) by utilizing two parts levy evaluating. It could be more proficient for water power to value water underneath its long run peripheral expense if the settled expense connected with waterways, dams and other base surpasses the variable expense of water supply.

19.6.4 Water Pricing in Practice

It has been mentioned above that marginal cost pricing of water is difficult for many reasons. There are different methods for pricing of water resources and efficient allocation which depends on natural and economic conditions of the projects. First, though, it is important to have some idea of the actual supplying costs of the water.

19.6.5 Assessment of Irrigation Costs

Assessment of the cost that should be recovered from the water users has been a debatable issue for a long time. Financial costs, which are sometimes referred to as the Full Supply Costs are further composed of following four costs: the cost of depreciation, the financial cost of capital, the cost of rehabilitation and the O&M cost at primary and secondary levels.

The financial cost of the capital (the interest rate payable on the costs associated with the development of the irrigation systems) and the cost of depreciation (capital consumption of the fixed assets) are often grouped together and called the capital charges. For the calculation of capital charges there is disagreement, as old methods use old accounting methods and just look for the cost that is associated with repayment of historical stream of investment.

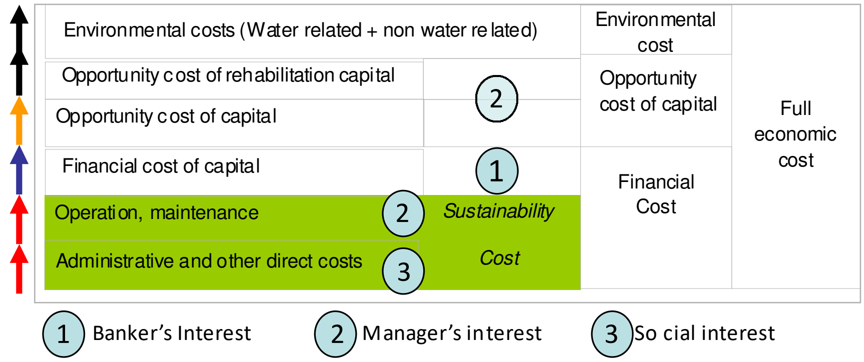


Fig. 19.1 Components of Surface Water Cost
Source: Adapted from Peter, 2004

O&M costs are related to daily running of the delivery system. In these costs, we include typical costs like labor, purchased raw water, repair materials, and other input costs of managing and operating the system at the primary level (i.e., at the reservoir/storage level) and at the secondary level (i.e. at the main canal level). Upgrading or overhauling the system is often called the costs of rehabilitation. In practice, there is typically little dispute as to what are considered as O&M costs or the costs of rehabilitation and how they are to be measured.

Fig. 19.1 depicts the different types of costs involved in the supply of irrigation water. The Fig. also depicts administrative costs along with the operation, maintenance and renewal costs, together which make up the sustainability costs of the system and these should have to be recovered from the users of irrigation services in order to make the system sustainable.

The sustainability costs only make a portion of the full economic costs and most of the time these are not intended to be recovered from the users of the irrigation services keeping in mind the social and political pressures. So most of the time when we talk about cost recovery, it is referring to the recovery of the sustainability cost only. It is important to differentiate between the two terms, i.e., water charge and water price. Although at various occasions, these two terms have been used interchangeably, a distinction has been made by various authors between water tax, water charge and water price. Water tax is generally levied as a compulsory payment to cover the expenses meant for the general revenue raising. No promise of provision of service is made in response to the payment of the tax. A water charge is a payment actually made by the users of a specific service to partly or fully cover the expenses of delivering that service. Water price reflects the value of the commodity determined by the forces of demand and supply and it includes recovery of the full cost.

19.6.6 Irrigation Charging Methods

The broad range of categories that have been used for the assessment of irrigation charges include:

- Area based charging system,
- Crop based charging system,
- Volumetric charging system,
- Quota or rationing system,
- Tradable water rights or water markets.

Different characteristics of these systems are described below. While discussing their characteristics the criteria used for the comparison of the above charging systems include: predictability, stability, ease of administration, productivity impacts, and demand management. There might be no single system that can fulfill the requirements of all of the above criteria. Each system is detailed below.

19.6.6.1 Area Based Charging System

Area based charging system can be divided further into two procedures;

A. Water charges based on the area of the farm. This type of charging system is not related to the area irrigated, types of crops sown, or the volume of water received; it is rather related to the actual cultivated area of the farm. This type of charging procedure is being used to cover the fixed costs of the irrigation service and these have no impact whatsoever on the productivity, efficiency or demand management. This procedure is very stable, predictability of revenue collection is relatively high and it is relatively easy to administer.

B. Alternatively, fixed charges on the basis of area irrigated may be levied. So the total area of the farm, crops sown or the quantity of the water used has no impact on the level of charges. This procedure differs from the first type in that it has little impact over the demand side, but at the same time it is less predictable than the first method.

Zone based charges, taking into account contrasts in water use via season or product, might have a percentage of the profits of volumetric estimating. Furthermore, it might be the circumstances if, in the wake of conspiring for yield and season there could be almost no progressions being used of water for every hectare. There are still a few issues exist in a range based evaluating on the grounds that the agriculturist at the head of waterway have a tendency to over flood and this issue might be determined by guaranteeing the in time conveyance of the obliged amount of water to the agriculturists, in this situation there will be no purpose behind over watering system.

19.6.6.2 Crop Based Charging System

In crop based charging systems, charges vary with the type of crop being cultivated. The water charge depends on the availability of water for different crops and on the "sweet will" of the policy makers. On the off chance that strategy producers want a productive allotment of water assets they need to permit higher watering system charges for high water expending products, for example, rice and sugarcane might be liable to higher charges for every hectare. With this charging framework if the distinction in charges is more extensive than agriculturist naturally switch to interchange crops. Anyhow if the government has some objective of the low nourishment value strategy, and needs to expand creation of any business crop than these favored yields will be charged more level than different harvests. Nonetheless, the mind must be taken in customizing the subsidies for delicate inputs, for example, water with the end goal of higher creation in light of the fact that subsidies some time prompts inefficiencies and abuse of the rare asset, for the most part with harvests, for example, rice and sugarcane. The product based charging methods have little effect on the interest administration of the watering system water, yet are less foreseeable and less steady than the range based charging techniques.

19.6.6.3 Volumetric Pricing System

The volumetric charging procedures can further be divided into categories described below.

(i) Charges Based on Marginal Price of Water

In this method, a fixed rate charging system for each unit of water used is levied. The charges are directly proportional to the volume of the water used by the farmers. Different research studies have concluded that these procedures have a positive impact on productivity and demand. But it is very difficult to assess whether these methods can assure the demand/ supply balance or not. On the other hand, the assurance and predictability of revenue collection are poor with a complicated system to administer.

(ii) Rising Block Tariff System

In this case, a variable rate of water levies per unit received is applied. Service charges are directly related to the amount of water received, but these charges are not proportionately distributed. Lower volume water consumers have a lower block of charges, while higher volume users are charged at higher rates. This procedure is relatively more effective in assurance of supply and demand balance as compared to the first type of volumetric method.

Practically, volumetric methods of supply of water to individual farmers are perhaps not practicable in many countries of the developing world. At present the reason is that these require installation of measuring devices and these costly devices are vulnerable to accidental and malicious damage. Volumetric charging procedures can serve as an incentive to reduce demand if an irrigation infrastructure and water distribution methods can allow different volumes of irrigation water supply to serve different consumers.

(iii) Two-Part Tariff

Another modification of the volumetric charging procedure is a two-part charge, if we combine volumetric pricing and a fixed charge it will be considered as two parts tariff. It has the advantage of overcoming the weaknesses of block method pricing. The volumetric part dependent upon minimal expense evaluating and empower less utilization of water, while repair part used to make any shortfalls and guarantee the stream of income without recognizing what amount of water is accessible and conveyed. Even there is a part of operational and maintenance cost which is fixed cost and has to be paid even water has not been used in any season. It has also a disadvantage that it is relatively difficult for farmers to understand and hard to calculate. Likewise, the management expenses on a piece valuing plan are prone to be to a degree higher than a solitary charge plan.

19.6.6.4 Quota or Rationing Charging System

This is a widely practiced charging procedure in the field. Quota limits the consumption at a threshold level, but it does not provide any incentive to farmers to utilize the available water efficiently below this limit. Although this system of charging water is quite efficient in the areas where water is scarce, but it also opens a political debate regarding the allocation of quota and its administration is also very difficult to manage.

19.6.6.5 Tradable water rights or Water Markets

Water markets or Tradable water rights are applicable in the countries where water rights can be traded formally or informally between individuals or companies at a particular price. Water markets oblige a decently characterized structure of rights, value to regulate the conveyance of water, wide manages for exchanging, legal body to manage exchanging exercises and focus question for effective working. A well-developed conveyance system for transportation of water to all participants is also required, if all these requirements are in place, supply and demand will be effectively adjusted by market equilibrium prices. This system of water market has very high effects on water productivity and it can manage supply and demand balance very effectively.

19.6.7 Global Water Pricing Schemes

Water charging followed by different countries of the world are given in Table 19.2

Table 19.2 Water Charging and Cost Recovery Conditions in Various Countries

Countries	Charging Scheme	Cost recovery	Cost recovery rate	Issues/Comments
Pakistan	$0.6 to 3.0 per acre-inch for different crops	About 35%, govt. subsidies cost of O&M	(30 to 35%)	ISC have little impact on efficiency and cost recovery
Syria	$110-190 for permanent irrigation	Fee for investment cost recovered in 30 yrs, Flat fee represent O&M part	90% of O&M cost	Govt. has not large networks, wells cover 59% of area
Cyprus	$0.108/m3	Govt. covers 38% of weighted cost	34% of weighted cost (more than 90% of target)	Calculation of weighted cost is responsibility of govt.
Morocco	$0.02/m3 to $0.053/m3 as per irrigation method	100% of O&M cost to be covered from beneficiaries	58 to 70%	Drought effects recovery rates
Turkey	$22.3 to 76.7 depending upon crop and irrigation method	Capital cost up to 10 yrs, O&M cost for previous year	55% to 93% depending upon the system	Low capital cost recovery and no inflation adjustment
Mexico	. $40/ha, determined by WUA	User pay 85% of O&M, govt. 15%	90 to 100%	Transfer prog. Raised charges (39 to 80%)
Jordon	ITB system, $0.01 to 0.05/m3 for 1000 to 3000m3 on monthly basis	Govt. subsidize about 30% of the O&M cost	--	Costs recovered by the users were not invested back in to the system
China	Complex system (Volumetric + crop based), $27 – 49.5/m3	Irrigation retain 75%, local management 25%	> 90%	
France	Volumetric (partially), $ 5.27 / 1000 m3	User pay 100 percent of O&M cost	> 90 %	System of charging recover sustainability costs in some areas

Source: Johansson, 2000; Bazza and Ahmad, 2002; Dinar and Mody, 2004; Cornish, 2005

19.6.8 Recent Changes in Pricing Policy

The income gathered from water asset is collected in the common treasury alongside other expense income and they lose their source personality. Consequently, we can't claim immediate relationship of water accuses of operational and support exercises. Cost of upkeep and administration expense of watering system water supply is more than receipts. Receipts have just 30-70 percent of cost on the operation and support of watering system. The remaining sum left in the wake of paying all non-water inputs from the terrible income gathered from the harvests indicates the returns to water and these might be considered as the most extreme sum for an agriculturist to pay. The conclusion for year 2000-01 gave Rs. 121 for every section of land inch for wheat, 57 for rice, 26 for cotton and 66 for sugarcane, correspondingly. These are steady with the conclusion dependent upon the expense of water tube wells. The estimation of peripheral quality item per–inch of water was Rs.70-107 in 1992. On the off chance that we express these pieces in 2000-2001, it compares to Rs.148-226. It demonstrated that negligible quality result of water is much higher than the current and flow water cost.

On the foundation of terrible salary for every section of land evaluations, utilizing the normal yields for year 1999-2000 and the legislature floor costs for that year, the proportion of ebb and flow water charges increased to horrible wage that have changed from 0.57 to 1.22 percent for different harvests. In the event that the rates of water build by two folds, agriculturists would just need to pay from 1.74 to 3.66 percent of their constraint salary, contingent upon the yield rehearsed, for trench water. The sensible and most suited charge for watering system water as a percent of horrible wages is 6% for Asian nations (this proportion is about 6.5 percent for the Philippines, Indonesia and South Korea). We can expand the water costs significantly even than this level can't be attained in Pakistan. On the off chance that we expand water charges by 100 percent than it will bring about degrees of water charges to net ranch wages that are harshly equal to those of various other Asian nations. Be that as it may, the increment in water charges has practically no impact on water use in view of the instrument of value framework. Ranchers will be eager to pay considerably higher water charges for great quality water and better administrations. In Punjab, yearly financial burdon on administration and upkeep of watering system frameworks is over 5 billion rupees. Income gathering of water valuing is much lower than uses, and this consequence in the procurement of huge subsidies to this area.

An expansive sum is additionally used in water charges accumulation, so a fitting water estimating component is the need of time for productive gathering, additionally for recouping the expenses all the more viably. It has likewise some suggestion for money division in country regions. Punjab government took a choice to change the waterway, water charging strategy from yield region cum-product sort based charging to harvest zone based level rate charging in 2013. Under the yield zone cum-harvest based framework, water charges separate by the condition, sort and season of the product and were imposed, depending upon the region trimmed. High charges executed for higher water expending harvests, for example, rice, and low charges for less water devouring yields, for example, wheat (for instance, for every hectare harvest based-water-charges preceding June 10, were Rs 37 for feed, Rs 148 for wheat, Rs 222 for cotton, Rs. 297 for rice, and Rs. 432 for sugarcane).

Under the new even rate framework for each hectare water expenses are settled for Rabi and Kharif seasons, despite the kind of yields created in every one season (new rate for each hectare are Rs 124 for Rabi and Rs 210 for Kharif products, paying little personality to the sort of harvests created).

19.6.9 Factors Responsible for the Change

a) The harvest based charging framework was viewed as old fashioned and not in accordance with the changing water and flooded horticulture circumstance;
b) It was thought to be controlled by the powerful agriculturists and government authority, (for example, distorting and miss-recording product sorts and yield zones, e.g., charging for grain rates when high water rate products, for example, rice or sugarcane were really developed);
c) The water charges appraisal was dependent upon the judgment of the income official, so it is generally obvious that it prompts an environment for rent looking for conduct;
d) The past arrangement of water charging was viewed as beneficial to enormous agriculturists and inconvenient to little ranchers that involve the incessant in the cultivating group; and
e) The harvest based charging framework prompts expansion weight on open subsidizes and broaden the hole between watering system costs and income gathering (e.g. as of late aggregate income gathered through water charges in the Punjab territory represented 31.4 for every penny (or Rs 1.6 billion) of the aggregate uses (of Rs 5.1 billion). It additionally uncovered that Punjab government is paying 3 rupees for each one rupee of water charge gathered. There is a blended response for this arrangement, while there are numerous supporters and a few faultfinders additionally for this approach change. There are three principle issues identified due to changes in approach. The new framework did not depend upon farm area and it is dependent upon the homestead region under harvest throughout the Rabi and Kharif seasons (i.e., level rate for every hectare of zone edited in each one season) the homestead range has water benefit or the region getting water.

f) Under the exhibited warabandi framework, portion of water is doneon the measure of homestead landholdings. In aggregate terms, substantial ranchers gather and utilize more trench water than little agriculturists. On hectare support, on the off chance that we consider that little and vast ranchers get an equivalent measure of water little agriculturist who have huge trimming force will pay more than the extensive agriculturists. In the past the flooded region halfway by waterway water and in part by ground water is charge completely for trench water charges. The individuals who use more groundwater and other variable inputs to expand their editing force might need to pay all the more in for every hectare water charges.
g) The most recent product range based level rate methodology, despite the fact that it does not report for intra-occasional harvest distinction, yet it represents between-season crop contrast and like the old framework, water charges in it are duty dependent upon region trimmed and trimming power throughout a season. So, while the new framework will support in tending to the product sort distorting issue, it might not resolve the issue of harvest region misreporting. The even rate for every unit of area is dependent upon the area size, free from product sort and trimming intensities are an improved elective to address both of these issues.

19.7 Groundwater Markets in Pakistan

Water showcases that exist in Pakistan are casual and are typically restricted to water markets spotted between contiguous agriculturists. The practice is extremely regular groundwater. Nonetheless, in spite of the fact that it is in numerous parts of Pakistan, the event of groundwater markets is not uniform. The region flooded through water markets, which is regularly recognized to be a substitute for the size of exchange water, shifts by locale and about whether relying upon various components, for example, drizzle, supply groundwater, editing examples, and the expense and accessibility of power. For instance, in water rare pockets of Punjab a significant zone inundated through groundwater markets. No methodical across the country appraisal of the degree of water exchanging.

Groundwater markets are truly normal in Punjab and North Western Frontier areas of Pakistan, where it is soft and fair water quality. Channel gathering and wells frequently utilize both saline and freshwater ranges; in saline zones ranchers blend the water to bring down the level of salt and sweet in the lack and deficiency of supplies strengths agriculturists to proceed with this practice. All head and medium ranchers offer water, while 87 percent of the tail itself, however offers groundwater through tube wells. In this way, groundwater markets are creating in the focal Punjab, where subsoil water is of good quality.

19.7.1 Competition between Buyer and Seller

Groundwater markets are not superbly intense markets where purchasers are allowed to browse various sellers - the force for the most part practiced a restraining infrastructure in these businesses. Groundwater rights are not generally characterized, and transaction expenses are a long way from being zero. Since purchasers and merchants are not nameless yet confront one another as neighbors consistently, a larger number of is included in these transactions than a straightforward offer of water.

One of the fundamental demands to rivalry in groundwater markets is that there are not an extensive number of water venders who can serve a specific zone of the area. Under the conditions overarching in a large portion of Pakistan, water tube well watering system is not a product that might be transported far from the source to the provision range. Transport misfortunes between the well pipe and the field, limits purchasers to purchase from wells found in the region of their fields (and confines merchants to those inside a constrained sweep well). The separation is doable and financially feasible to transmit water relies on upon the dirt, geography and channel sort (open or private) that is utilized to transport water. Physical nearness is not just the relationship impacts the improvement of focused markets groundwater. Social and agrarian relationship between the purchaser (and occupant) and the vender likewise limit the deal and buy of groundwater, whether tube well managers are just ready to offer to close relatives or individuals who have different ties. A significant explanation behind the deal between relatives is that relatives frequently have the closest land because of legacy examples.

19.7.2 Nature of Groundwater Markets

The altered hourly charge pump is the most well-known manifestation of business contracts groundwater in most market zones of groundwater. This kind of plan happens in different sorts of tube wells. Water in diesel pumping supplies ordinarily sold under an agreement by which the purchaser supplies the diesel and motor oil pump and pays an extra charge for every hour for the manager to blanket the motor wear. Offer development contracts for water are utilized under diesel and electric wells.

Overviews have uncovered that 96 percent of the wells were introduced for particular and business use. Most diesel wells are determined and the number fluctuates from one to three in each one homestead. The force of the tube wells fluctuates from 15 to 20 and the download speed shifts from 0.75 to 1.25 cusecs and the profundity is something like 130 feet with a reach of 100-170 feet. The expense of introducing tube well changes from Rs 300,000 Rs 30,000 relying upon the force supply (i.e. tractor, diesel or power). Yearly using shifts from PKR 15,000. 40,000 tube wells in tractor driven, diesel driven using reaches from PKR 2500 to PKR 21000 and controlled power is in the reach of PKR 4000-20000. The normal time for every section of land differs from 2.5 hours, 2 hours and 2.5 hours on the tractor, diesel and power worked tube wells with a reach of 2-4 hours.

The costs charged rely on upon the pump sort, limit and area, as depicted above. Higher costs for fuel worked water wells reflect the high cost of working this kind of pump. The normal cost of water under the compensation framework is pretty nearly the same for diesel and electric wells, despite the fact that the previous are by and large more costly to work. The normal expense for every hour of water to the buyer of diesel tube wells is marginally higher under the framework purchaser - bring - fuel under the altered charge for every hour. Water merchants' diesel pumps are apparently just recouping its expenses of operation and upkeep under any kind of agreement. Transaction expenses of the merchant in the procurement of fuel and working or administering the operation of the pump are probably higher in hourly load contracts, yet there may be some hesitance to let purchasers work the pumps themselves under the purchaser framework - brings - fuel.

The capability of agriculturists to pay for water might be assessed from the individuals who rely on upon water markets groundwater. Private-wells gave just about 30 percent of the water, leaving the homestead throughout the year 1997-1998. In Punjab, something like 40 percent of the aggregate accessibility of water through tube wells (Government of Pakistan, 2002) Today, the normal offering cost of water from a tube well is about 120 PKR for every hour for introducing a limit of one cubic foot for every second, which is proportionate to more or less one section of land - inch of water for every hour (100 m3/hr). This charge is more than twofold what a rancher depending quite on the trench water pay for the same volume of water for the same products.

19.7.3 Problems in Groundwater Markets

Groundwater markets are indigenous establishments generally independent to remain useful without a great deal of government intercession. These plainly assume a significant part in stretching access to groundwater assets discriminating part in Pakistan. Since access to such ground water is free in light of the fact that there is no confinement on the withdrawal of ground water markets and water have additionally expanded the control of ranchers on watering system. In spite of the preference of water markets, there are a few issues, which are in the improvement of groundwater markets.

The primary impediment to market improvement of groundwater is renewable groundwater that forces restriction on the amount of wells that could be introduced and worked in a practical way. Punjab overall surpasses energize pumping in excess of 25 percent. This implies that the supply of a tube well for all ranches is not a reasonable long haul result.

The level of water control gave buys of ground water is not as incredible as that of the tube well holders. Managers of tube wells treated water deals as a remaining classification to help their fields. The offers of groundwater when all is said in done are not an exchanging organization in which dealers have an enthusiasm toward helping their customer base. Accordingly, water purchasers can't hope to get more water they require and when they require it. Consequently, the tube well water is purchased, not as profitable as the water from their wells.

Watercourses lined pipes and guarantee that buyers accept more water from the water from the well-paying tube and offering allows a more extensive field of each one tube potential number. So, transport structures lined run together with the improvement of more aggressive markets groundwater. Regardless of these points of interest in groundwater markets, there has been minimal private financing in the covering or tubes in Pakistan. By and large, the channels are adjusted field just in the initial 20 meters of tube well, which is basically used to assimilate the vitality of water from tube wells being pumped into the channel.

The conduits of agriculturists to utilize water from a tube well regardless of the procurement of the Act seepage channel and that whole make the rate of water utilization are assessed for the waterway watering system. Nespak (1991) study proposes that this law limits the offer of tubewell water. The Canal and Drainage Act further confines the transport of water through tubewells to agriculturists by precluding the transport of water through open water courses.

19.7.4 Seller and Buyer Preferences

19.7.4.1 Sellers' Preferences

Research shows that there are a number of preferences which sellers of ground water keep in mind while selling water. These include:

- Relatives and friends,
- Timely payments,

- Religious sects,
- Bradrism (caste-centered), and
- Anyone who could pay the price.

19.7.4.2 Buyers Preferences of Purchasing Water

There are different types of preferences indicated by purchasers. The following are the important factors which affect the decisions of the buyer for irrigation water:

- Relatives and friends,
- Quality of irrigation water,
- Location of tube well relative to irrigation requirements,
- Price of water,
- Availability of water at the time of need,
- Provision of tube well on fuel basis,
- Provision for making payment at harvest, and
- Other reasons like religion and Bradari.

19.8 Economic and Financial Analyses of Irrigation Projects

An economic analysis is defined as ‘‘a systematic approach to determine the optimum use of scarce resources, involving comparison of two or more alternatives in achieving a specific objective under the given assumptions and constraint”.

The financial analysis only takes the point of view of stakeholders on a project, like investors, be those the government, farmers, NGOs, etc. But economic analysis also incorporates the societal perspective in the analysis and seek weather the project will benefit the whole society. Economic analysis has the objective to maximize benefits at the national level instead of profit maximization of primary stakeholders.

19.8.1 Fixed Costs

Fixed Costs are those costs, which in total do not vary with changes in the level of output. It has to be paid even when the firm (or farmer) stops working i.e. when the output is zero. For example, land rent, interest rate on money borrowed from the bank, permanent hired labor etc.

19.8.2 Variable Costs

Variable Costs are those costs, which change with the level of output. The increase in variable costs is associated with each one unit increase in output.

Total Cost: Fixed and variable costs can be summed at each level of output.

$$TC=TFC+TVC \quad (4)$$

Where;

TC = Total cost

TFC = Total fixed costs

TVC = Total variable costs

19.8.3 Gross Margins

This is an important economic concept which may be defined as:

Gross Margin= Total Revenue – Total Variable Cost

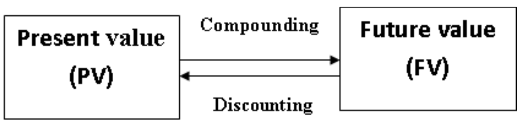
It may be noted that cost has two components, variable cost and fixed cost. In calculating gross margins only variable costs are subtracted from the total revenue. Positive gross margins sometimes indicate that investment/intervention is worthwhile. But this is not a perfect measure to decide on whether to implement the project or not because there may be several other benefits and costs associated with a project. Nevertheless, gross margins provide a rough idea of the usefulness of the project.

19.8.4 Marginal Cost

Marginal cost is an economic concept is profit maximization and cost theory. Marginal cost – also called the incremental cost – is defined as the additional amount of money incurred to produce one extra unit of output. In case of groundwater, the marginal cost of using water may be defined as extra dollars spent on using an extra cubic meter of water. For canal water usage, marginal cost may be defined as extra amount of money spent to deliver one cubic meter of water to the field.

19.8.5 Net Benefits and Costs

Net benefits are defined as total benefits minus total costs when both are measured in monetary terms. This is a concept used in cost-benefit analysis. For irrigation projects, the net benefits may be calculated by summing all the expected benefits and costs of a proposed irrigation project (in monetary values) and then subtracting the latter from the former. A positive net benefit Fig. may be an indication of an economically feasible project but this measure should be used with care when comparing different projects.



$$\text{Discount Factor} = \frac{1}{(1+r)^n} \quad (5)$$

$$PV = FV \times \frac{1}{(1+r)^n} \quad (6)$$

$$FV = PV(1+r)^n \quad (7)$$

Where:

FV = Future value (total amount payable)

PV = Initial amount borrowed (present value)

r = Interest rate

n = Number of years

19.8.6 Costs-Benefit Analysis

Cost-Benefits Analysis (CBA) or Benefit-Cost Analysis (BCA) is used in economic analysis. It makes use of comparing the costs and benefits of a project as the basis of decision before initiating the project.

Cost-Benefits Analysis has two purposes:

- To determine the soundness of an investment
- To compare different competing projects for the choice of the best one

In CBA, expected costs and benefits are usually discounted to assess their present values. This is done using a discount rate. So, CBA actually compares discounted benefits and costs. Therefore, in the CBA, the benefits and costs are brought on the same temporal footing.CBA attempts to measure the benefits and costs of a project which may accrue to users of project, non-users of a project, the externality effects, and social benefits costs.

19.8.7 Benefit -Cost Ratio (BCR)

The benefit cost ratio is defined as "the present value of the estimated benefits divided by the present value of estimated costs".

$$BCR = \sum_{i=1}^{n} Bi/\,(1+r)^{i} \qquad (8)$$

When using BCR, the decision rule is:

- If BCR > 1, then accept the policy or the project.
- If BCR<1 then reject the policy or the project.
- If there are different policies or projects, select the one with the highest BCR value.

19.8.8 Net Present Value (NPV)

Net present value is defined as the "present values of estimated benefits minus present value of cost". Mathematically it can be expressed as:

$$NPV = \sum_{i=1}^{n} \frac{(Bi-Ci)}{(1+r)^{i}} \qquad (9)$$

Where;

NPV = Net Present Value

Bi = stream of benefits

Ci = stream of costs

When using NPV, the decision rule is

- If NPV> 1, then accept the policy or project.
- If there are different policies or projects, select that one with the highest NPV.

19.8.9 Internal Rate of Return (IRR)

A good way of using the incremental net benefit stream or incremental cash flow for measuring the worth of a project, is to find that discount rate, which makes the net present value of the incremental net benefit stream or incremental cash flow zero. This discount rate is called the Internal Rate of Return (IRR) and is obtained through an iterative process. It is the average earning power of the resources used in the project over its lifetime. Following are the two types of IRR, which are used to evaluate development projects.

Financial Internal Rate of Return (FIRR)

Economic Internal Rate of Return (EIRR)

$$IRR = LDR + \frac{(HDR-LDR)\times NPVatLDR}{(NPVatLDR-NPVatHDR)} \qquad \ldots\ldots\ldots\ldots.. (10)$$

Where:

IRR = Internal Rate of Return

HDR = Higher Discount Rate

LDR = Lower Discount Rate

NPV = Net Present Value

IRR must be greater than the cost of borrowing for the project to be feasible.

19.8.10 Determination of economic values

To focus the monetary qualities from an undertaking's execution, the budgetary costs are utilized and balanced for different elements that twist the true worth to the general public. The principle components that are incorporated in these alterations are:

- The premium on foreign exchange
- Transfer payments
- Price distortions in traded items
- Price distortions in non-traded items
- Evaluation of land and labor

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