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Review Article

The Economics of Water Resources: A Review of Recent Research

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Abstract: Water is essential for human survival and all human activities. It is also widely accepted that there is a growing demand for water due to socio–economic development while there is a shrinking supply due to global climate change. The finiteness and increasing shortage as well as scarcity of water have thus created worldwide water related problems. However, in the past, the management and allocation of water resources global have been far from optimal. Both water quantity and quality have been deteriorating at an alarming rate, and without proper water resources management and allocation practices in place to tackle this situation, water shortage and depletion would be inevitable in the future. The failure of proper management and allocation in the past was mostly attributed to the failure to understand the true nature of water as an economic good. Compounding to the problem, water is a special economic good as it can be both a private and a public good depending on its source and use, thus requiring special market–based mechanisms in place of a pure command–and–control approach in management and allocation. This paper provides up–to–date information on the research of water resources economics through the review of more recent advances in concepts and policies. Through the improved understanding, it is expected that better management practices could be established for the sustainable management and allocation of water.

Keywords: Water; Water economics; Economic policy; Water management.

1. Introduction

Water is one of the most important resources as no life could exist without it. However, water sources are definite, and with the growing global population, the increase in living standards and the intensifying effects of climate change, water scarcity is becoming an imminent threat to further sustainable development [1]. Economics is the science of research on how people and society choose to use scarce resources to produce goods (services) and distribute them for current or future personal consumption and groups of people in society. As water is no longer an abundant resource, there is an emerging consensus that effective water resources management includes the management of water as an economic good. In the 1960–1990 period, a number of studies related to water economics and economic values of water stemming from the research branches of scientists studying microeconomics, customer behavior theory and the formation of a water trade market were introduced. These studies can be seen as prerequisites for proposing principle 4 – "Water has an economic value in all its competing uses and should be recognized as an economic good", which was recognized and approved by the international community at

the association Dublin–Rio Conference 1992. Previous failure to acknowledge the economic value of water has resulted in wasteful use of water resources and environmental damage. Managing water as an economic good is an important way to use it effectively and efficiently, to encourage the conservation and protection of water resources, and to formulate policies for water investment and development.

There have been a number of practical studies to determine the economic value of water use based on geographical locations and water uses. At the basin level, the economic value of water has been determined at the Zambezin basin [2]. At the national level, water resources have been valued in Namibia [3] and Jordan [4]. These studies provided the foundations for numerous other studies on water resources economics. This includes the study by [5] introducing the principles and methods of determining the economic value of water resources.

It is commonly agreed that water is not just an ordinary economic good. Traditional demand rationing of water in the past had led to market failures and the ineffectiveness of water allocation. As an example, water prices do not truly reflect delivery cost. Thus, economic policies to allocate and manage water is crucial to the sustainable use of water as a scarce resource.

The aim of this paper is to perform a review of recent advances made in water resources economics to give a more comprehensive view for future researches. Firstly, special characteristics that make water different from other ordinary economics goods and difficult to allocate and manage, will be identified. The article will then present the problems in water cost and price that should be addressed to avoid market failures. Finally, we will discuss new advances made in efforts to balance water demand–supply and economic policies to enable water economics.

2. Water as a special economic good

Based on the degree of excludability and rivalry, it is complex to classify water into just one type of economic good. Exclusion reflects whether it is easy or difficult to exclude or limit consumption by other users, and rivalry refers to the degree to which the use of a unit of a good by one individual reduces the potential for others to use that same unit. These two concepts define interchanging characteristic of water [6–7] that has created serious challenges in water management.

This complexity of water characteristic is highly relevant in the case of domestic water. Domestic water use can be understood as rivalrous in that an individual drinking a glass of water can prevent others from drinking it, and excludable in that when it has been used nobody else can use it. In this case water is considered as private good. However, access to safe drinking water and sanitation was declared a ‘human right’ by the UN in 2010, which makes water, unlike most private goods, unable to be traded in markets and allocated to its highest value uses [8]. In this view, it can only be used and distributed effectively after basic needs have been satisfied [9].

A change of classification has also been observed moving into more recent times. In the past of abundance, water in its original state was once an open access resource. No one had exclusive property rights to water and one person’s use did not prevent others from using it (rivalry). However, in the current face of water scarcity, water has become a “rival” and “non–excludable” good, thus defined as common–pool resource [10].

Moreover, the intended use of water can also change its definition as an economic good. Water can be “excludable” when water infrastructure projects only benefit a group of

people. An example for this would be community based irrigation schemes. In this case, water is defined as club–good. On another hand, it will be described as public good when these benefits are both non–rival and non–excludable, for example: people can all be protected from flooding when a dam is built [11].

As evidenced above, the classification of water will depend on water sources and its uses, as well as the particular context. For example, Dosi distinguished differences in rivalry and exclusion at each step in one value–added use, classifies irrigation water as a club good [12] while Ostrom, Elinor, Wai Fung Lam, and Myungsuk Lee figured it as a common pool resource–reflecting different perspectives and contexts for their analyses [13]. In other words, the chosen frame of reference for analyzing rivalry and exclusion can result in a particular characterization of the resources. Thus, under changing circumstances, water can transform from one type to another. This complexity means that while markets can be used to allocate water resources, it requires management to adapt to better incentive compatibility and improve economic outcomes [14].

3. Water prices–Water costs

Around the world, water is generally underpriced. Firstly, most water agencies set price to cover the past cost of the water system rather than the anticipated future replacement cost. The gap between these two expenses is often large because of the longevity of water supply infrastructure. Secondly, after a major water system is completed, since supply capacity so far exceeds current demand, the price tends to be set just to cover the short–run marginal cost (operating cost). However, as demand eventually grows, it will be economically optimal to switch to charging on long–run marginal cost (replacement cost). Despite this, water agencies are often politically locked into a low water price schemes and lose incentive to invest in future system [15–16].

It is also important to emphasize that the water prices paid by most users does not reflect its value of scarcity. Users pay for the capital and operating costs of the water supply infrastructure but there is no actual charge for the water itself. The reason water cost does not cover a scarcity cost is that most monopolies don't have to pay for their water. Water is thus treated differently than oil, coal, or diamond for example. While some European countries charge fees to withdraw water, they are often just administrative fees and are not based on the economic value of the water being withdrawn.

Due to water's special characteristics and the ensuing impacts, a traditional market trading scheme would be suboptimal for social welfare. In a well–functioning market, the efficient allocation of goods is reached at the point where the market price balances supply and demand. At this point each water user consumes a level of water where the additional or marginal benefit to withdrawing an additional unit of water is equal to the cost of withdrawing it. However, unlike other goods, the impact of water uses may result in negative externality costs that the users are unaware of. Water use in the agricultural sector, for example, is often associated with negative externalities such as groundwater contamination by fertilizers and pesticides. These external impacts of water use are not typically reflected in water prices and included in the costs, so regulators and users do not take them into account when making decision about how much water to withdraw. Due to these negative externalities, social welfare is decreased and water resources are often undervalued and overused (Figure 1).

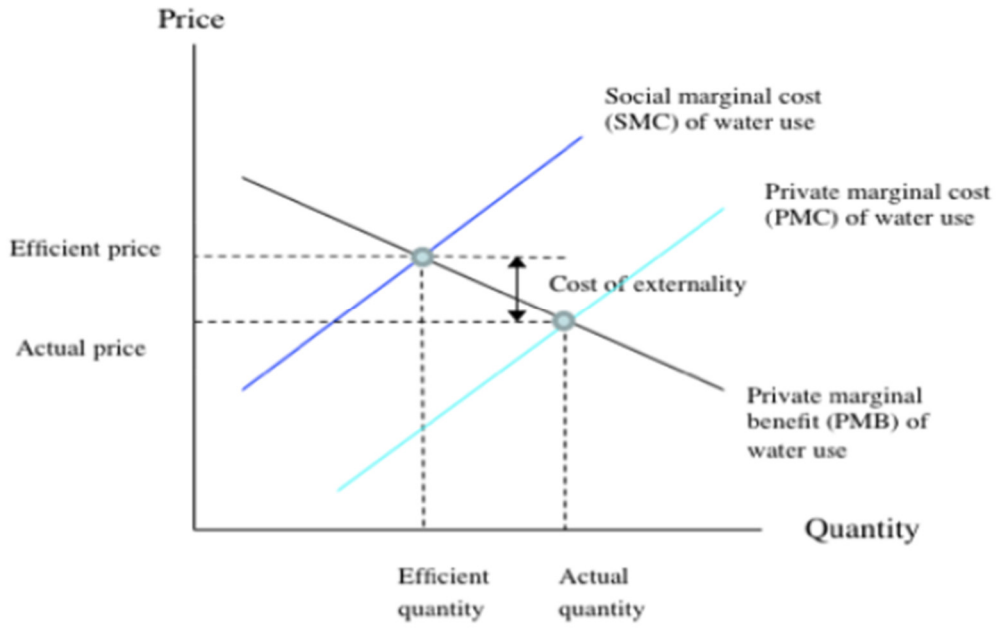

Figure 1. Cost of externalities [17].

4. Water demand – Water supply

Water shortages consistently rank among the global risks of greatest threat to world leaders and policy makers around the world (World Economic Forum, 2019), and without thoughtful solutions these challenges will keep intensifying and spreading as demand grows [18–19]. To adapt to this situation, sustainable water economics has been created, researched and become the highest rated solution to water scarcity. Over the last few years, many authors have set the focus on sustainability and most works are devoted either to water supply enhancements or to water demand strategies [20].

Water price is, as discussed above, way too cheap and being heavily subsidized in many countries [21]. As a consequence, the scarcity cost is not visible to water users. In developed countries, the fact that water is essential for human life is almost irrelevant because people use it more as a commodity than as a necessity. Even in some developing countries people are not fully aware of water scarcity and have comfortable water consumption as their income rises. That consumption patterns together with population growth, economic development are the reasons why water demand more often exceeds water supply.

Whenever water demand exceeds water supply, there are two types of measures to balance supply and demand [22]:

Supply Enhancement Strategies	Demand Management Strategies
1. Build/enlarge dams	1. Establish water-conserving plumbing codes requiring certain fixture types (such as low-flow toilets and showerheads)
2. Drill/improve wells	2. Establish drought contingency plans
3. Build interbasin water transfer facilities	3. Ration water or constrain water use (e.g., alternate-day watering schedules)
4. Repair leaky infrastructure	4. Buy/lease/sell water rights
5. Build desalinization plants	5. Raise water rates
6. Reprogram reservoir operations (e.g., more storage with less flood protection)	6. Educate water users about conservation options

Figure 2. Supply Enhancement and Demand Management [22].

Supply enhancement methods have always dominated, but with fresh water supplies being physically limited, these methods are getting more and more expensive than in the past. We can spend money on new supply and new technologies, but those too will not be able to meet the increasing demand if the consumers do not have to pay the full cost of delivering their water [23]. Recent sustainable supply researches took advantage of another distinctive feature–water's mobility–to create water circular economics concept. This makes water different from other goods because it can be used/reused sequentially. For example, water used for irrigation will then seep into the ground and become available to other users. Furthermore, it is very costly and often difficult to keep track of water flows, thus often making it impossible to establish property rights to return flows. Water reuse would then be an opportunity to create the availability of safe and clean water supplies. This model's goal is to optimize water resources use and reuse, and at the same time minimize the generation of wastewater. Examples of this include generating biofuels from sewage mud to provide energy [24] and using wastewater sludge for the manufacture of construction materials [25–27]. Also, water can be treated for different reuse purposes like supplying agricultural systems, irrigation of parks and gardens, lawn and car washing, or even for drinking water.

The key concept is simple: water is withdrawn from streams, reservoirs, oceans, and groundwater aquifers or collected directly as rainwater and used in four traditional categories: Agriculture, Municipality, Industries, Environment. This includes both consumptive and non–consumptive uses. Non–consumptive used water is then returned to the basin directly or through a municipal treatment facility. Depending on the location within the basin this returned water can then be reused downstream or lost to the basin in similar ways as the consumptive uses.

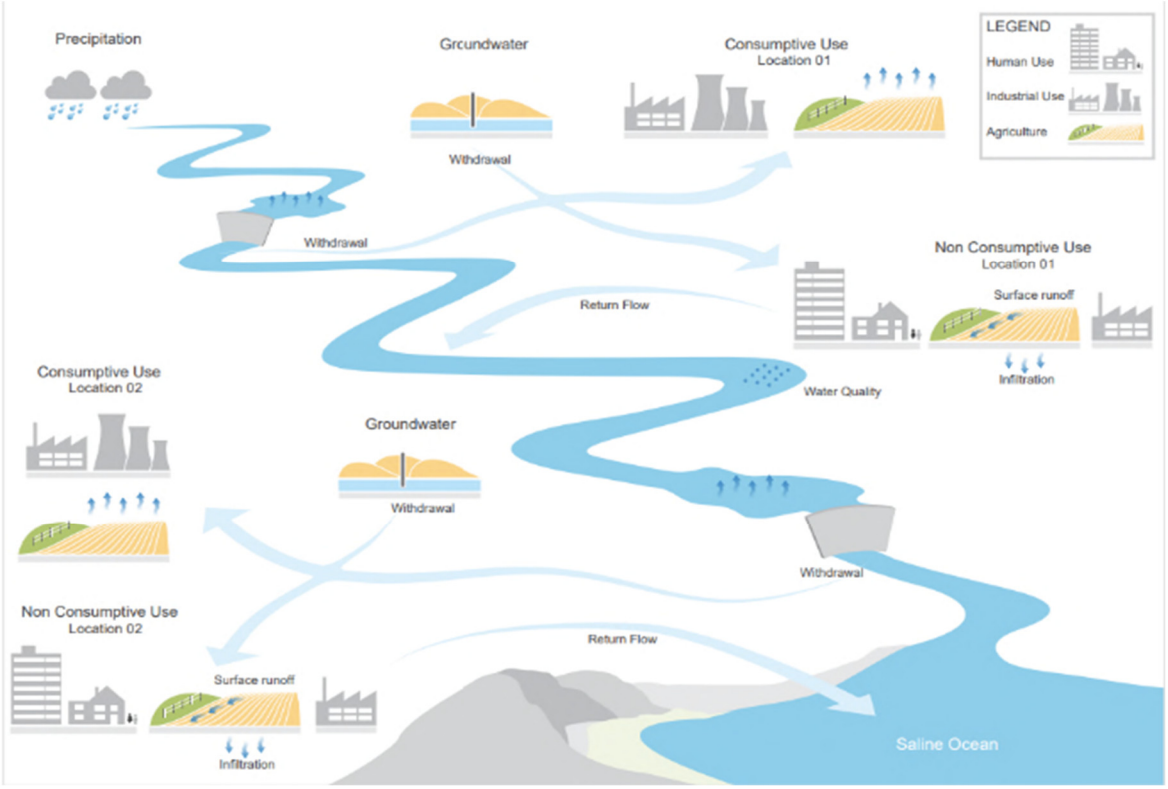

Figure 3. Water flows in a basin [28].

As the progression for supply enhancement slow down, the opportunities of demand control have simultaneously increased. The importance of water demand management rises as the threat of scarcity looming large. If demand management strategies can be applied effectively, they will become very powerful tools for balancing demand and supply. There are now many examples of how demand–side control can be designed: The US has developed numerous conservation strategies to reduce water demand by utilizing pricing schemes, educational measures, efficient equipment subsidies and water rationing. Water rationing is a widely used method in the US; however, there are ongoing discussions about consequent welfare losses as the water is not allocated according to the marginal willingness to pay of customers [29].

Similarly, Australia developed a mix of water instruments to reduce demand to effectively cope with severe drought. The Cairns regional council has launched a campaign to promote wise water use in addition to mandatory restrictions [30]. Many municipal cities in Australia have implemented water–wise rules. These rules aim to save water in the everyday life of households. Households in Sydney must use hoses fitted with a trigger nozzle and irrigation systems when irrigating the garden. The irrigation time is restricted from 4 pm to 10 am and there is a fine of $220 for households breaching this rule. However, the water–saving impact is often smaller than expected because behavioral changes partially neutralize the efficiency effect of the water–saving techniques [31].

5. Economic policy of water resources

As discussed above, water can be better described as a rather complex economic good than a homogeneous good because of its special characteristics, leading to three very potential tasks for governments to enable water economics potential: managing water

infrastructure, redefining property rights and pricing water. The first one, financing water infrastructure, in comparison to other economic goods, is a struggle. As previously noted, water supply systems are exceptionally capital intensive. This capital is very long lived and has no other values. In the US, for example, the water industry is 2.3 times more capital intensive than that of electricity, and 2.4 times more capital intensive than the telecoms industry [32]. Therefore, the main financing pathway most desirable is direct financing supported by foreign aid. The question is whether this is a realistic proposition as the water sector is relatively unattractive for private investors. Furthermore, climate extremes have magnified the challenges of water scarcity and its temporal variability. Variability and uncertainty caused by climate change have led to a range of unsuccessful infrastructure measures [33].

The benefits of defining property rights increase as scarcity intensifies and, property rights will develop when the benefits outweigh the costs [34]. Tradable water rights gain has been estimated to reflect the benefits of property rights reform [35]. In Australia, models of water trading point out that annual gains from trade are over AU$2.5 billion, which could be further increased with the removal of barriers to trade. The strategy for communication and compensation is pivotal when discussing property rights of water [36]. In this case, the key issues concentrate on who receives and who pays the compensation, how much and how to limit future adjustments [17]. Property rights reform, like all economic policy, is a political choice that requires special attention to distributional conflicts.

Pricing is often the first and the most important effective tool in economics, which goes the same for water. To ensure efficient use of a typical economic good, it should be priced at its (long–run) marginal cost. However, this is usually not the case for water. As discussed above, the price of water almost never equals its value and rarely covers its costs. Because there is a human right to water, rationing it using price may seem unethical. When price raising is not cost–justified, it could be politically infeasible and even sometimes illegal. In California, for example, Proposition 218 stipulates that municipal water rates be "proportional to the cost of service".

In Europe, an effort aimed at such policy has been made with the Water Framework Directive (WFD). WFD responds to the increasing threat of water pollution and increasing public demands for cleaner water bodies. It aims to protect and achieve good chemical and ecological quality in all bodies of water. In each EU nation, WFD is then translated to national laws and governance. Within this framework, the European Commission commanded that significant water–related project must conduct Cost Benefit Analysis (CBA) to calculate the financial rate of returns (FRR) and the economic rate of returns (ERR). While the FRR corresponds to the financial profit from the private sector's point of view, ERR represents the socio–economic benefits of the project to the society in a whole. As discussed before, profit–oriented perspectives may cause undesirable effects on the society. In CBA, these harmful effects are in the form of shadow prices, externalities and other nonmarket effects, which make up the difference between FRR and ERR. In general, for a project to be approved, the ERR shall be greater than FRR, which means society as a whole will benefit from such project.

There has been a group of researches contributed to good water governance by addressing best practices for stakeholder engagement and political decision–making. [37] address an innovative approach to implementing Ostrom principles in a community–based governance context. [38] analyze public participation and stakeholder engagement and knowledge co–creation in water planning in the context of EU WFD regulation. [39] also

review the application of the concept of disproportionate cost in the WFD, which should be used when a water mass cannot achieve a good environmental status (GES). Finally, also in the WFD context, [40] explore the concept of GES in German waters.

Looking closely at surface water and ground water laws, all the property forms are represented, albeit with an exception: clearly defined open access resources laws. Nevertheless, these institutions are not rigidly established; they are all evolving. Where water scarcity is increasing, eastern permits will soon replace riparianism (rights to an unspecified share of the flow). If these permits become transferable, another transition to private property will take place. Moreover, absolute ownership (weak common property), reasonable use (common property), correlative rights (common property), prior appropriations (incomplete private property), and the Vernon Smith system (advanced private property) are listed when examining groundwater law. All of the existing institutions are deficient in most cases, leaving water depletion decisions to those who are not rewarded for water conservation and therefore, are not fully incentivized to act in the public interest. Current institutions are still incoherent and inconsistent. In addition, all societies require a mixed system of water management institutions, involving both private and public rights to allocate an efficient amount of water to instream and inground applications. Therefore, efficiency cannot be achieved until all incentives encourage people to behave with the understanding of scarce water value.

6. Conclusion

In the traditional market–based approach, commodity is allocated efficiently for competing demands where producers and consumers interact and agree upon the price and allocation for the available resources. However, as discussed above, water is a special economic good, not just a homogenous good, traditional market based approach alone will lead to market failures. In this case, it is best to apply a mix of public and private roles to create a sustainable market–based mechanism to allocate scarce water resources. The government, with a broad range of social goals rather than profit–oriented goals of private sector, may intervene and mitigate social inequalities to provide substantial access to water for all people and limit market failures.

The goal of this paper is to review recent advances in concept and policies of water economics. To give a better understanding of the transitions in recent years, some change in key elements of water resources economics is presented in this review article. Researches devoted to sustainable water economics in recent years have a prominent growth due to growing population concerns about increasing water shortage and its worldwide related problems. Many authors have been studying different disciplines in order to develop a comprehensive analysis framework for the sustainable management of water resources. However, most works are focused either on water supply or water demand. Different authors from the economic field prefer the control of demand using technologies and policies to solve water shortage problems since the supply side requires huge investment in time and money. There are also works that analyze the sustainable increase of supply through new concept of circular water economy, which might be the key to solve the incoming threat of water scarcity.

To support the sustainable use of water, there is a need to make the problem of scarcity visible to water consumers through water pricing. Price should be able to reflect full costs of water including externality costs and scarcity costs to promote efficient water use by the consumers. However, we should also consider that improved pricing requires attention to

inequalities and affordability concerns that have fueled resistance and perverse consequences in the past. Thus, this creates a challenge to align the incentives of individuals with the interests of the community.

The article attempted to review the state of the art of the economic management of water. However, this paper has only reviewed water resources economics in general. There is a need for a specific basin research along with further researches on surface and ground water separately.

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