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REVIEW ARTICLE

Water Pricing Policy and Subsidies to Irrigation: a Review

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Abstract This paper aims to provide an international review of water pricing policy with an emphasis on the alignment of costs with prices. The paper raises questions around the mechanics of promoting policy changes for more sustainable irrigation management as well as environmental protection in the future. The information and data used for this review were extracted from available published studies but use was also made of information from research institutions and development organizations, country reports, working papers, conference proceedings, and some unpublished documents. My initial hypothesis was that developed countries are more likely to approach full cost recovery policy for irrigation while in developing countries subsidies were considered more likely. The concept of full cost pricing has been employment in shaping policy in a number of countries, including Europe. Although environmental externalities from irrigation are seen as an important part of irrigation costs, in practice these are seldom included as a component in charges for irrigation. While most developed nations have been promoting full supply cost recovery, subsidies are still dominated in irrigation in both developing and developed countries. Full cost for irrigation water consists of three components: supply cost, economic and resource cost, and environmental cost. Capturing the costs of each component into pricing policy arguably leads to more sustainable development and environmental protection in the water sector. The political will to reach full cost recovery seems beyond most governments.

Keywords Water pricing · Irrigation · Subsidies · Full cost recovery · Policy reform

1 Introduction

Subsidies have long been a popular policy instrument in the context of water management (Tiwari and Dinar 2002). In the case of irrigated agriculture in particular, this has resulted in the subsidisation of one of the main inputs- water resources (Scheierling et al. 2006; Fan et al. 2008; Ward 2010). While many challenges relating to water issues exist, such as increasingly

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scarce water resources (FAO 2012), related food security issues (FAO 2015), and water-related environmental stress (Gilboa et al. 2015; Guse et al. 2015), calls for sustainable development of water management continues (Varis and Abu-Zeid 2009).

The response from most economists is to seek clear price signals to enhance the efficient allocation and use of scarce resources. In principle, the price should reflect marginal social cost of water provision. Social welfare is maximized when the marginal social benefit of an additional unit of water is equal to the marginal social cost of supplying the additional unit. In this case, economic efficiency is achieved and it is impossible to increase the social welfare by reallocating the resource to alternative uses. If water and water services were provided under competitive conditions this result would generally follow. However, competitive markets for water and water services are rare and regulation is usually relied on to match prices and costs. However, regulatory approaches often do not succeed and are certainly not without problems. In practice, prices of irrigation are usually set below supply cost (Molle 2009) and subsidies from public funds are common. In many cases, this has led to unsustainable finance for suppliers, poor use of resources, and negative impacts on the environment (Renzetti and Dupont 2015). Accordingly, many countries are again considering pricing as an important element in their policy intervention (Dinar et al. 2015) with pricing seen as an important component for efficient and sustainable management of water resources (Hansjürgens 2016).

The aim of this paper is to provide an international review on water pricing policy and subsidies to irrigation. In doing so, I focus on specific components of cost and reflect on the alignment of prices with these costs. The paper itself comprises five additional parts. Section two is used to clarify the concept of full cost recovery of irrigation water supply. Some issues regarding public versus private benefits in irrigation and challenges to setting prices are discussed in the next section. Section four provides a synoptic review of cost components and subsidies to irrigation in selected countries; whilst not universal, the review provides sufficient cases for useful comparison. Section five reviews the issues facing the irrigation sector, and considers the merits of policy reforms. The paper ends with some concluding remarks.

2 Full Cost of Irrigation Water Supply

The literature on irrigation reveals a wide range of water pricing methods as well as practical challenges to modifying water prices. Important contributions in this area include Johansson et al. (2002), Tsur et al. (2004) and Tsur (2005). For example, Johansson et al. (2002) provide a comprehensive review of theoretical and practical issues regarding pricing irrigation water. In this regard, various methods for allocating irrigation water were reviewed and factors such as physical, social, political and institutional settings were identified as having an important impact on pricing policies used in different countries. Tsur et al. (2004) emphasize that demand management should be a central point in contemplating water pricing policies to promote efficient use of water, while Tsur (2005) discusses the economic aspects of irrigation water pricing with an emphasis on supply management and the implication for policy development.

Traditionally, the concept of full cost of irrigation water was conceptualized simply as the financial costs of irrigation provision. However, it has been recognized that irrigation may induce costs to other economic actors, including those who gain utility from the environment. The contemporary conceptualization of full cost of irrigation thus includes consideration of the resource cost, and environmental cost of water provision, although there is some conjecture about the demarcation between each. This approach to the full cost of water was discussed in detail in Rogers et al. (1998), and has subsequently been widely supported by a number of scholars and practitioners (see, for example, Rogers et al. 2002; Ward and Pulido-Velazquez 2009; Bithas et al. 2014).

Figure 1, modified from Rogers et al. (1998), depicts the elements of the full cost of water and its related services. It shows schematically the various components that comprise full cost. There are three main concepts: 1) the full supply cost, that involves operation and maintenance (O&M) costs and capital costs; 2) the full economic cost, representing the sum of the full supply cost and the opportunity cost associated with the alternate use of the water resource; and 3) the full cost being the combination of the full economic cost and the environmental externalities or public health and ecosystem impacts of water use.

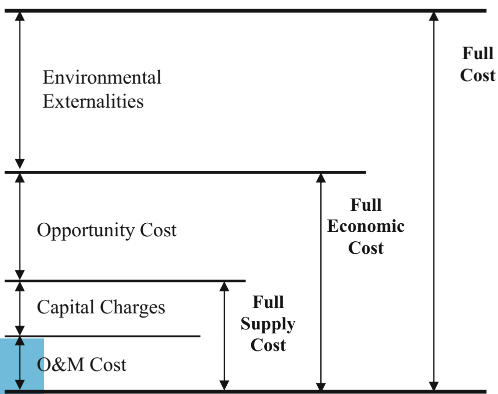
Whilst helpful as a starting point, the framework offered by Rogers et al. (1998) has been subject to criticism. For example, the distinction between so-called economic costs and environmental externalities may be misleading as it is possible to argue that environmental externalities are themselves ‘economic’ at least to the extent that there are some property rights to the environment. Similarly, what Rogers et al. (1998) describe as ‘opportunity cost’ requires cautious interpretation. For example, where water is abundant relative to demand, its opportunity or scarcity value might approach zero. There is also the issue of whether water can be physically transferred to other uses- if transfer is not possible then the cost to alternative users is irrelevant. In addition, not all public policy practitioners, especially in the developed world, will be keen to acknowledge low or zero scarcity prices (for example, see Dwyer 2006), largely because of the intrinsic value of promoting conservation. Nonetheless, the approach developed by Rogers et al. (1998) has some benefits.

First, the framework makes it clear that there are different components that make up the cost of irrigation. What is also clear from this framework is that if, for any reason, water users do not pay the full cost, then the costs must necessarily be borne by others in society, implying a degree of inefficiency and welfare losses for society at large.

3 Issues of External Costs in Water Use

The presence of environmental and resources costs of water and failure to account for those costs can have an impact on the environmental sustainability. In this context, a number of scholars have emphasized the role of considering the issues of externality or the relationship

Fig. 1 General principles for cost of water (modified from Rogers et al. 1998)



between environmental externalities and sustainability in formulating public policy. For example, van den Bergh (2010) states that unsustainability occurs when there is a falling of natural resource stocks or an increase of pollution concentrations to the environment or the loss of nature and biodiversity. In this respect, he insists sustainability requires that specific attention be given to such changes.

In the same vein, Bithas (2011) insists that environmental impacts and the relevant environmental externalities stand to inhibit sustainability. Thus, long-term consideration of the interests of future generations is required to account for sustainable development. From a policy perspective, externalities can be internalized by ensuring all costs are captured in the prices of goods or services. This gives a signal to adjust production and use of the good/service. In this regard, environmental taxes can ensure the environmental sustainability (Bithas 2011).

In the case of water, there has been much concern regarding environmental issues stemming from irrigated agriculture. The return flows from irrigation may contain substances such as nitrogens and pesticides from agricultural production and these are considered major sources of non-point pollution in different countries. For example, nitrate contamination is becoming a very serious problem in the Low Tagus basin which requires prompt action in order to meet the Water Framework Directive (WFD) quality standards of the European Union (EU) (Garrido and Iglesias 2011). Over-exploitation of water may also lead to deteriorating water quality (Fuentes 2011; Thiam et al. 2015), and excessive groundwater abstractions could reduce wetland areas and threaten biodiversity (Fuentes 2011).

In this regard, the OECD (2005) notes that subsidies are often harmful to the environment, especially if they lead to higher levels of waste and emissions than what would be the case without the support measure. In simple terms, if water prices were higher, production would be lower and it follows that the harm to the environment would also be lessened. The links between subsidies and their environmental effects are nonetheless very complex (OECD 2003; OECD 2005). In this respect, Ribaudo (2009) asserts that the extent and level of the environmental problems associated with irrigated agriculture differs widely across regions and countries. The OECD further notes that the links vary from being very direct to very indirect. Against this background, OECD classified production linked subsidies as being overwhelmingly environmentally harmful (Schmid et al. 2007). Perhaps not surprisingly, a number of empirical studies indicate that an increase of water price leads to a significant reduction in fertiliser use, resulting in improvements in environmental quality (see, for example Berbel and Jómez-Limón 2000; Gómez-Limón and Riesgo 2004b; Gómez-Limón and Riesgo 2004a; Manos et al. 2006; Bartolini et al. 2007; Bartolini et al. 2010). In order to solve the environmental problems in the irrigation sector, many scholars insist that the polluter pays principle needs to be followed and incorporated into prices of water (Howarth 2009). Nevertheless, it is well recognized that the estimation of environmental costs and placing a price on environmental damage for water services is not a simple matter. The prospect of raising water prices more generally is also attended by significant political challenges.

4 Public versus Private Benefits in Irrigation and Challenges to Setting Prices

The concept of water as an economic good has been widely discussed in the literature since the International Conference on Water and the Environment in Dublin 1992. There, it was proposed that 'water has an economic value in all its competing uses and should be recognized as an economic good' (United Nations 2003, p.5). Specifying water as an economic good conveys the necessity for considering the opportunity cost of its alternative uses. Nonetheless, there is also a related risk that this will result in simplifying other public good components of water, and/or the services and infrastructure used to deliver it to irrigators.

There are some cases where irrigation might possess 'club good' characteristics, such that access is excludable but strictly non-rival (Oakland 1987) – thus modifying the focus on the opportunity cost of water use. In a newly commissioned irrigation project with ample water endowments, for instance, it may be possible for farmers to take up access rights (even if not clearly specified as such) on the proviso that they meet some use conditions imposed by the state. This is broadly analogous to a club good, at least until the growth in access starts to bind the water using behavior of others.

Another common perception is that irrigation is considered as a public good since it involves non-rival and non-excludible attributes (Oakland 1987). Even in developed countries, the debates about irrigation are replete with descriptions of the 'broad' public benefits of these activities. Claims about the wider non-excludible benefits of irrigation, say in the form of enhanced security through stabilized food production, fit within this genre (see, for example, National Irrigators' Council 2010). Similarly, in developing countries irrigation is often portrayed as a public good, insomuch as it provides an incentive for the rural poor to remain in rural areas, thereby limiting the public dis-benefits that come from relocation to crowded urban spaces (Tardieu 2005). There is also a common supposition that irrigation is well-equipped to deliver equity improvements since prima facie subsidies in this domain would benefit the rural poor (Hussain 2007). Many irrigation projects and the related infrastructure are designed around delivering multiple benefits. A dam that harvests water for irrigation also serves a flood mitigation role. To the extent that these types of arguments hold, there is a case for modifying the notion of cost recovery - if there are public benefits from providing water and water infrastructure then part of the cost should be incurred by public beneficiaries.

One way of thinking about the dichotomy between public and private benefits is to unbundle the various costs associated with water delivery and consider the efficacy of assigning costs to different parties. This is explained with the aid of Fig. 2, below.

If we assume a stand-alone irrigation-only project where farmers seek to maximise their individual commercial benefits, then it follows that all of the charges detailed in Fig. 2 should legitimately accrued to beneficiary farmers, including a charge for a return on capital (reflecting the opportunity cost of the investment of funds), and another charge reflecting return of capital (to cover the depreciation costs of the infrastructure). However, as noted earlier, this may not always be clear cut and the project may have multiple aims and potential beneficiaries. In that context, it may be more efficient to use taxation revenues from a broader suite of beneficiaries to cover some of these costs. The political attraction of this is also clear.

It is also the case that there are historical and cultural contexts that play a part in the assignment of costs. For example, if it has historically been the case that dams and irrigation

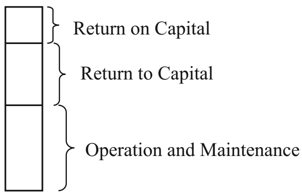


Fig. 2 A framework for cost recovery in irrigation

infrastructure have been conceived as manifestation of public sector achievement, it will likely prove difficult to then assign costs to individual water users. The fact that costs relating to return on and to assets are not always immediately apparent may not sit easily with water users with a different timeframe. This can manifest in water users being unwilling to pay for the long-term replacement and upkeep of assets when their own planning horizon is more myopic.

In addition, there are significant theoretical and practical challenges to setting administrative prices in the irrigation sector. For example, there is disagreement about the appropriate treatment of water assets and how these should be valued and then factored into prices (see, for example, Pawsey and Crase 2012). It is also unclear how the resource itself might be valued when water markets are often absent, or poorly developed. The appropriate treatment of prices when the scarcity of water varies over time and space is also open to debate. The upshot is that setting prices for irrigation water and irrigation services that equate to opportunity costs may be theoretically desirable, but the response to some of these practical price-setting challenges can give rise to very different and often muted signals to end users.

The following section reviews the irrigation water pricing policies in selected countries. I hypothesize that the task of removing subsidies and introducing cost recovery is more problematic in developing countries. The corollary is that full cost recovery should be more common in the developed world, at least to the extent that institutional reform should be more manageable in this context.

5 How Close Are Current Water Prices to Full Cost Recovery?

Most reviews of the international experiences on water pricing and water charges for irrigation focus on pricing methods and specifying the price level for water (for example, Tsur and Dinar 1995; Dinar and Subramanian 1997; Tsur and Dinar 1997; Dinar and Mody 2004; Easter and Liu 2005; Berbel et al. 2007; EEA 2013; Garrido et al. 2014). In this paper, the current water pricing policies of selected countries in different regions were reviewed with a focus on differentiating cost components of irrigation water and the implied subsidies to users. In order to locate available studies and relevant documents to review, a comprehensive search of academic databases, research institutions and development organisations such as IWMI, OECD, FAO, World Bank, and ADB was undertaken. Other sources of information include country reports, working papers, conference proceedings, and unpublished documents. I targeted and used materials that were published relatively recently and that provided information on irrigation water policy in specific countries.

A bifurcation between developed and developing countries is used to provide tentative insights into policy trends across jurisdictions. The distinction between developing and developed nations invoked in this case does not purport to be definitive. For example, there is arguably a wide disparity in wealth, income and governance capacity across the countries examined here. Nonetheless, for the purposes of this analysis, I contend that the categorization is adequate.

5.1 Developed Countries

Historically, subsidy-oriented policies within the irrigation sector have been popular in developed countries. For example, in the US, for over a half of the twentieth century, farmers in the western states enjoyed low prices for irrigation water, due partly to federal policies that encouraged the settlement and development of arid lands (Wichelns 2010). The same situation occurred in Europe and other developed countries. Berbel et al. (2007) assert that in most of Europe, investment costs of irrigation received significant subsidies from governments as a policy to promote rural development.

However, for the last 30 years or so, most developed countries have been undertaking major policy reforms to the water sector. For example, in Europe, the decline in water quantity and quality has urged the EU to respond by implementing new policies (Brugge and Rotmans 2007). More specifically, the European Water Framework Directive (WFD) was issued in 2000 with its major objectives to protect and achieve the sustainable, balanced and equitable use of water with an emphasis on the implementation of full cost recovery for the pricing of water use, including irrigation. Higher prices for irrigation water have been imposed in some jurisdiction as a result of this policy shift. Many EU countries have implemented new legislative and frameworks to transpose the EU's WFD into national legislation. For example, in France, water charges have been increasing to reflect three main concerns: 1) financial stability; 2) stress on water in several basins during summer or drought periods; and 3) environmental pollution (Garrido and Calatrava 2010). In Greece, the current cost structure for irrigation water charges has included the financial cost, resource cost, and environmental cost. However, the average cost recovery level in Greece for agricultural users stands for only 54 % (Garrido and Calatrava 2010). Similarly, an assessment from EEA (2013) revealed that the current policy in various states of the EU's region has failed to achieve the target of full costs in line with the WFD.

In the US, the enactment of the Reclamation Reform Acts of 1982 and 1992 set the legal foundation for the implementation of full-cost charges for irrigation water at the farm level. State and local water agencies have required farmers to pay larger proportions of full supply cost of water and to be paid in full for future irrigation projects (Wichelns 2010). In Canada, the price for agricultural water has increased significantly over time, aiming to support the related infrastructure, but nonetheless does not reflect the resource costs or environmental costs (Renzetti and Dupont 2015). In Australia, the government has made continuous progress toward water reforms and an important component of these reforms has been the use of corporatisation and privatisation in both the urban and irrigation sectors (Saleth and Dinar 2004). Meanwhile, in New Zealand, during 1988–1990, the sale of 49 public irrigation projects to private owners was undertaken and now prices cover capital costs, operational costs, and an allowance for a small surplus (Jenkins 2015).

Although trends toward higher charges are evident in these countries, subsidies to irrigation are still applied to some extent by most governments. For example, in the US, the 'ability to pay' principle is applied to irrigation reclamation projects (Ward 2010). This is clearly at odds with the notion of full cost recovery. In Spain, the plan *de choque de regadíos*, introduced in 2006, provided around 2 billion Euros of subsidies for so-called modernisation. In Italy, the traditional role of agriculture is to secure food and fibre production, and this remains a major policy consideration in preference to cost recovery (Bartolini et al. 2010). In Australia, an important nuance appears in the treatment of irrigation assets. More specifically, irrigation infrastructure that is 'gifted' by government is not reflected in the asset base upon which prices are determined. With the national government set to spend another $5.8 billion on irrigation 'renewal', the extent to which irrigated agriculture genuinely faces full cost recovery remains questionable (Pawsey and Crase 2012). In Japan, water charges for irrigation cover O&M costs and some part of capital costs. Charges relating to capital costs range from 3 to 25 % (Nickum and Ogura 2010, p. 13).

In contrast to the purported trends toward cost reflective pricing in many countries, South Korea is moving toward increased levels of government support for irrigators. Since 1970, the irrigation sector had operated on the principle of full cost recovery, but in 2000, an effort to encourage farmers to grow rice to meet food security objectives (Nickum and Ogura 2010) led to a move to fully exempt farmers from water charges in public-owned irrigation systems.

On the basis of this, albeit incomplete analysis, full cost recovery for the irrigation sector in developed countries appears the exception rather than the rule. Whilst rational policies pronounce cost recovery pricing as an ambition, the reform process appears far from complete. There is also some evidence that the political will to implement cost recovery pricing can weaken, as would appear to be the case in Australia and South Korea for instance.

5.2 Developing Countries

Morocco is a developing country where water is considered a private good. Agriculture in Morocco is a key sector and the country has invested heavily in developing its water resources with the support of government (Faysse et al. 2010). However, the macroeconomic crisis of 1983 and the decision to increase economic liberalisation resulted in major reforms in water policy and management. Water services having largely private good properties had to be fully paid for by users (Doukkali 2005). Water charges for irrigation consist of three components: 1) initial investment recovery constituting 30–40 % of total cost depending on farm size; 2) full recovery of O&M costs through volumetric pricing; and 3) a minimum consumption charge to cover the fixed parts of O&M costs.

A popular trend in irrigation policies in developing countries has been to promote the transfer of irrigation infrastructure to local communities/or water user associations (WUAs). Many countries have pursued this type of policy, for example, Mexico, Chile, Pakistan and India. The rationale for this approach is that the water sector faces serious deterioration of irrigation infrastructure and governments are not able to provide enough funds for O&M and rehabilitation of irrigation structures. The upshot has been that subsidies in irrigation should have often declined and water charges for irrigation significantly increased when this policy approach has been adopted. Price reform is nonetheless inconsistent and there are several cases where cost recovery has succeeded and others where recovery has worsened with devolution of control.

For example, in Mexico, prior to the implementation of its water reforms in 1998, water users paid only about 60 to 80 % of total costs. However, after the reforms, water charges were increased and water users in most districts were reportedly paying 100 % of O&M costs (Wilder and Lankao 2006). In Chile, for irrigation systems managed by WUAs, water charges cover full O&M costs but only partly cover capital costs. In South Africa, water charges for irrigated agriculture in state-funded infrastructure include two components: all O&M costs and part of capital costs (Schreiner 2015). Nevertheless, in South Africa, substantial subsidies to small irrigators in the irrigation sector remain, primarily on the basis of social objectives, food security, and rural development ambitions (Speelman et al. 2009).

Many countries are heavily subsidizing irrigation water users. For example, in India, water charges are highly subsidized and the revenue from the charges is much lower than even O&M costs (Reddy 2009). Saleth and Amarasinghe (2010) contend that current water charging rates still sit at less than 20 % of O&M costs in most states. In Pakistan, while a nominal fee for irrigation water is charged to farmers, it is only about 25 % of the total O&M costs of the irrigation systems on average (Bell et al. 2014).

Several countries have been providing irrigation water to farmers almost for free. For example, in Egypt, the provision of irrigation water in canals has been free of charge, although there can be considerable costs associated with pumping, where surface water is conveyed to fields lying above irrigation canals (Luzi 2010). In Thailand, water is supplied to agriculture free of charge to support farmers, regardless of emerging water shortages (Molle 2007). In Vietnam, water charges to farmers have been waived for the major components of irrigation systems from head-works to secondary canals since 2008 (François and Hoanh 2011). Farmers pay only a small part of the O&M costs managed by communities at the farm level.

In sum, this partial review reveals varied levels of failure on cost recovery pricing for water and water services. Most countries are applying some form of subsidy to water users in the irrigation sector. A summary of the form and extent of irrigation subsidies in various countries is offered in Table 1. Here, an effort has been made to provide a typology of government support based on the notions of cost recovery offered in Section 2.

Table 1 illustrates that developed countries show some progress to full cost recovery. In some countries, water prices cover most elements of full supply cost, and a few countries, such as Greece, have applied mechanisms to include resource costs and environmental costs within the pricing structure. However, most countries are still applying policies that result in some subsidies, especially to the capital costs of irrigation infrastructure. Whilst there are clear trends that developed countries are pursuing policies toward full cost recovery of irrigation water, this is still far away from expectation. The application of full cost recovery for the irrigation sector in developed countries appears the exception rather than the rule. There is also at least anecdotal evidence that 'retreat to subsidy' can occur, even after cost recovery has been accepted as the norm. Recent policy changes in Australia and South Korea are illustrative on this front.

In contrast, in developing countries, charges to users for irrigation generally fall well short of full cost. There are few countries charging farmers full O&M costs and many overlook capital costs completely. A number of countries continue to provide water almost exclusively as a subsidy by government (for example, Egypt, Thailand, and Vietnam). The review also highlights relationships between the significance of irrigated agriculture, the priority of government policies and the willingness to support farmers. The issue of food security also appears to play a role in shaping the attitude of governments to irrigation, although, as noted in the review of the developed world, 'food security' is itself ill-defined.

It can also be concluded from Table 1 that there is no geographic pattern around the level of cost recovery for irrigation. This is true even among EU member states despite the influence of the WFD. This supports the view that a range of national influences continued to influence the deployment of policy. There are also factors influencing irrigation policies that are embedded within socio-economic, cultural, and political characteristics of the countries. In some cases, the extant policy is the result of a legacy of policy decisions taken in earlier phases of history, illustrating the importance of path dependencies in this domain. Once prices are subsidized, a great deal of political will is required to shift to cost recovery.

Notwithstanding the ongoing government support outlined in Table 1, in general, the level of subsidy to the irrigation sector has declined over the last two decades, direct subsidies are increasingly being replaced by indirect subsidies and less production support is apparent (Daniel and Kilkenny 2009). The reduction in price support lessens the impact on farmer production choices and is arguably more efficient. However, the pervasive influence of price distortions in this context remains with the irrigation sector generally using more water than is socially optimal.

Table 1 Cost components of charges and subsidies in irrigation water of selected countries in different regions

Region/country	Pricing agency	Components of irrigation water costs charged				Subsidies	References
		O&M costs	Capital costs	Resource costs	Environmental costs		
Developed countries							
North America region							
United States	State agencies	All	All	No	No	None[a]	Ward (2010); Wichelns (2010)
Canada	Government agencies	All	Part	No	No	Part of capital costs	Renzetti and Dupont (2015); OECD (2008)
European region							
Croatia	Government agencies	Part	No	Yes	Yes	Part of O&M, all capital costs	Berbel et al. (2007)
France	Basin authorities	All	Part	Yes	No	Part of capital costs	Montginoul et al. (2015); Brelle and Dressayre (2014)
Greece	Government agencies	All	Part	Yes	Yes	Part of capital costs	Garrido and Calatrava (2010)
Italy	Public agencies	Most	Part	No	No	Part of capital costs	Massarutto (2015); Garrido and Calatrava (2010)
Portugal	Public agencies	Most	Small part	Yes	Yes	Most of capital costs[b]	Garrido and Calatrava (2010)
Spain	Basin authority and irrigation districts	All	Part	No	No	Part of capital costs	(Calatrava et al. 2015); EEA (2013)
UK	Regions	All	All	Yes	Yes	None	OECD (2008); Berbel et al. (2007)
Oceania region							
Australia	Rural water businesses	All	Part	Yes	No	Part of capital costs	Parker and Speed (2010)
New Zealand	Irrigation companies	All	All	No	No	None	Jenkins (2015); OECD (2008)
East Asia region							
Japan	Land improvement districts	All	Part	No	No	Part of capital costs	

Table 1 (continued)

Region/country	Pricing agency	Components of irrigation water costs charged				Subsidies	References
		O&M costs	Capital costs	Resource costs	Environmental costs		
							Nickum and Ogura (2010); Shobayashi et al. (2010)
Korea	Exempt from charges	No	No	No	No	Subsidies all to farmers	Nickum and Ogura (2010)
Developing countries							
Latin America region							
Chile	Public agencies	All	Part	Yes	No	Part of capital costs	Donoso (2015); Palerm-Viqueira (2010)
Mexico	Water Commission	All	No	No	No	Capital costs	Guerrero-Garcia-Rojas et al. (2015); Garrido et al. (2014)
African region							
Egypt	No charges	No	No	No	No	Subsidies all to farmers	Gohar and Ward (2011); Luzi (2010)
Morocco	Regional authorities	All	Part	No	No	Part of capital costs	Faysse et al. (2010); Doukkali (2005)
South Africa	Government agencies	All	Part	No	No	Part of capital costs	Schreiner (2015); Speelman et al. (2009)
Central Asia region							
India	State agencies	Part	No	No	No	Part of O&M, all capital costs	Malik et al. (2014); Saleth and Amarasinghe (2010)
Kingdom of Jordan	Government agencies	Part	No	No	No	Part of O&M, all capital costs	Molle et al. (2008); Venot et al. (2007)
Pakistan	Provincial government	Part	No	No	-	Part of O&M, all capital costs	Bell et al. (2014); Farooqui et al. (2012)
Turkey	Water users' organisations	All	Small part	No	No	Most of capital costs	Cakmak (2010); Brezonik et al. (2008)
East and Southeast Asia region							
China	Government agencies	Part	No	No	No	Part of O&M, all capital costs	Huang et al. (2010); Webber et al. (2008)

Table 1 (continued)

Region/country	Pricing agency	Components of irrigation water costs charged				Subsidies	References
		O&M costs	Capital costs	Resource costs	Environmental costs		
Thailand	Government agencies	No	No	No	No	Subsidies all to farmers	Molle et al. (2007)
Vietnam	Government agencies	Small part	No	No	No	Most costs subsidised	François and Hoanh (2011)

[a] The state of Georgia does not charge farmers for irrigation water albeit it issues permits that allow farmers to irrigate

[b] In irrigation schemes managed by private ownership, farmers pay full supply cost of water service (this type of ownership occupying for about 75 per cent% of irrigation schemes)

The components of costs shown in the table above imply that:

- O&M costs: operation and maintenance costs
- Capital costs: replacement cost, interest costs, and major repair costs
- Resource costs: opportunity costs of alternative water uses
- Environmental costs: environmental damages due to abstraction, storage, impoundment, discharge, etc.
- Meaning and magnitude of signs: All: all element cost is charged (nearly 100 %); Most: a major part of the element cost is charged (more than 80 %); Part: a significant proportion of the cost is charged (between 20 % to 80 %); Small part: a small proportion of the cost is charged (less than 20 %); Yes: some charges are applied; No: no charges; None: no subsidies are provided

6 Issues Facing the Irrigation Sector

The ongoing existence of subsidies in the irrigation sector and the difficulties associated with winding them back have resulted in the emergence of three major issues: the shaky financial status of supplying agencies, scarcity of water, and environmental concerns. Each of these is briefly addressed.

Over the last two decades, scholars have expressed concerns about the deterioration of irrigation infrastructure (for example, see OECD 2009; Mishra et al. 2011; Brelle and Dressayre 2014). This is a consequence of inadequate funding for maintenance, rehabilitation, and replacement. In many countries, the irrigation sector fails to adequately fund O&M, since the cost recovery targets are set too low. In addition, state budgets are unable to allocate more funds because of the tightening overall fiscal constraints (Raju and Gulati 2008; Molle 2009). Commentators warn that failure to reverse this trend does not bode well for the irrigation sector and may potentially threaten food production (Raju and Gulati 2008). This is ironic insomuch as the rationale for subsidy is often premised on the notion of food security.

The presence of a subsidy often stimulates demand for water and water services, and this may potentially limit access by other users, especially in times of water shortage. Expanded recognition of resource scarcity and the potential impacts of climate change on water resource availability raise important questions about the rationality of current policies around water pricing and allocation. Nonetheless, problems persist, including the misuse and waste of irrigation water (Molle and Berkoff 2007; Molle 2009), and unsustainable water use (Ward and Pulido-Velazquez 2009). What is less clear is the mechanics of moving toward a more cost-reflective approach.

Environmental deterioration has also been attributed to a failure to account for the externality effects of irrigation (OECD 2012) embodied in low charges for water (Varela-Ortega 2007). Over-irrigation often causes run-off and increases the contamination of nitrate, phosphate and pesticide substance to rivers and aquifers, as well as expanding soil degradation through compaction and salinization. Overexploitation of water can also lead to saltwater intrusion in coastal areas and deteriorating water quality, while the excessive abstraction of groundwater could lead to the depletion of aquifers and cause negative impacts on biodiversity of water ecosystems (Fuentes 2011).

By implication, some scholars suggest applying full cost recovery of irrigation water where all environmental and resource costs should be fully compensated (see, for example, Howarth 2009; Bithas et al. 2014). The implementation of a cost recovery approach constitutes an important change in water policy that rests on the need to take into account environmental, socio-economic, and regional specific impacts. In this regard, Molle and Berkoff (2007) contend that charging for the full cost of water use is not an end in itself, but an instrument for achieving one or more policy objectives, including: ensuring water conservation, enhancing economic activity, and promoting environmental sustainability. Similarly, Bithas et al. (2014) insist that three key objectives can be achieved from a full cost recovery pricing system, involving use efficiency, resource sustainability, and social equity/justice.

7 Concluding Remarks

The hypothesis formulated at the commencement of this review was that progress towards full cost recovery was likely to be evident in developed countries with established institutions.

However, this hypothesis has weak support, at best. There is no evidence of a systematic pattern, and water policies in different countries appear to be driven by a range of factors, such as socio-economic, cultural, political drivers, and even the history of earlier policies. The context of complex and extensive water regulation also influenced the formulation of these policies (Cabezas 2012), and the appetite for pricing reform undoubtedly changes between states and over time. The application of full cost recovery is heavily influenced by context, so that even in developed countries, it is very difficult to generalize.

Theoretically at least, full cost recovery for irrigation water includes three main components: supply cost, resource cost, and environmental cost. Capturing the costs of each component arguably leads to more sustainable development and subsidies tend to shift behavior in the opposite direction. Overwhelmingly, the economic literature cautions against the provision of subsidies in the form currently witnessed in irrigation. This would imply benefits from the imposition of a price regime to ensure that the activities themselves are financially viable, that there is wider economic efficiency, and to ensure environmental protection. What is less clear is the process by which such subsidies might be reduced or limited. One option would be to explore the conceptualization of public and private benefits from the perspective of water users, and then assess the costs of modifying the attitudes of the citizenry to better align with the economic classification of benefits. Put differently, if the citizenry comes to expect that water is a private good then the case for subsidy from the public purse is weakened and the scope for full cost recovery practice is improved. This is particularly challenging in the developing world.

One of the major challenges with irrigation generally, and particularly in the developing world, is 'how do we get farmers to pay the costs associated with water and water delivery'. The literature published in this field deals with issues such as '...how to implement the price policy, and how high to raise the prices' (Rogers et al. 2002, p. 16) or how water should be priced for agricultural use (see Ward 2010). This has led to a heavy focus on cost and supply but there has been much less attention to the process of developing and imposing acceptable price regimes. What farmers will actually pay for, especially with regards to various cost components of irrigation water (i.e., O&M costs, capital costs, resource cost, and environmental costs), and the contextual and behavioral factors that shape these attitudes, are largely unexplored and deserving of further research. Farmers' and landholders' motivations are recognised as an important factor in this context (Toan et al. 2015) but other variables are also likely to be important.

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References

Bartolini F, Bazzani GM, Gallerani V, Raggi M, Viaggi D (2007) The impact of water and agriculture policy scenarios on irrigated farming Systems in Italy: an analysis based on farm level multi-attribute linear programming models. Agric Syst 93:90–114. doi:10.1016/j.agsy.2006.04.006

Bartolini F, Gallerani V, Raggi M, Viaggi D (2010) Water management and irrigated agriculture in Italy: Multicriteria analysis of alternative policy scenarios. Water Policy 12:135–147

Bell AR, Shah MAA, Ward PS (2014) Reimagining Cost Recovery in Pakistan's Irrigation System through Willingness-to-pay Estimates for Irrigation Water from a Discrete Choice Experiment, Water Resour Res 50: 6679–6695 doi:10.1002/2014wr015704

Berbel J, Jómez-Limón JA (2000) The impact of water-pricing policy in Spain: an analysis of three areas. Agric Water Manag 43:219–238
Berbel J, Calatrava J, Garrido A (2007) Water pricing and irrigation: a review of the European experience. In: Molle F, Berkoff J (eds) Irrigation water pricing: the gap between theory and practice. CABI, Oxford, pp. 295–327
Bithas K (2011) Sustainability and externalities: is the internalization of externalities a sufficient condition for sustainability? Ecol Econ 70:1703–1706. doi:10.1016/j.ecolecon.2011.05.014
Bithas K, Kollimenakis A, Maroulis G, Stylianidou Z (2014) The water framework directive in Greece. Estimating the environmental and resource cost in the water districts of western and Central Macedonia: methods, results and proposals for water pricing. Procedia Econ Finance 8:73–82. doi:10.1016/S2212-5671(14)00065-3
Brelle F, Dressayre E (2014) Financing irrigation. Irrig Drain 63:199–211. doi:10.1002/ird.1836
Brezonik PL, Stefan HG, Dadaser-Celik F (2008) Agricultural and environmental changes after irrigation management transfer in the Develi Basin, Turkey. Irrig Drain Syst 22:47–66
Brugge R, Rotmans J (2007) Towards Transition Management of European Water Resources. Water Resources Management 21:249–267. doi:10.1007/s11269-006-9052-0
Cabezas F (2012) The European water framework directive: a framework? Int J Water Resour Dev 28:19–26
Cakmak EH (2010) Agricultural water pricing: Turkey. OECD Publishing, Paris
Calatrava J, García-Valiñas M, Garrido A, González-Gómez F (2015) Water pricing in Spain: following the footsteps of somber climate change projections. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 313–340
Daniel K, Kilkenny M (2009) Agricultural subsidies and rural development. Agric Econ 60:504–529. doi:10.1111/j.1477-9552.2009.00214.x
Dinar A, Mody J (2004) Irrigation water management policies: allocation and pricing principles and implementation experience. Nat Res Forum 28:112–122. doi:10.1111/j.1477-8947.2004.00078.x
Dinar A, Subramanian A (1997) Water Pricing Experiences: An International Perspective. Technical Paper No. 386. The World Bank. 164 Pages
Dinar A, Pochat V, Albiac-Murillo J (2015) Introduction. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 1–12
Donoso G (2015) Water pricing in chile: decentralization and market reforms. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 83–96
Doukkali MR (2005) Water institutional reforms in Morocco. Water Policy 7:71–88
Dwyer T (2006) Urban water policy: in need of economics. Agenda 13:3–16
Easter KW, Liu Y (2005) Cost Recovery and Water Pricing for Irrigation and Drainage Projects. The World Bank
EEA (2013) Assessment of Cost Recovery through Water Pricing. Technical Report No 16/2013. European Environment Agency. 123 Pages
Fan SG, Gulati A, Thorat S (2008) Investment, subsidies, and pro-poor growth in rural India. Agric Econ 39:163–170. doi:10.1111/j.1574-0862.2008.00328.x
FAO (2012) Coping with Water Scarcity: An Action Framework for Agriculture and Food Security. FAO Water Report 38. Food and Agriculture Organisation of the United Nations. 61 Pages
FAO (2015) Towards a Water and Food Secure Future: Critical Perspectives for Policy-makers. White Paper. Food and Agriculture Organisation of the United Nations. 61 Pages
Farooqui AZ, Zubair A, Tariq AA, Hassan S (2012) Pricing Irrigation Water in Pakistan: Issues and Prospects. DPRC Senior Project Research Series. 41 Pages
Faysse N, Errahj M, Kuper M, Mahdi M (2010) Learning to voice? The evolving roles of family farmers in the coordination of large-scale irrigation schemes in Morocco. Water Alternatives 3:48–67
François M, Hoanh CT (2011) Implementing Integrated River basin Management in the Red River Basin, Vietnam: a solution looking for a problem? Water Policy 13:518–534
Fuentes A (2011) Policies towards a Sustainable Use of Water in Spain. OECD Economics Department Working Papers No. 840, Organisation for Economic Co-operation and Development. 30 Pages
Garrido A, Calatrava J (2010) Agricultural water pricing: EU and Mexico. OECD Publishing, Paris
Garrido A, Iglesias A (2011) Lessons for Spain: a critical assessment of the role of science and society. In: Garrido A, Ingram H (eds) Water for Food in a Changing World. Routledge, London
Garrido A, Donoso G, Melo O, Solanes M (2014) Economic instruments for allocating water and financing services. In: Willaarts BA, Garrido A, Llamas MR (eds) Water for food and Wellbeing in Latin America and the Caribbean. social and environmental implications for a globalized economy. Routledge, New York, pp. 343–364
Gilboa Y, Gal G, Markel D, Rimmer A, Evans BM, Friedler E (2015) Effect of Land-use Change Scenarios on Nutrients and TSS Loads. Environ Processes 2:593–607
Gohar AA, Ward FA (2011) Gains from improved irrigation water use efficiency in Egypt. Int J Water Resour Dev 27:737–758

Gómez-Limón JA, Riesgo L (2004a) Irrigation water pricing: differential impacts on irrigated farms. Agric Econ 31:47–66
Gómez-Limón JA, Riesgo L (2004b) Water pricing: analysis of differential impacts on heterogeneous farmers. Water Resour Res 40:W07S05
Guerrero-Garcia-Rojas H, Gómez-Sántiz F, Rodríguez-Velázquez JR (2015) Water Pricing in Mexico: Pricing Structures and Implications. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 231–247
Guse B, Pfannerstill M, Fohrer N (2015) Dynamic Modelling of Land Use Change Impacts on Nitrate Loads in Rivers. Environ Processes 2:575–592
Hansjürgens B (2016) Theory, the market and the state: agricultural reforms in post Socialist Uzbekistan between economic incentives and institutional obstacles. In: Hüttl RF, Bens O, Bismuth C, Hoechstetter S (eds) Society - water - technology: A critical appraisal of major water engineering projects. water resources development and management. Springer International Publishing, New York, pp. 169–186. doi:10.1007/978-3-319-18971-0_12
Howarth W (2009) Cost Recovery for Water Services and the Polluter Pays Principle. In: ERA Forum, Springer, vol 4. pp 565–587. doi:10.1007/s12027-009-0134-3
Huang Q, Rozelle S, Howitt R, Wang J, Huang J (2010) Irrigation water demand and implications for water pricing policy in rural China. Environ Dev Econ 15:293–319
Hussain I (2007) Poverty-reducing impacts of irrigation: evidence and lessons. Irrig Drain 56:147–164. doi:10.1002/ird.298
Jenkins B (2015) New Zealand water pricing. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 263–288
Johansson RC, Tsur Y, Roe TL, Doukkali R, Dinar A (2002) Pricing irrigation water: a review of theory and practice. Water Policy 4:173–199. doi:10.1016/s1366-7017(02)00026-0
Luzi S (2010) Driving forces and patterns of water policy making in Egypt. Water Policy 12:92–113
Malik RP, Prathapar S, Marwah M (2014) Revitalizing Canal Irrigation: Towards Improving Cost Recovery. International Water Management Institute. Working Paper 160. 42 Pages
Manos B, Bournaris T, Kamruzzaman M, Begum M, Anjuman A, Papathanasiou J (2006) Regional impact of irrigation water pricing in Greece under alternative scenarios of European policy: a Multicriteria analysis. Reg Stud 40:1055–1068
Massarutto A (2015) Water pricing in Italy: beyond full-cost recovery. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 201–230
Mishra A, Ghosh S, Nanda P, Kumar A (2011) Assessing the impact of rehabilitation and irrigation management transfer in minor irrigation projects in Orissa, India: a case study. Irrig Drain 60:42–56
Molle F (2007) Thailand's 'free water': rationale for a water charge and policy shifts. In: Molle F, Berkoff J (eds) Irrigation water pricing: the gap between theory and practice. CABI, Oxford, pp. 126–142
Molle F (2009) Water scarcity, prices and quotas: a review of evidence on irrigation volumetric pricing. Irrig Drain Syst 23:43–58
Molle F, Berkoff J (2007) Water pricing in irrigation: mapping the debate in the light of experience. In: Molle F, Berkoff J (eds) Irrigation Water Pricing: The Gap between Theory and Practice. CABI, Oxford, pp. 21–93
Molle F, Venot J-P, Hassan Y (2008) Irrigation in the Jordan Valley: are water pricing policies overly optimistic? Agric Water Manag 95:427–438. doi:10.1016/j.agwat.2007.11.005
Montginoul M, Loubier S, Barraqué B, Agenais A-L (2015) Water pricing in france: toward more incentives to conserve water. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 139–160
National Irrigators' Council (2010) Submission to the 'guide to the proposed murray-darling basin plan'. NIC, Canberra
Nickum JE, Ogura C (2010) Agricultural water pricing: Japan and Korea. OECD Publishing, Paris
Oakland WH (1987) Theory of public goods. In: Auerbach AJ, Feldstein M (eds) Handbook of public economics, vol II. Elsevier, North-Holland
OECD (2003) Environmentally Harmful Subsidies: Policy Issues and Challenges. Proceedings of the Workshop on Environmentally Harmful Subsidies in November 2002. Organisation for Economic Co-operation and Development. 217 Pages
OECD (2005) Environmentally harmful subsidies: challenges for reform. OECD Publishing, Paris
OECD (2008) Water Resources in Agriculture: Outlook and Policy Issues. OECD. http://www.oecd.org/dataoecd/15/16/48498988.pdf. Accessed 20 May 2015
OECD (2009) Managing water for all: an OECD perspective on pricing and Financing. OECD Publishing, Paris
OECD (2012) Water quality and agriculture: meeting the policy challenge. OECD Publishing, Paris
Palerm-Viqueira J (2010) A comparative history, from the 16th to 20th centuries, of irrigation water Management in Spain, Mexico, Chile, Mendoza (Argentina) and Peru. Water Policy 12:779–797

Parker S, Speed R (2010) Agricultural water pricing: australia. OECD Publishing, Paris
Pawsey N, Crase L (2012) The mystique of urban water pricing and accounting: the case of water tariffs in Victoria, Australia. Econ Pap 32:328–339
Raju K, Gulati A (2008) Pricing, Subsidies and Institutional Reforms in Indian Irrigation: Some Emerging Trends. In: Ballabh V (ed) Governance of Water: Institutional Alternatives and Political Economy. Sage, New Delhi, pp. 79–99
Reddy VR (2009) Water Pricing as a Demand Management Option: Potentials, Problems and Prospects. In: Saleth M (ed) Strategic Analyses of the National River Linking Project of India. International Water Management Institute, Colombo, pp. 25–46
Renzetti S, Dupont DP (2015) Water pricing in Canada: recent developments. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 63–81
Ribaudo MO (2009) Non-point pollution regulation approaches in the US. In: Albiac J, Dinar A (eds) The management of water quality and irrigation technologies. Earthscan, London
Rogers P, Bhatia R, Huber A (1998) Water as a Social and Economic Good: How to Put the Principle into Practice. Global Water Partnership. TAC Background Paper No. 2. 35 Pages
Rogers P, Rd S, Bhatia R (2002) Water is an economic good: how to use prices to promote equity. Efficiency, and Sustainability, Water Policy 4:1–17
Saleth RM, Amarasinghe UA (2010) Promoting irrigation demand Management in India: options, linkages and strategy. Water Policy 12:832–850
Saleth RM, Dinar A (2004) The institutional economics of water: a cross-country analysis of institutions and performance. Edward Elgar, Cheltenham
Scheierling SM, Young RA, Cardon GE (2006) Public subsidies for water-conserving irrigation investments: hydrologic, agronomic, and economic assessment. Water Resour Res 42:1–11. doi:10.1029/2004wr003809
Schmid E, Sinabell F, Hofreither MF (2007) Phasing out of environmentally harmful subsidies: consequences of the 2003 CAP reform. Ecol Econ 60:596–604. doi:10.1016/j.ecolecon.2005.12.017
Schreiner B (2015) Water pricing: the case of South Africa. In: Dinar A, Pochat V, Albiac-Murillo J (eds) Water pricing experiences and innovations. Springer, Dordrecht, pp. 289–311
Shobayashi M, Kinoshita Y, Takeda M (2010) Issues and options relating to sustainable Management of Irrigation Water in Japan: a conceptual discussion. Int J Water Resour Dev 26:351–364
Speelman S, Buysse J, Farolfi S, Frija A, D'Haese M, D'Haese L (2009) Estimating the impacts of water pricing on smallholder irrigators in north West Province, South Africa. Agric Water Manag 96:1560–1566
Tardieu H (2005) Irrigation and drainage services: some principles and issues towards sustainability an ICID position paper. Irrig Drain 54:251–262. doi:10.1002/ird.172
Thiam DR, Muchapondwa E, Kirsten J, Bourblanc M (2015) Implications of water policy reforms for agricultural productivity in South Africa: scenario analysis based on the Olifants River basin. Water Resour Econ 9: 60–79. doi:10.1016/j.wre.2014.11.001
Tiwari D, Dinar A (2002) Role and Use of Economic Incentives in Irrigated Agriculture. Working Paper. The World Bank, Washington, D.C. 69 Pages
Toan TD, O'Keefe S, Crase L (2015) Farmer heterogeneity and water pricing reform: a case study from Vietnam. Int J Water Resour Dev:1–17. doi:10.1080/07900627.2015.1085368
Tsur Y (2005) Economic aspects of irrigation water pricing. Can Water Resour J 30:31–46. doi:10.4296/cwrj300131
Tsur Y, Dinar A (1995) Efficiency and Equity Considerations in Pricing and Allocating Irrigation Water. Policy Research Working Paper 1460. The World Bank. 40 Pages
Tsur Y, Dinar A (1997) The relative efficiency and implementation costs of alternative methods for pricing irrigation water. World Bank Econ Rev 11:243–262
Tsur Y, Dinar A, Doukkali RM, Roe T (2004) Irrigation water pricing: policy implications based on international comparison. Environ Dev Econ 9:735–755
United Nations (2003) Water for people, water for life. UNESCO Publishing, Paris
van den Bergh JCJM (2010) Externality or sustainability economics? Ecol Econ 69:2047–2052. doi:10.1016/j.ecolecon.2010.02.009
Varela-Ortega C (2007) Policy-driven determinants of irrigation development and environmental sustainability: a case study in Spain. In: Molle F, Berkoff J (eds) Irrigation Water Pricing: The Gap between Theory and Practice. CABI, Oxford, pp. 328–346
Varis O, Abu-Zeid K (2009) Socio-economic and environmental aspects of water management in the twenty-first century: trends, challenges and prospects for the MENA region. Int J Water Resour Dev 25:507–522. doi:10.1080/07900620902972679
Venot JP, Molle F, Hassan J (2007) Wells and canals in Jordan: can pricing policies regulate irrigation water use? In: Molle F, Berkoff J (eds) Irrigation water pricing: the gap between theory and practice. CABI, Oxford, p. 1
Ward FA (2010) Financing irrigation water management and infrastructure: a review. Int J Water Resour Dev 26: 321–349. doi:10.1080/07900627.2010.489308

Ward FA, Pulido-Velazquez M (2009) Incentive pricing and cost recovery at the basin scale. Environ Manag 90: 293–313. doi:10.1016/j.jenvman.2007.09.009

Webber M, Barnett J, Finlayson B, Wang M (2008) Pricing China's irrigation water. Glob Environ Chang 18: 617–625. doi:10.1016/j.gloenvcha.2008.07.014

Wichelns D (2010) Agricultural water pricing: United States. OECD Publishing, Paris

Wilder M, Lankao RP (2006) Paradoxes of decentralization: water reform and social implications in Mexico. World Dev 34:1977–1995. doi:10.1016/j.worlddev.2005.11.026