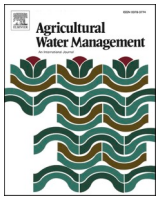
Agricultural Water Management 260 (2022) 107284

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat



Irrigation subsidies and their externalities

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ARTICLE INFO

Keywords:
Externalities
Market failure
Reform
Social objectives
Subsidies

ABSTRACT

Subsidising irrigation is a legitimate approach that governments have used to achieve a set of social objectives. Yet it may simultaneously impose negative externalities, especially in the form of environment degradation. Could subsidies be reformed to be less harmful? To answer this question requires an insight into how various kinds of subsidies work, the interplay between subsidies and externalities, and the political complexity of subsidy reform. In this paper these insights are investigated using supply-demand graphs. It is argued in this paper that a broad definition of subsidies should be used, one that includes the implicit subsidies that result from partial cost recovery. It is also shown that even without subsidies, externalities due to irrigation would still exist and that any reform of existing subsidies will counter the positive impact irrigation may have, which may not be a desirable outcome.

1. Introduction

Irrigated agriculture, by far the largest consumptive user of water globally, is a heavily subsidized sector. The establishment, operation and maintenance of many irrigation schemes have by-and-large been subsidized by governments, development banks and donor agencies. In addition, governments subsidise the agricultural sector in general, increasing the price of the goods produced from irrigation water, and/or reducing the costs of the inputs. All these actions by governments are either direct subsidies to irrigation or general interventions that happen to affect irrigation.

There is no universally accepted definition of a subsidy. The OECD (2005) p. 16] defines subsidies as: "A result of a government action that confers an advantage on consumers or producers". It includes on-budget subsidies, which appear on the national accounts as government expenditures such as direct cash transfers, low interest or reduced rate loans. It also includes off-budget subsidies, which comprise indirect subsidies such as tax exemptions and rebates, preferential market access, limited liabilities, and accelerated depreciation allowances. The above definition could be broadened to also include a lack of full-cost pricing.[1]

The imposition of subsidies is seen as a beneficial act by some. People like the cheaper food that can result. Irrigators invest on the basis of the existing subsidies needing to profit from their investment. Those who provide the inputs to the irrigation sector and services that are derived from it get to sell more from a subsidised industry than one that is not. However, subsidies can also add to and encourage the environmental destruction associated large scale irrigation. Many of these beneficial and negative impacts are externalities; those that are not accounted for in the market system. The role of subsidies and their impacts on both positive and negative externalities needs to be explored.

Externalities, which are uncompensated spill overs and impact that result in a market, are typically not discussed with subsidies, because they are difficult to measure due to the assumptions, uncertainties and the significant economic modelling required to measure them (Honkatukia, 2002; Coady et al., 2019). The definition of subsidies also needs to include consideration of 'non-action'. In some cases, non-action, (e.g., not applying pricing to cover costs of water, not internalizing externalities), can also lead to prices not reflecting environmental and social costs and hence create implicit subsidies.

Market failures arise in the water sector due to the existence of

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[1] Taking a historical accounting approach would lead to the value of the original subsidy on infrastructure being included in an assessment of the impacts. However, if a reasonable discount factor is applied then the value would be minimal. Thus, it is more practical to take a full current account costing approach, one where only the current costs and benefits arising from a subsidy are assessed. This is the approach used by analysts who reduce subsidy reform to a pricing exercise, where prices should be equated to covering operations and maintenance and possibly future refurbishment. Thus, care should be exercised in determining whether the subsidies is placed capital, O&M and on other inputs and outputs.

https://doi.org/10.1016/j.agwat.2021.107284
Received 21 April 2021; Received in revised form 27 September 2021; Accepted 19 October 2021
Available online 30 October 2021

externalities and the open access nature of water which leads to the tragedy of the commons, see Coase (1960). In taking a welfare economics approach to subsidies, (i.e., where the market for water is assessed using the techniques of supply and demand to assess the changes in economic surplus, etc.) would require that some form of market failure be identified before policies like subsidies are directed towards the sector. Using this approach government intervention is justified if the market is failing (where market prices do not reflect the true costs of production and consumption), however, policies should not be deployed unless the benefits of intervening outweigh the costs (Quiggin, 2019).

Subsidies in the water sector can be justified on the grounds of meeting societal objectives or coordinating and overcoming failures to invest in high fixed costs. The flow-on effects to the rest of the economy (food security, employment, preserving foreign exchange, poverty reduction, etc.) that result from irrigation are also a form of market failure if they are not accounted for in the market process. They are a positive externality.

The problem is that irrigation developments produce both positive and negative externalities simultaneously. One way of resolving this balancing act is to impose quotas on irrigators so that the water taken does not exceed the sustainable limits needed to maintain a river's environmental condition, thus minimising the negative externalities. An alternative is to impose a tax on irrigators for the environmental damage they do. Either act, i.e., imposing taxes or quotas, will in effect do the exact opposite of what a subsidy is intended to do, which is to account for the positive externalities associated with irrigation activity that leads to better social outcomes. Similarly, subsidising production as a means of correcting for the uncompensated social benefits when negative externalities are evident exacerbates the problems of environmental damage.

Another issue associated with the definition of subsidies occurs because of the way water is used. The demand for water is derived in part from the demand for the products it is used to produce, as water is an input. Taking this argument, a little further the derived demand for water is also affected by its substitute and complementary products (fertilizer, electricity, etc). What this means is that it is possible to subsidise irrigation by subsidising the products produced from water and/or by the inputs used in conjunction with water.

In practice, what 'defines' a subsidy is what one chooses as the baseline (or counterfactual), whether that is the market price/cost or the social cost (i.e., which includes the externality). While a broad definition of subsidies, including both full-cost pricing for resources and the internalization of externalities, is operationally difficult to measure, it is important to recognize that implicit subsidies also exist and that they can be quite significant.

Mostly, the environment of the catchments in which water is regulated can suffer negative externalities as subsidies to irrigation often result in greater diversions of water to agriculture. Yet, governments continue to subsidise water in order to gain a set of social objectives and benefits. These social objectives and benefits can reflect positive externalities in the water market and are a legitimate reason why governments may pay subsidies for irrigation.

The interplay between subsidies and the range of externalities that exist in the irrigation sector needs to be appreciated when evaluating their impacts. Thus, it is necessary to assess the precise impacts individual subsidies have, first by way of an audit and then eventually through a comprehensive assessment of subsidies. The impact subsidies for irrigation have on a catchment needs to be known if they are ever to be reformed or abolished. Even if this is not the objective, just knowing the full impact a subsidy has is informative for future policy direction. While the physical measurement of an externality may well exist, a far greater problem lies in placing an economic value on them. Thus, a dilemma that policy makers in the water sector need to resolve when thinking about removing subsidies, is whether the benefits gained from reducing negative externalities is worth the losses that accrue when accounting for the positive externalities. It could therefore be asked whether, and how, subsidies could be reformed to be less harmful. Further, it must be asked if it is even possible to reform current subsidy regimes. In this paper the difficulties in reforming subsidies in irrigation and the success factors that may provide lessons learnt for policy reform in other countries are highlighted.

To be able to address these questions, some insight is required into the various kinds of irrigation subsidies that exist and how they work. This is undertaken when the subsidies are classified (in Section 2) and with the supply-demand diagrams (in the Annex). The interplay between irrigation subsidies and externalities (Section 3) and the political complexity of subsidy reform (Section 5) are also presented. The aim of this paper is to identify, classify and expose the wide-ranging nature of irrigation subsidies in such a way that policy makers become aware of the full costs and benefits of them. The likely impacts irrigation subsidies may have on the environment and socially are discussed. Finally, some examples of countries who have attempted to reform their subsidies are presented, highlighting difficulties that they have experienced.

2. Classifying subsidies

Subsidies to any sector come in a variety of ways (a distinction will be made between subsidies that affect irrigation and agriculture), several which are not at first obvious, through shifting any of the supply schedules in a market associated with the good in question. The way various kinds of subsidies work (their impact on the input and the output market) is explained in Annex A using basic supply and demand schedule diagrams. Fig. A1 shows that implementing a subsidy for the good can be done per unit supply of the good (as an ad valorem subsidy) and a subsidy can be paid as a 'lump-sum'. Fig. A2 shows that implementing a subsidy on the input reduces the production costs of the output. Fig. A3 shows that a subsidy to an output will also have an impact on the input market. Whether subsidies will affect in practice the market-clearing price of water depend on whether there is a water market in place. Water is rarely marketed and hence a market clearing price rarely exists. Hence, the price is often below the market price (which is a subsidy).

At this juncture there is a need to ascertain the role of prices, as they exist in the economic concepts associated with a free market and as they do not appear to exist in the not-so-free water market. To an economist a price exists where supply and demand interact to clear a market. This could be called the free-market price as it is the price at which the market is at its most efficient, distributing resources in its most efficient manner. It could be thought of as some theoretical and unrealistic nicety, but in reality, it important as it is the reference point upon which the actual prices and the existing market outcomes can be compared. Once prices are fixed, or not paid, or a subsidy is imposed, or an externality exists, the price 'observed' in the market will bear no resemblance to this market price. While these two prices are different, it does not mean that either of them is irrelevant. Rather, the difference between the two it becomes most important as the difference reveals the discrepancy between the subsidised externality affected market that currently exists and what could exist in an efficient market. To suggest that any theoretical efficient market price should be ignored in favour of a realistic observed and in some cases non-existent price misses a very fundamental point and renders any assessment of the impacts of subsidies and externalities meaningless and incomparable.

An easy way of segregating subsidies is to isolate them by where they are imposed. A benefit of this approach, whether they are either ad valorem or lump-sum, is that at this level they are usually quite transparent. Using this approach, the subsidies to the water sector can be classified as those that assist the:

1. **Direct fixed costs of irrigation**, like the capital needed to build and drain the systems. These subsidies tend to be of a lump sum type (see Q_{s2} in Fig. A1). Examples of these are those that contribute to the

building of infrastructure, which will increase the supply of water and hence reduce the prices of produce;

2. **Direct variable costs of irrigation**, like assistance with the cost of pumping. They tend to be ad valorem subsidies (see Q_{s3} in Fig. A1). Examples of these are the assistance governments provide irrigators by not collecting the full charges for operations and maintenance. They cause the water supply schedule to fall;
3. **Indirect variable costs of other inputs**, those subsidies on the inputs to the production process other than water, like fertilizer and fuel. These subsidies tend to shift the input supply for water schedule downward; The impact of subsidising the input is in theory to reduce the price of the finished good (provided the price of water is market determined) and increasing its output (see Q_{sw1} in Fig. A2);
4. **Direct outputs**, provided to raise the prices irrigators receive for the crops they produce, shifting the output supply schedule outward (to Q_{sf1} in Fig. A3); and
5. **Indirect outputs** (other uses of water) provided for dual-purpose systems, those that also produce electricity, flood mitigation, etc. These subsidies are sometimes known as cross-subsidies. Subsidies that encourage water savings that can be used in other sectors could be included herein, as they are targeted to another legitimate user of water, i.e., the environment.

Classifying subsidies in this way allows for a more structured approach to the problem and can result in the tabulation of the aims, irrigator behaviour responses to potential reforms, social and environmental impacts, etc. of each subsidy grouping. While most (if not all) subsidies result in a reduction in the price of water and a concomitant increase in the quantity used, the impacts on participants in the irrigation sector are different. In addition, the fiscal cost and dead weight social losses that arise from subsidies will differ with the type imposed, and depend largely, but not exclusively, on the own-price elasticity of demand for water. By definition the own-price elasticity of demand for water is a measure of the responsiveness of the quantity demanded to a change in the price. As irrigators use water to produce a range of products, each product will have a different own-price elasticity of demand. Whether the quantity demanded will respond to the price depends on whether the price of water is market-determined and price elastic.

3. Socioeconomic and environmental externalities of irrigation

Looking beyond the impacts subsidies for irrigation may have on the sector, there is a need to examine the wider relationships they may have with society as a whole and on the environment. This is required because desirable impacts on society are the usual rationale for imposing subsidies in the first place, while the negative social and environmental impacts have become the rationale for reforming subsidies.

3.1. Socioeconomic

Food self-sufficiency is an important reason for countries to subsidizing irrigation. However, increasing food production is not the only reason for subsidizing irrigation. Countries have a variety of reasons for subsidizing irrigation. Other reasons may well include improving the economic and social well-being of the rural population, stabilising rural regions, regional growth, the need to gain political support, etc. However, changing land-use and water use patterns may also have negative impacts on the social and economic structure of the project area. Small plots, communal land use rights, and conflicting traditional and legal land rights all create difficulties when land is converted to irrigate agriculture. Land tenure/ownership patterns can be disrupted by major rehabilitation works, as well as when a new irrigation project is established. Similar problems arise as a result of changes to rights to water. Increased inequity in opportunity often results from changing land use and/or water use patterns. Irrigation projects also tend to lead to changes to the demographic and ethnic composition, either because of the increased production of the area or because they are part of a resettlement project. Equavoen and Tesfai (2012) have argued that the introduction or formalizing of irrigation is likely to affect men and women, ethnic groups and social classes unequally. Groups that use common land to make their living or fulfil their household duties may be disadvantaged if that same land is taken over for irrigated agriculture or for building irrigation infrastructure. Women, migrants groups and poorer social classes have often lost access to resources and gained increased workloads. Conversely, the increased income and improved nutrition from irrigated agriculture may benefit women and children in particular.

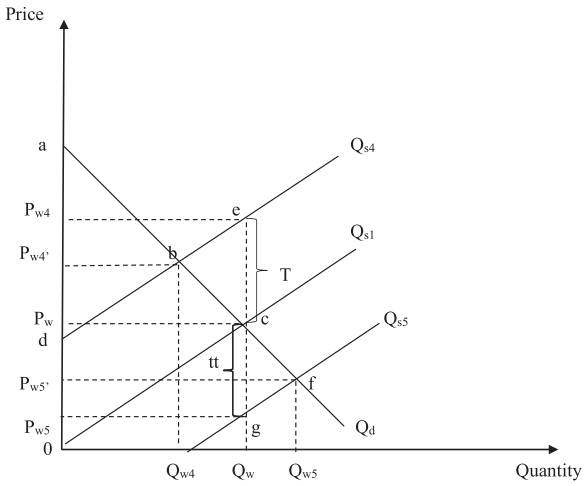

Fig. 1. The simple view of supply-side negative and positive externalities.

3.2. Environment

A major environmental impact of irrigation is represented by the spatial and temporal changes that occur to the flows of water. Changes in the seasonality of the flows due to irrigation can have various impacts on the environment. Changing the flow of a river will not only affect the timing and the amount of water involved, but also what is carried within that flow. In particular, the flow of sediment carried in a river is greatly affected if water courses are interrupted by dams and weirs, diverted by levies and sluiced through canals. The carriage of sediment is critical to the formation of rivers. In the upper reaches of a river where the water flows quickly, sediment is gouged from the banks, carried through the middle stages and eventually deposited when it slows down towards the mouth. Hence changes in the flow will alter the geomorphology of the river and the vegetation in rivers and on its banks. It can adversely affect the ecological system and hence native species that live along rivers. It can lead to river closure and may cause seawater intrusion and the destruction of estuarine environments. Irrigation can lead to a built up of salts in the soil and drainage will be needed to flush out the salts in the soil. Drainage is often subsidized as well. Drainage can also help the environment as the salt drained away into a salt pan does not enter a river. If irrigation only exists because it is subsidised, then all the impacts that arise from irrigation on the environment can be attributed to the subsidy, which is usually not the case.

3.3. The interplay between subsidies and externalities

The interplay between subsidies and externalities is best described in diagrammatic form (see Fig. 1). If the observed supply schedule in a market is shown as Q_{s1}, then if externalities exist, this schedule will not account for all the costs of supplying the good in the market. If there is (say) an environmental cost to the supply of the good, then the true costs of the good would be higher and the true supply curve would be Q_{s4} (in

Fig. 1). The difference between the two supply curves (Q_{s1} and Q_{s4}) is the external cost of producing the good which is not accounted for in the market. At equilibrium, where Q_w of the good is traded at price P_w, the external cost is equivalent to T (in Fig. 1). In such circumstances the market price of water (P_w) is lower than the socially acceptable price ($P_{w4'}$) and the quantity used in the market is also greater (by the difference between Q_w and Q_{w4}). The impact on the economic surplus is to increase it from abd to ac0, an increase of dbc0, shared between producers and consumers. The deadweight social loss from ignoring this negative externality is equal to the area bec (all in Fig. 1).

A positive supply induced externality works in the opposite direction. The true social supply schedule (the one that accounts for all the unaccounted-for benefits of production) is shown by Q_{s5} (in Fig. 1), while the market supply schedule is shown as Q_{s1}. The difference between Q_{s1} and Q_{s5} (equal to tt in Fig. 1) is the uncompensated spill overs associated with producing the good. With a positive externality the price in the market (P_w in Fig. 1) is higher than that which would exist in the market without the externality ($P_{w5'}$) and the quantity traded is lower by the difference between Q_{w5} and Q_w. The amount of economic surplus foregone in this case is equal to 0cfQ_{w4} (in Fig. 1) and the deadweight social loss is equal to the area cgf.

There are two suggested solutions to the existence of an externality. The first is to take a 'Coaseian' approach to the problem, which in essence fixes the quantity of the good at the socially optimal level (Q_{w4} in the case of a negative externality or Q_{w5} in the case of a positive externality). Participants in the market then bid for the set quantity supplied, resulting in the appropriate price prevailing. An alternative approach to the problem is to 'internalise the externality'. With a negative externality policy makers impose a tax on the good equal to the external cost (T in Fig. 1). That level of tax places market participants on the higher supply schedule (Q_{s4}), resulting in prices rising (to $P_{w4'}$) and the quantity traded falling (to Q_{w4}). In the case of a positive externality policy makers do the opposite, impose a subsidy (equal to tt in Fig. 1). That is equal to placing participants on the true social supply schedule (Q_{s5}), with prices falling (to $P_{w5'}$) and the quantities rising (to Q_{w5}).

The problem for policy makers in the water sector is that both positive and negative externalities exist together. The policy solution to one (a subsidy or a tax) is directly contrary to the other. So as subsidies are paid to account for the positive externalities, the impacts of the negative externalities (on pollution) become worse. Alternatively, reforming (removing) subsidies to the water sector may well exacerbate the undersupply of positive externalities evident in the market.

4. The political economy of irrigation subsidies reform

Many analysts have researched the irrigation subsidy reform process. Most literature focuses on the full-cost recovery approach, aiming for full recovery of the capital and O&M costs while conveniently ignoring the subsidies for the environmental and the social costs of irrigation. The OECD (2012) and Fuentes (2011) both raise the concern that adverse environmental externalities have resulted from not recovering costs. Wichelns (2010) makes the link between the lack of full-cost pricing being a subsidy, whereas Molle and Berkoff (2007) p. 21] suggest that "charging for water use or disposal is not an end in itself, but an instrument for achieving one or more policy objectives", including water conservation, enhancing economic activity and promoting environmental sustainability. Barraqué and Montginoul (2015) discuss how to integrate social objectives into water pricing with social tariffs. While their work centred on residential water use, what they found applies equally to irrigation water.

Reforming and removing subsidies from the irrigation sector is a difficult process, due to strong opposition from pressure groups, such as landowners, farmers lobby organisations, electricity and supply companies, and fertiliser producers. According to the OECD (2009) the main barrier to the reform of 'harmful' subsidies has been the resistance by vested interests and the associated difficulty of gaining political support to push for changes. Subsidy reforms are often politically costly; politicians are rarely willing to campaign to seek a popular mandate for a policy change for the common good, especially when water-consuming farmers have important electoral power (Alkon and Urpelainen, 2018; Toan, 2016). Moreover, the public has little interest in supporting the reforms because the cost of agricultural and water subsidies is very thinly spread among taxpayers and not always transparently communicated, while the benefits of the subsidy are visible and concentrated in the hands of a small group who can more easily organise and lobby for the status quo (OECD, 2007). The three main policy options for subsidy reform that exist are the complete elimination of the subsidy, the gradual reduction of the amount of subsidies, or decoupling the subsidies from production (Dinar, 2018).

The removal of a subsidy is likely to be perceived as the withdrawal of an entitled benefit, thereby generating great resistance which may require additional compensation and increased effort to ensure farmers' buy in to the idea. In specific cases, transitory and time-bound compensation may be necessary to assist with the structural change and overcome resistance, but it needs to be carefully designed when used to ease the subsidy reform process. Lump-sum decoupled payments enable farmers to retain the same welfare (farmers are given a cash transfer of an equivalent amount of the subsidy) while the new price provides an incentive to undertake changes in water consumption (change in crop patterns, reduction of irrigated area, adoption of water saving-technologies) (Ávila et al., 2005). However, whether this will result in an improved environmental outcome is extremely dubious. There is enough work undertaken on the Jevons Paradox and the rebound effects in irrigation to know that improvements in efficiency can lead to an increase in demand. Thus, this approach to subsidy reform is one that should not be recommended as it may lead to adverse outcomes.

Research and pilot studies can be used to assess realistic solutions that result in phasing out subsides that negatively impact on water resources and used to identify the optimal option (elimination, gradual removal or decoupling the subsidy) and the adequate scale and the scope of the reform.

There are several ways to make subsidy reform less sensitive. Unbundling policies so that different objectives attract different policies, for example by providing direct income support for farmer welfare instead of subsidising water, may well facilitate change. Another way is by a gradual increase in water pricing and by buying back rights given to a sector may all work better than just eliminating subsidies.

5. Discussion on approaches to reform subsidies

If the reform of subsidies is to be considered, then a few themes can be followed. First, it is necessary to recognize that nations subsidize water for a variety of reasons, and not necessarily for the sole benefit of irrigators. Second, the imposition of subsidies, and their removal, is intrinsically linked to the issue of both positive and negative externalities. Their imposition, while a possible attempt at redressing the uncompensated effects of societal needs, also enhances the uncompensated impacts irrigation has on the environment. Knowing the value of these external effects and a subsidies contribution to them, should play some role in their reform. Third, subsidies for water come in many different formats. It is not enough to account for just the subsidization of water prices (those that cover O&M costs) that need to be considered, but also the subsidization of the finished products, complementary inputs, complementary outputs, establishment costs, etc.

In other words, auditing irrigation subsidies is an essential component needed if they are to be reformed. That audit process would require a recognition of why subsidies were implemented in the first place. It would require knowledge of the impact irrigation has in generating both the negative and positive externalities and the contribution subsides play in promoting these externalities. Finally, any audit would need to account for the wide range of subsidies that have been used in the

irrigation sector.

Following this line of thinking leads one to suggest that subsidy reform and/or removal is all about pricing reform. In other words, all that is required is to make sure the price of water paid by irrigators equates to the full costs of water provision. As many have found out, such reforms are extremely difficult to implement (Molle and Berkoff, 2007; Davidson et al., 2019). Examples of the difficulties of reforming subsidies are the phasing out of the electricity subsidy for groundwater pumping in Mexico (Foster et al., 2018), initiatives in India to find reform solutions (Malik, 2007), groundwater reforms in Yemen (Hellegers et al., 2008) and a water buyback scheme in the Murray-Darling river basin in Australia (Wheeler et al., 2020; Grafton and Wheeler, 2018; Grafton et al., 2020). Despite their transparency, the complex ways subsidies entwine themselves through a community means that any reform process will require some degree of compensation to be paid to those who lose.

Rationing water while subsidising technology to increase productivity would seem to be promising in capturing the benefits of irrigation while avoiding the costs, as it would cap the increased demand for water use that results from the increase in productivity embedded in the rebound-effect. However, it is difficult to cap water use in places where the volumes are usually unknown and not well controlled. The approach would require the ability to measure the volumes extracted, including the runoff, is something not many countries can do. There is a reason why in many countries area-based charges are applied instead of implementing the more efficient volume-based charges and these reasons have little to do with a lack of desire to achieve more efficient outcomes and more to do with the actual control water managers have over the supply and distribution of water to small holders. In theory it can be done and sometimes in case of groundwater extraction may well be ideal and undertaken.

6. Conclusions

In this paper it was shown that subsidies to the irrigation sector were not only both beneficial and harmful, but that they were also far-reaching, insidious, and complex to reform. They not only included the direct subsidies one usually accounts for, but also the indirect subsidies that resulted from the non-internalization of externalities or the lack of full-cost pricing as well. It is important to note that irrigation has caused externalities and that subsidies have made these externalities worse. However, even without subsidies such externalities would still exist. Further, reforming subsidies by undertaking pricing reform will go against the positive impacts that are thought to result from irrigation.

In sum, there is an argument that irrigation usually has environmental costs that are not internalised, and subsidies typically, usually, always exacerbate that situation. Thus. the tension between "good" outcomes (more food and higher rural incomes) and exacerbate the "bad" outcomes (faster aquifer depletion, drying estuaries, environmental degradation). Are there subsidy regimes that can capture the benefits while avoiding the costs, subsidies directed towards environmental protection? Some attempts, such as rationing water to acceptable levels of consumption while subsidising technologies that maximise the productivity of the limited resource, would seem to be the preferable approach, but are difficult to implement. The gains and losses from these types of reform are questions that can only be evaluated once the effects of the mix of subsidies and externalities (which are detailed in this paper) are understood. They should be the subject of further research. Further research is also needed on the political process that will lead to successful subsidy reform.

Ultimately, the decision to pay subsidies is one taken by governments in order to obtain some desirable objectives. These objectives can change over time and, when combined with the limited size of public budgets and negative externalities, can lead governments to ultimately question the wisdom of why they subsidised irrigation in the first place.

Decisions to reform subsidies are, of course, political in nature and reform processes are not the preserve of those who analyse and advise on such matters. Nevertheless, policy makers need to have a system of classifying and objectifying subsidies in a meaningful manner.

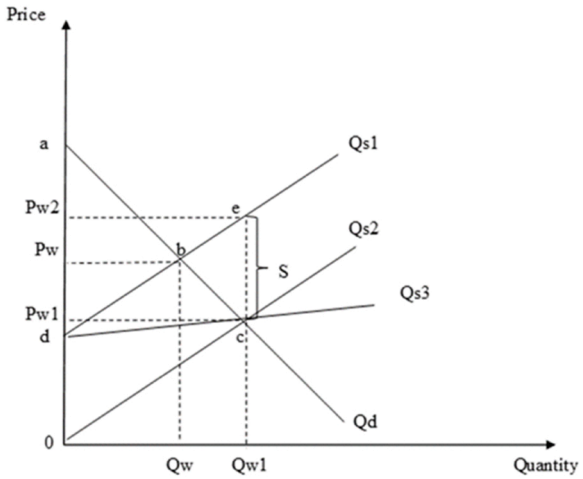

Fig. A1. The simple view of subsidies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Annex A

With a normal consumer good, which water is not, the impacts of a subsidy can simply be shown in a basic supply and demand schedule diagram (see Fig. A1). The unsubsidised market for water is shown by the supply and demand schedules (Qs1 and Qd, respectively). In this unsubsidised market the ruling price and quantities that constitute an equilibrium (Pw and Qw, respectively), yield the revenue from the market, (equivalent to the area PwbQw0). The value of water (shown by the area abd in Fig. 1), can be segregated into the consumers surplus (abPw) and producers surplus (bdPw). The costs of provision are equivalent to the area bQw0d, the area under the supply schedule between the origin and the quantity traded in the market (Qw).

Implementing a subsidy for the good, (equivalent in size to S in Fig. A1), can be done in one of two ways. First, it could be a subsidy paid on the per unit supply of the good (which can be referred to as an ad valorem subsidy). In this case the supply schedule would rotate down to become Qs3. So, at Qw1 the level of subsidy is equal to S, but would be lower if less water were involved, or greater if more water were involved. An example would be the subsidisation of variable operation and maintenance costs. Alternatively, subsidies can be paid as a 'lump-sum'. In such cases the whole supply schedule would shift down parallel to the original supply schedule (to Qs2 in Fig. A1). So, regardless of the quantity of water involved the subsidy remains the same. In this case the total subsidy paid is S in Fig. A1. An example would be governments paying for infrastructure or underwriting the cost of financing the development.

While for the purpose of presentation both an ad valorem and lump-sum subsidies shown in Fig. A1 have the same impacts on the prices and the quantities of the good at equilibrium (reducing prices from Pw to Pw1 and raising the quantity consumed and produced from Qw and Qw1), the impacts on value are very different. With an ad valorem subsidy consumer surplus increase by PwbcPw1 (in Fig. A1), while producers surplus changes from bdPw to Pw1cd. The revenue changes from PwbQw0 to Pw1cQw1. With a lump-sum subsidy the changes in revenue, prices, quantities and the consumer surplus are like that of an

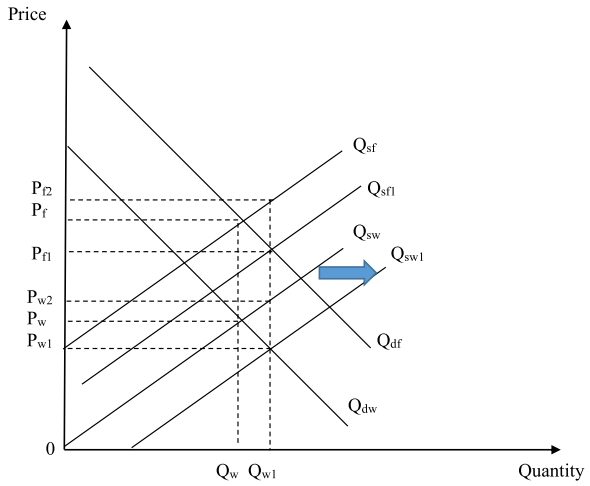

Fig. A2. Subsidising the cost of water.

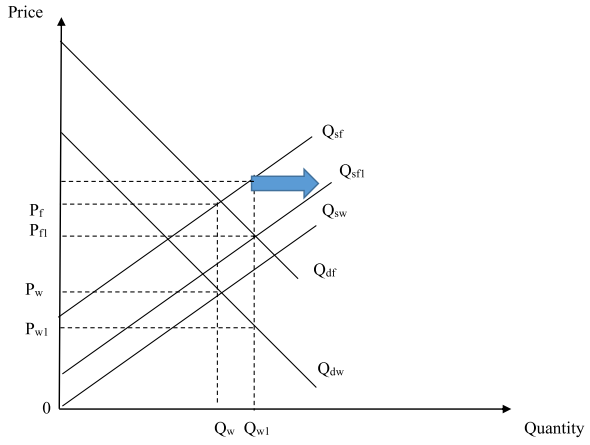

Fig. A3. Subsidising the supply of the final good has an impact on the supply of water.

ad valorem subsidy, (in Fig. 1 because of the way it is drawn), yet the impact on the producer surplus value changes from bdPw to Pw1c0.

The impact of subsidies on the input and the output market

Given the relationship between the demand for the crop and the input, any attempt to subsidise the input is going to have an impact on the demand for the output (see Fig. A2). Again, simplifying the subsidy to a lump-sum type, although an ad valorem type will have similar broad impacts, the supply schedule for the input shifts away from the origin, resulting in more of the input being used, out to Q_{w1}. The price of the input falls from P_w to P_{w1}. The impacts on the consumer, producer and economic surplus and the deadweight social losses are as described above, in Fig. A1.

The subsidy paid on the input also reduces the production costs of the output. Effectively, the supply schedule for the output would also move to the right in line with the fall in the input supply schedule and be parallel to Q_{sf}, running through the coordinate point $P_{f1}Q_{w1}$ Q_{sf1} in Fig. A2). The impact of subsidising the input is to reduce the price of the finished good and increasing its output. The concomitant impacts of the consumer, producer and economic surplus can also be traced, along with the deadweight social loss.

Just as an input subsidy can affect the market for the finished good, a subsidy to an output will also have an impact on the input market (see Fig. A3). The subsidy shifts the finished good supply schedule to the right, reducing prices of both the good itself and the inputs (from P_f to P_{f1} and from P_w to P_{w1}, respectively). The quantity of the output and the input also rise. Altogether, the surplus values change in accordance with those observed above. The essence of this finding is that not only do the subsidies that directly relate to the irrigation sector needed to be assessed, but also those for the all the finished goods water is used in.

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