8-4

# Allocating Irrigation Water in Egypt

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CASE STUDY #8-4 OF THE PROGRAM:
"FOOD POLICY FOR DEVELOPING COUNTRIES: THE ROLE OF GOVERNMENT IN THE GLOBAL FOOD SYSTEM"
2007

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## Executive Summary

Agricultural production in Egypt is virtually fully dependent on irrigation. Egypt gets more than 95 percent of its annual renewable water resources from the Nile, and the construction of the High Aswan Dam, which was completed in 1971, has allowed Egypt to take full advantage of its share of Nile flows and increase both cropping intensity and size of the cultivated area. Egypt may face significant water scarcity within the foreseeable future, however, because of the combination of a more or less fixed supply of fresh water and increasing demands for water owing to population growth and reclamation of desert land for agricultural production. Because agriculture is the major water user in the Egyptian economy, it will be important to ensure efficient allocation of irrigation water across users and uses.

In situations characterized by water scarcity, irrigation activities may be associated with several types of externalities, which in turn have implications for water use efficiency. A classic externality is when some farmers are able to appropriate as much water as they like while the other farmers receive only what is left over, resulting in possible drought damage to their crops. Another type of externality arises because not all water applied to the fields ends up being consumed (that is, evapotranspired) by the crops. Parts or all of the excess water may subsequently be returned to the basin water system and become available for another diversion cycle. Thus, even if individual farmers use inefficient irrigation technologies, this need not result in large water losses at the river basin level. Both of these externalities are present in various regions in Egypt and should be considered when designing policies for efficient allocation of irrigation water.

Using water in a socially efficient manner is not merely a question of physical efficiency in water use. Whereas improving physical efficiency is about conserving water by increasing the share of water applied that is beneficially used, increasing economic efficiency is about maximizing the economic value of water use through physical measures and allocation of water between water uses and users (Cai et al. 2001). Within the cropping sector, economic efficiency may be improved by reallocating water from low- to high-value cropping activities or in some cases by adjusting the choice of production technique and using deficit irrigation (that is, applying less than the full crop water requirement).

Many different policy instruments can be used to regulate farmers' use of water. The options include volumetric taxes and non-volumetric taxes (like crop-specific land or output taxes), various types of quotas, market-based allocation mechanisms, and user-based allocation mechanisms. The degree of efficiency that can be achieved in water allocation differs across these policy instruments, and so do the costs of implementing the policies. Regulating farmer water use has not only efficiency implications, however, but also distributional implications. Stakeholders in irrigation water allocation issues may be roughly divided into three groups: farmers, agents outside agriculture like industries and households, and agents in other countries. Although efficiency in water allocation policies should be an important matter for everyone in regions with water scarcity, stakeholders are also likely to be highly concerned with the distributional implications, which depend on the choice of policy instrument. All these aspects consequently must be taken into account when choosing what policy mechanisms to use for allocating scarce irrigation water resources in Egypt and elsewhere.

Your assignment is to discuss the efficiency and distributional implications of using tax policy instruments versus quota policy instruments to regulate farmers' use of irrigation water. Then, based on the features of the Egyptian economy and irrigation system, design a policy strategy for regulating farmers' use of irrigation water in Egypt, considering economic efficiency aspects, implementation costs, and stakeholder issues.

## Background

Egypt is characterized by an arid climate with very limited rainfall. The vast majority of the country is desert land, and crop production is virtually fully dependent on irrigation. The Nile supplies more than 95 percent of Egypt's annual renewable water resources, and Egypt is not likely to be able to significantly augment its supply of Nile water. Because demands for water are meanwhile increasing in Egypt, the country may well experience significant water scarcity within the foreseeable future.

The major water user in the Egyptian economy, agriculture accounts for more than 80 percent of total water diversions in Egypt (Mohamed 2001). Given the prospect of water scarcity and the agricultural sector's dependence on irrigation, it is important to consider what policy instruments can be used to achieve an efficient allocation of irrigation water across farmers and crops. The present case will provide an introduction to the issues of efficiency in irrigation water allocation and policies targeting farmers' use of irrigation water with particular reference to the Egyptian irrigation system.

To appreciate the irrigation water policy issues facing Egyptian society, it is necessary to first consider the characteristics and complex nature of the Egyptian irrigation system. The background section will therefore present an overview of the Egyptian irrigation system, and the subsequent sections will explore policy issues, stakeholders, and policy options.

## The Egyptian Water Balance

The Nile Delta has been under cultivation for more than 5,000 years (Abu-Zeid and Rady 1992). Initially irrigation practices were intimately related to the natural flow of the Nile, characterized by the summer Nile flood, which reaches Egypt in late July and recedes in late October. Over time the irrigation system was developed in various ways to expand agricultural production possibilities, and complete control of the Nile flows was finally achieved by the construction of the High Aswan Dam, which was completed in 1971. Lake Nasser in front of the High Dam has a storage capacity of 164 billion cubic meters (BCM), amounting to almost twice the average annual Nile inflow of 84 BCM. The High Dam has thus allowed Egypt to take full advantage of its share of Nile flows by evening out these flows across seasons and between years. This water availability in turn has resulted in significant increases in both cropping intensity and size of the cultivated area.[1]

The Nile Basin is spread over 10 countries—Burundi, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda, and Zaire—and Egypt is located downstream from the 9 other Nile Basin countries. So far the use of Nile waters has largely been governed by two treaties—one from 1929 between Egypt and Britain and one from 1959 between Egypt and Sudan. The 1929 treaty stipulates that no country can engage in projects that reduce the amount of water reaching Egypt, and the 1959 treaty governs the division of Nile waters between Egypt and Sudan (Nkrumah 2004). Under the 1959 treaty Egypt and Sudan are respectively afforded 55.5 and 18.5 BCM of Nile water annually, and evaporation and other water losses from Lake Nasser account for the remaining 10 BCM of average annual Nile flow (FAO 2005).

Egypt has had favorable access to Nile waters under the two treaties, and the country therefore cannot expect to increase its share of Nile flows to cover the rising domestic water demands. In fact, upstream countries' desires to use Nile water might in the future lower the amount of Nile flows reaching Egypt, although cooperation with upstream countries may also open up technical solutions to augment Nile flows by reducing seepage and evaporation losses.[2] Egypt also has some water sources unrelated to the Nile, including fossil groundwater, and these water sources may provide some additional water in the future. Egypt is not likely, however, to be able to substantially increase its supply of freshwater in the short to medium term.

Egyptian water demands, on the other hand, will increase noticeably in the coming years. In 2005

[1] The construction of the High Aswan Dam has also implied that the fertile sediments, which come with the Nile floodwaters, no longer reach the Nile Valley and Delta but instead accumulate in Lake Nasser.

[2] One option for reducing evaporation losses is the construction of the so-called Blue Nile Reservoirs in Ethiopia. These reservoirs would make it possible to shift over-year storage from Lake Nasser upstream to the upper Blue Nile region, where evaporation rates are around 50 percent of the rates in Egypt and Sudan (Whittington et al. 1995). A total of 85 percent of Egypt's water supply originates in Ethiopia, however, and the issue of how to secure a regular supply of water if the Blue Nile Reservoirs were constructed is clearly very important to Egypt.

Another project, which also seeks to reduce the amount of Nile evaporation losses as well as losses from seepage and over-bank flows to swampland, is the so-called Jonglei project. This project consists of a series of canals designed to drain water from the vast Sudd Swamps in southern Sudan. The project was stalled because of the instability in the region, and environmental concerns have also been raised in the discussions about resuming the project (Whittington et al. 1995; Bader 2004).

the Egyptian population had reached 74 million people and was growing at an annual rate of 1.9 percent (World Bank 2007). The growing economy and population can be expected to increase the demand for water in and of themselves. The implications of the growing population are further compounded, however, by the fact that although Egypt is a large country, only a small fraction of the land is cultivable. In 1997 agricultural land holdings amounted to approximately 8 million *feddan*,[3] which corresponds to less than 5 percent of the total land area.

The need to feed the growing Egyptian population early on led the Egyptian government to adopt a strategy of expanding the country's limited agricultural area by reclaiming large amounts of low-quality desert land (Hvidt 1998). The Land Master Plan of 1986 estimated Egypt's additional reclaimable lands at approximately 3.4 million *feddan* (Hellegers and Perry 2004). According to Hanna and Osman (1995), the major objective of the land expansion is to increase the production of food, feed, and fiber for the growing population, while also providing work opportunities and alleviating population pressure on the old cities and the ensuing loss of cropland to urban development. According to the Ministry of Water Resources and Irrigation (2005a, 2-31–2-32), "[t]he present agricultural strategy is not based on self-sufficiency but on food security, using Egypt's competitive advantages.... Egypt is increasingly in a position to produce higher-value food crops (e.g. fruits and vegetables) and non-food crops (e.g. flax and cotton) and trade them to purchase staples and have additional revenue and employment as well. Maximizing national income is therefore considered a more reliable approach to food security than self-sufficiency."

Although progress in land reclamation has generally been much slower than planned (Mohamed 2001), the land reclamation plans remain very ambitious, aiming to increase agricultural land by more than 35 percent compared with the 1997 level (Ministry of Water Resources and Irrigation 2005b). These land reclamation plans require substantial amounts of irrigation water, and if they are carried out, Egypt may thus face significant water scarcity within the foreseeable future.

[3] A *feddan* is the Egyptian area measurement unit. One *feddan* corresponds to 0.420 hectare (or 1.037 acres) (World Bank 1993).

## General Features of the Egyptian Irrigation System

The Egyptian irrigation system is enormous and highly complex. Hvidt (1998, 10) reports that the system consisted of "the Aswan High Dam, eight main barrages..., approximately 30,000 km of public canals, 17,000 km public drains, 80,000 km private canals (*mesqas*) and farm drains, 450,000 private water lifting devices..., 22,000 public water control structures, and 670 large public pumping stations for irrigation."

The water delivery canals in the Nile irrigation system are classified hierarchically starting with the principal canals (which receive water directly from the Nile) through the main canals to the branch canals and the distributary canals. *Mesqas* (private ditches) receive water from the branch canals or the distributary canals and distribute this water either directly to the fields or into *marwas*, which are private off-takes from the *mesqas* conveying water to fields located away from the *mesqa* (Hvidt 1998). A similar hierarchy exists for the drainage system. The state is responsible for the entire irrigation and drainage system above *mesqa* level. The *mesqas* are owned (although not necessarily constructed) by the landowners, and they are responsible for maintaining the *mesqas* and field drains (Hvidt 1998).

The state distributes the irrigation water across the different segments of the irrigation system. Before 1992 cropping patterns in Egypt were determined by the state. Based on information on cropping patterns, the water requirements of each crop, the size of planted area, and the soil type, as well as the expected conveyance losses and on-farm losses, the Ministry of Agriculture and Land Reclamation was able to calculate the amount of irrigation water required for the following year. The request for irrigation water would then be sent to the Inter-Ministerial Committee on Water Planning, along with requests for water from other concerned ministries, and a day-by-day plan for releases from the High Aswan Dam would be drawn up, including the allocation of these releases between the different segments of the irrigation system. After 1992 cropping patterns were liberalized, however, and it consequently became difficult to calculate the needs for irrigation water and ensure appropriate allocations of irrigation water to the different segments of the irrigation system (Hvidt 1998, 2000).

The problems of allocating water appropriately across the different segments of the Egyptian irrigation system will be compounded by increasing water scarcity because the traditional Egyptian irrigation system has not been constructed to handle scarcity. According to Hvidt (1998, 9) "up to the present day, the system has been characterized by water abundance.... The structure, management, and technical properties of the [traditional] Egyptian irrigation system have been designed and operated within a situation of water abundance, which means that up to the late 1980s very little emphasis was placed on improving the efficiency of water use." As the following sections will outline, this system has implications for the policy options that can be used to promote efficient water use by farmers.

## Regional Differences in Irrigation Practices

Egypt can be split into two major regions with different agricultural and irrigation characteristics. The so-called Old Lands encompass the Nile Valley and the Nile Delta, which have been cultivated since historic times. The so-called New Lands, on the other hand, are desert areas that have been reclaimed for cultivation since 1953 (Skriver and Moeslund 1998). The technical and hydrological characteristics of the land and irrigation system vary significantly across these regions of Egypt, with implications for the irrigation policy issues.

The Old Lands regions are characterized by clayey soils, and water is normally applied to the field using surface irrigation techniques. These techniques generally have lower application efficiencies than the modern and more capital-intensive sprinkler and drip irrigation techniques. Consequently, the field irrigation efficiency—defined as the fraction of water applied to the field that ends up being consumed by the plants—will, other things being equal, be lower under surface irrigation techniques than under sprinkler or drip irrigation.[4,5] The remaining water, which is not consumed by the crops, either ends up in the drains or percolates into the ground. In the Nile Valley, drainage water is returned to the Nile or to the main irrigation canals, whereas in the Delta, drainage water is either pumped back into the irrigation canals for reuse or pumped into the northern lakes or the Mediterranean Sea (FAO 2005). In most of the Delta and Nile Valley, water that percolates into the ground either returns to the river or recharges the shallow Nile aquifer from where it can be recovered (Keller et al. 1996).[6] Return flows from the Nile Valley are thus virtually fully recoverable, and return flows from the Delta are partially recoverable.

In the traditional irrigation system in the Old Lands, water is delivered to farmers on a rotational basis, which is normally applied at the branch canals. There are different types of rotations, but one typical rotation pattern in Middle Egypt entails that water will be on for 5 days and then off for the following 10 days. When the water is on in the local segment of the irrigation system, each farmer simply pumps irrigation water from the open

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[4] Surface irrigation techniques apply water to the field by gravity flow either by flooding the entire field (basin irrigation), feeding the water into small channels (furrows), or feeding the water to strips of land (borders). Sprinkler irrigation resembles rainfall because water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads. Drip irrigation, on the other hand, conveys water to the field through a pressurized pipe system from which it drips slowly onto the soil through emitters located close to the plants (Brouwer et al. 1988). According to FAO, average field application efficiency for sprinkler and drip irrigation is 75 percent and 90 percent, respectively, compared with 60 percent for surface irrigation techniques (Brouwer et al. 1989, annex 1). These general field application efficiency numbers do not account, however, for the effects of different soil types on overall field irrigation efficiency. According to Caswell and Zilberman, "the fraction of water applied which is actually utilized by the plant is a function of the water-holding capacity of the soil and the method of water application" (Caswell and Zilberman 1986, 799). Clayey soils, like the ones found in the Old Lands, tend to be less water-permeable than sandy soils, which are found in large parts of the New Lands.

[5] Crop water consumption is here equated with crop evapotranspiration. Evapotranspiration is defined as the "the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration" (Allen et al. 1998, 1).

Precipitation is generally disregarded in the present case study, because it is not a relevant factor for agricultural production in Egypt. It is implicitly assumed that the entire water requirement of the crop is covered through irrigation.

[6] In the northern part of the Delta, drainage and groundwater salinity levels are quite high, and these water flows are therefore of limited value for reuse (Keller et al. 1996).

*mesqas* using a pump that the farmer either owns himself or hires when he wants to irrigate. Irrigation water is generally delivered below field level, and thus farmers incur pumping costs when irrigating. This cost in principle should give them an incentive to conserve water, but over time low-cost powered pumps have become available, lowering the cost of pumping and reducing the time it takes to pump a given amount of water (Hvidt 1998; Abu-Zeid 1995; Hellegers and Perry 2004).

The rotational irrigation system suffers from a number of drawbacks. The system is ill suited for cultivation of short-rooted crops like vegetables, which require more frequent irrigation, and it is very difficult to secure an even distribution of water along the canals, which in turn results in unequal water deliveries and so-called tail-end problems (see the next section). Inadequate deliveries of water have led many farmers to manipulate the system in various ways to deliver larger amounts of water. In some locations, the rotation schedule is also observed somewhat loosely, making it difficult to predict when irrigation water will be available. Farmers may thus have rather limited water control, which in turn leads them to adopt inefficient irrigation practices like irrigating too soon and applying too much water. According to Hvidt (1998), studies have shown that farmers have applied 50 percent to 250 percent more water than required by the crops and for the purpose of leaching.[7] In addition to these problems of the rotation system, the structures of the irrigation system are also old and deteriorating, and farmers also increasingly face water pollution problems (Hvidt 1998; Hellegers and Perry 2004).

To address the shortcomings of the traditional irrigation system as well as the predicted demands of the 21st century, Egypt has adopted the Irrigation Improvement Project (IIP). The IIP calls for improving about 3.5 million *feddan* (of which some 70 percent are located in the Delta) by the year 2017 (Ministry of Water Resources and Irrigation 2005a). Given the speed of implementation, however, the total area covered by IIP in 2017 is likely to be somewhat smaller.

The purpose of the technological package implemented under the IIP is to ensure efficient water use and optimal crop production by giving farmers the flexibility to irrigate at the time, rate, and duration required by their crops. The IIP package includes both technical and social changes to the irrigation system. The fundamental change introduced by the IIP is the replacement of individual farmer pumping at multiple points along the *mesqa* with collective pumping at a single point. To this end, the IIP introduces continuous flow in branch and distributary canals, high-level *mesqas* with single point lifting, water user associations (WUAs), downstream control/demand irrigation, and an Irrigation Advisory Service (IAS) (Hvidt 1998).

The aim of replacing the rotational operation of the branch and distributary canals with continuous flow is to enable farmers to irrigate according to the water needs of their crops. Continuous flow only implies continuous availability of water, however—not increased amounts of water. Each command area will still receive the same amount of water each month as it did under the old rotational system. The old *mesqas* below field level are being replaced by elevated concrete-lined *mesqas*. Instead of the previous system in which individual farmers pumped water at multiple points along the old *mesqas*, water is pumped from a single point at the branch canal into the elevated *mesqa* and then flows by gravity within the *mesqa* to the field outlets. Only two or three farmers will typically be able to take water at the same time. Water user associations will schedule irrigation flows among the different farmers (Hvidt 1998; Hellegers and Perry 2004).

Hellegers and Perry (2004) point out, however, that the new IIP system is not problem free. Introducing pumps at the head of *mesqas* without ensuring sufficient capacity in the distributary canals may simply move the supply constraint upstream to the distributary canals. Furthermore, there is some evidence to suggest that farmers have found the new pumps at the head of the *mesqas* unreliable. Many have therefore resorted to installing their own pumps and drawing water directly from the distributary canals, thus circumventing the new *mesqas*. The construction standards for the new elevated *mesqas* have also been poor, and failures in the aboveground system are unfortunately much more serious than failures in the traditional below-ground system. Finally, there is the issue of volumetric measurement of water

[7] Leaching here refers to the practice of applying extra irrigation water in order to prevent salts from building up in the soil (that is, salinity control).

allocations, which was not feasible under the traditional system owing to the individual multipoint pumping system. The new system is in principle capable of measuring the amount of water farmers pump into the elevated *mesqa* (thanks to the collective single-point pumping mechanism), but this often does not work, and volumetric water allocation can therefore not yet be used to balance supply and demand (Hellegers and Perry 2004).

As mentioned, the land and irrigation characteristics of the New Lands differ substantially from those of the Old Lands. The soils in the New Lands are typically sandy or calcareous and poor in organic matter. The New Lands are located at the ends of the irrigation system and mostly outside the Nile's drainage basin, and farmers in the New Lands are required by law to use either sprinkler or drip irrigation (FAO 2005; Hellegers and Perry 2004). Unlike surface irrigation, sprinkler and drip irrigation typically require a continuous supply of water. The modern irrigation system in the New Lands implies that metering water at the point of delivery is in principle possible (Abu-Zeid and Rady 1992).

The New Lands also differ from the Old Lands with respect to yields, crop water requirements, and cropping patterns. Crop yields tend to be substantially lower in the New Lands than in the Old Lands. According to the Ministry of Water Resources and Irrigation (2005a, 2-31), "this is expected to improve with time, but initially, newly reclaimed lands do not achieve the yields of the older lands." Crop water consumption rates are in many cases also higher in the New Lands (Mohamed 2001, appendix). In 1997/98, however, the average value of production per area unit was higher in the New Lands than in the Old Lands, because the higher-value fruit and vegetable crops make up a significantly larger share of the cultivated area in the New Lands than in the Old Lands (Ministry of Water Resources and Irrigation 2005a).

## Policy Issues

Agriculture is, as previously outlined, the major water user in the Egyptian economy. As water scarcity becomes more pronounced, it will become even more important to ensure efficient use of irrigation water.

### Externalities and Different Measures of Water Use Efficiency

There are many aspects to the notion of using irrigation water efficiently. One of the important issues is how to ensure an efficient allocation of water resources across different farmers. Although irrigation water is an important input in agricultural production in developing countries, there is often no market for irrigation water. In some cases, the state or groups of water users may have formulated water allocation policies or mechanisms themselves to compensate for the missing water market, but these water allocation policies are not necessarily designed to ensure an efficient allocation of irrigation water across users.

If the right quantities of water were always available at the right time, in the right place, and with the right quality, there would be no need for markets or other types of mechanisms to regulate the allocation of water. When some kind of water scarcity prevails, however, whether it is a global, local, or seasonal phenomenon, the lack of mechanisms for allocating water efficiently between competing uses will result in inefficient use of water resources and water users' imposition of externalities on each other. A classic example of externalities in irrigation is the so-called head-end–tail-end problem, where farmers at the head of the system can appropriate as much water as they like, whereas farmers in the tails of the system receive only what is left over, resulting in possible drought damage to their crops (Perry et al. 1997). In Egypt there is ample scope for farmers to impose these kinds of negative externalities on each other owing to the lack of mechanisms for efficiently regulating individual farmers' appropriation of water. As outlined in the previous section, although the centralized water allocation system does imply a kind of quota scheme for allocating water between different segments of the irrigation system, the traditional irrigation infrastructure in the Old Lands has not allowed for a quota scheme to be implemented at the individual farmer level.

This type of externality related to farmers' water diversions can typically be attributed to ill-defined (or in some cases poorly enforced) property rights over irrigation water. It is well known from the general literature on externalities that inefficiencies from externalities can be alleviated through a variety of policy instruments, including taxes, quotas, or the establishment of some sort of bargaining or market mechanism. As noted by Turner et al. (2004), all these instruments imply the explicit or implicit assignment or modification of the property rights to the water resource. The inefficiencies of the water diversion externality are thus alleviated by explicitly or implicitly addressing the underlying cause of the externality.

Another aspect of efficient use of irrigation water is to minimize nonbeneficial losses of this resource. Looking at the individual farmer's use of water, substantial amounts of water may be lost through the use of inefficient irrigation technologies. As already mentioned, surface irrigation techniques tend to generate lower field irrigation efficiency than modern sprinkler and drip irrigation technologies. Surface irrigation techniques may therefore, other things being equal, result in the loss of a higher fraction of water applied than sprinkler and drip irrigation.

What matters from society's point of view, however, is not necessarily the irrigation efficiency of the individual farmer. As noted by Perry et al. (1997, 10), "[o]ne of the most important, yet least appreciated, facts about water is that in a basin, a substantial amount of it is recycled." In irrigated agriculture the recycling of water stems from the fact that the part of the applied water that is not consumed may be returned to the basin water system. This recycling occurs if drainage water is channeled back to the main water source or irrigation canals or if water that percolates into the ground ends up in aquifers from where it can be retrieved. What matters from a social efficiency point of view is thus not necessarily how much water is applied to the field, but rather how much water is actually consumed by the plants or otherwise irretrievably lost, because this is the amount of water that is in fact taken out of the system.[8] The recoverable return flows thus constitute another type of externality arising from irrigation activities when they become available for yet another diversion cycle "at another time, another place, and at another quality" (Perry et al. 1997, 10).

In most of the Old Lands in Egypt, drainage water is returned to the Nile or the irrigation canals and most percolation flows end up in aquifers from where they can be retrieved. Although farmers in these areas use a less efficient irrigation technique, this consequently does not result in large water losses at the basin level. In the New Lands, on the other hand, water that percolates into the ground is generally lost. It is therefore important to use the more efficient irrigation techniques in these areas, as mandated by law. Another factor that tends to reduce potential water losses in the Old Lands while increasing them in the New Lands is soil type. The clayey soils in the Old Lands are less water permeable than the sandy soils in the New Lands.[9]

Although the concept of water system (or basin) efficiency is important, it also has its limitations from an economic point of view, because it relates only to the physical quantities of water and consequently does not address the issue of whether water is being used in the most economically productive way. Although improving physical efficiency is about conserving water by increasing the fraction of water applied that is beneficially used, increasing economic efficiency is about maximizing the economic value of water use through physical measures and allocation (or reallocation) of water between water uses and users (Cai et al. 2001).

The differences in the value of water in alternative uses can be captured by the concept of water productivity. Water productivity can be increased either by increasing the amount of a given output per input unit of water or by reallocating water from lower- to higher-value production either within the agricultural sector or between sectors (Molden and de Fraiture 2000). Within the cropping sector, economic efficiency may thus be improved by reallocating water from low- to high-value cropping activities (Keller et al. 1996). Economic efficiency can also be improved by adjusting the choice of production technique, as in some situations it may be more efficient to produce crops by using less than the full crop water requirement (that is, water-stressing the crops through deficit irrigation) even though this practice also reduces crop yields. To maximize the social economic efficiency of water, however, the use of

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[8] The quality of the return flows will typically be lower, however, than the quality of the water initially applied (see the next section).

[9] Water losses also occur from the water conveyance and distribution system. Such water losses include both seepage and nonbeneficial evaporation. The former types of water losses may be recoverable, however, if the seeping water ends up in an accessible aquifer. There are also substantial evaporation losses from Lake Nasser behind the High Aswan Dam.

water must be evaluated using social prices rather than market prices, because the latter may not reflect the true social costs and benefits. Water use can then be retargeted to the activities producing the highest socioeconomic returns through the introduction of various price and nonprice "demand management" measures (see Mohamed 2001).

### Water Quality and Cost Recovery

The discussion of water scarcity implications has so far focused on water quantity. Water scarcity is not merely an issue of quantity, however, but also an issue of quality, because severe deterioration in water quality may render water unusable. Every time water is diverted and used for irrigation, the quality of the resulting return flows will be lower than the quality of the water that was applied owing to increased concentration of salts and pollutants. Thus, on its way from the High Aswan Dam to the Mediterranean Sea, the salt and pollution concentration of the Nile increases. Mohamed (2001) cites a study from 1995, however, that suggests that polluted spots were still localized in the Nile system and states that water quality was still adequate for most uses upstream from the Delta. Throughout the Delta, severe water pollution is found downstream from large communities and industrial cities (Mohamed 2001).

Another issue, which is connected to the notion of efficiency in water use, is the degree to which the costs of delivering the water are covered and carried by the appropriate agents. Traditionally the costs of operating and managing the irrigation and drainage system, as well as investments and rehabilitation costs, have been borne by the Ministry of Water Resources and Irrigation. Apart from the cost of pumping water onto their fields, farmers have not paid directly for their irrigation water, but they do pay land taxes, which cover part of the cost of the irrigation system.[10] These land taxes, however, do not depend on crop type or the amount of water used (Hellegers and Perry 2004). Before the liberalization of agricultural policies in the 1990s, farmers were also taxed indirectly through the mandatory sales of agricultural produce to the state at low prices, but after liberalization farmers are rather free to determine what to grow and whom to sell it to (Ministry of Water Resources and Irrigation 2005a; Hvidt 1998). Because the land taxes do not cover all the costs of delivering irrigation water and maintaining the irrigation and drainage system, the state must cover these expenses through other revenue sources. The provision of irrigation water is thus in effect subsidized, which tends to encourage socially inefficient use of this resource.

## Stakeholders and Policy Options

Water is a resource that affects everyone in society on a daily basis. The group of stakeholders in water allocation issues thus ultimately includes the whole society. Furthermore, because water flows across national borders, parties outside the country in question may also be considered stakeholders to the extent that they are influenced by the water allocation policies. Efficiency in water allocation should thus be an important matter for virtually everyone in regions where water scarcity prevails. Many stakeholders, however, are more likely to care about the income and distributional consequences of water allocation policy instruments.

The group of agents that is most directly influenced by the choice of irrigation water allocation policies consists of Egyptian farmers. Using tax policy instruments to regulate farmers' use of water will, other things being equal, have a negative impact on farmers' income unless the tax revenue is somehow returned to the farmers. Depending on the degree of water scarcity and hence the degree to which farmers' water use must be curtailed, the reductions in farmer incomes may be substantial. According to a study by Löfgren on water cost recovery and water scarcity in Egypt, reducing farmers' water use by 15 percent through water charges would lead to a 22 percent reduction in net farm incomes (Löfgren 1996).

Although it seems reasonable to assume that farmers' net income will be reduced if water use is regulated through a tax mechanism, the distributional implications of water-regulating policies for

[10] Some parts of the New Lands are irrigated by groundwater, and according to a World Bank study (2001) farmers pay the full cost of groundwater abstraction in the New Lands. Farmers also repay on-farm investments that are part government programs (like the Irrigation Improvement Project), but there is an extensive grace period for repayment of these investments, which amount to a subsidy (Ministry of Water Resources and Irrigation 2005a).

groups of farmers are not a priori clear. Certain policy schemes may inadvertently result in redistribution between different regions of the country. This would be the case, for instance, if farmer water use were to be regulated through a single set of crop-specific land taxes based on the average national water consumption rates for each crop. Such a tax scheme would tend to favor the New Lands at the expense of the Old Lands to the extent that crop water consumption rates are higher in the New Lands than in the Old Lands (Gersfelt 2007).[11] If, on the other hand, tax rates were regionalized, it would alleviate these types of regional redistribution issues.

Farmers may also be heterogeneous within regions, differing, for instance, with respect to soil type, degree of land leveling, access to input and output markets, managerial skills, and water-regulating policy may result in redistributions between farmers. This is not to say that redistributions are necessarily negative—in fact, they may be desirable from society's point of view. Regardless of social desirability, however, redistributions will often meet with political opposition, which may make it difficult to implement the necessary reforms of the water allocation mechanism.

Cultural and religious factors may also have implications for whether it will be possible to implement a given set of water-regulating policies. Hellegers and Perry (2004) report that although it is in principle acceptable to charge for the service of providing water in Egypt, charging for irrigation water itself is not acceptable, which makes volumetric water charges a contentious issue. It is thus not surprising that "charging agriculture for water and water services is … a politically sensitive issue in Egypt" (Hellegers and Perry 2004, 41). According to Gutner (1999), there has generally been a legacy of government caution toward economic reforms in Egypt since the 1977 riots, which were sparked by cuts in the food subsidy program, which led to high, sharp price increases that were perceived to be inequitable. Since then, however, the government has succeeded in reforming the food subsidy program by adopting a gradual approach. In the 1990s the Egyptian government also succeeded in reforming land rent legislation, which had protected and favored tenants by keeping land rents much lower than market value. Over the course of a five-year period, land rents were raised from 7 times the land tax to 22 times, and since October 1997 farm tenancy and land rents have been determined by the market (Nassar and Mansour 2003). It is consequently possible to implement such types of reforms in Egypt, provided it is done in a gradual manner. Furthermore, attitudes toward water pricing might also slowly start to change as water becomes scarcer and the need for a transparent and efficient water allocation mechanism becomes more evident.

One alternative to using tax policy instruments to regulate farmers' water use is to use quotas, which could be allocated to farmers free of charge. If farmers are highly heterogeneous, however, it may be quite costly to determine the socially optimal farmer-specific quotas. Furthermore, to be accepted by farmers, the quota assignment process would probably have to be not only transparent, but also based on criteria perceived to be fair. Quotas by themselves would also not generate the revenue to cover the part of the operation and maintenance costs for the system that the state is currently subsidizing. The revenue from tax policy instruments, on the other hand, could be used to cover these expenses, and any remaining revenue could in principle be channeled back to the farmers and the rural community.

Agents outside of agriculture like industries or households are also stakeholders in the national Egyptian water economy. In most countries, however, municipal and domestic water needs, as well as industrial and commercial water needs, are given priority over agricultural water needs (Perry et al. 1997), and this is also the case in Egypt. Water use by these nonagricultural agents may nonetheless still be affected by salts and pollutants in the return flows from agriculture. Moreover, unless the agricultural sector is made to bear its full share of the costs of operating and maintaining the irrigation system, these other sectors will in effect subsidize the irrigation system.

Agents outside of Egypt may also be stakeholders in the Egyptian national water economy. Egypt is the last country before the Nile reaches the Mediterranean Sea, so no countries are located downstream the Nile from Egypt. As already mentioned, however, upstream countries are also

[11] Regional differences in field irrigation efficiency and return flow recoverability would also affect the distributional implications for the different regions (see Gersfelt 2007).

indirectly affected by Egypt's water policies. Under the 1929 and 1959 treaties, Egypt has assumed the right to veto upstream projects that would adversely affect its water interests (Nkrumah 2004). The upstream countries—with the exception of Ethiopia—were all colonies of European powers at the time the 1929 treaty was established, and they now strongly object to the treaty and renounce it as invalid. Egypt, on the other hand, has repeatedly stated that a unilateral change in this treaty would amount to a breach of international law, and upper riparian countries may fear—not without grounds—that Egypt would use military power to secure control of Nile water. Discussions on these transboundary water-sharing issues are now taking place within the so-called Nile Basin Initiative, which includes the different Nile basin countries (Nkrumah 2004). Consequently, how Egypt chooses to address its domestic water challenge may affect the upstream countries with respect to the options and terms for future Nile Basin water agreements.

## Policy Instruments

The policy instruments that can be used to regulate farmers' use of water include volumetric water taxes, non-volumetric taxes, quotas, market-based allocation mechanisms, and user-based allocation mechanisms (Johansson et al. 2002).

Volumetric water taxing implies that a tax is placed on the amount of water the farmer diverts for irrigating his fields, which in effect places a direct price on the farmer's water diversion. This approach can involve a single tax rate on water diversions or it can take more sophisticated forms, such as tiered pricing, where the water tax rate varies according to the amount of water diverted, or two-part tariff pricing, where the farmer pays a constant marginal price per unit of irrigation water purchased as well as a fixed annual or admission charge for the right to purchase water (Tsur and Dinar 1997).

Non-volumetric taxes seek to regulate a farmer's use of water by taxing other variables, which are somehow correlated with the farmer's use of water, and hence indirectly pricing the farmer's use of water. Possible non-volumetric taxes for regulating irrigation water usage include land taxes or output taxes.[12] The simplest form a land tax scheme can take is a uniform per area charge. Such a scheme can influence the farmer's use of water only through his decision about how large an area to irrigate. To affect the farmer's cropping pattern decision, land taxes (and also output taxes) can be made crop-specific so that they better target the differences in water requirements across crops.

Instead of using tax instruments, it is also possible to regulate farmers' water use through quotas. The most direct approach is to assign individual water diversion quotas to farmers, but the quota could in principle also relate to land use or output quantities. If a water quota or some other measure of farmer water entitlement is made tradable, water markets can be established and water can then be allocated through the market mechanism. Finally, water can also be allocated through user-based allocation mechanisms, which—as the name suggests—entail that the water users allocate the water among themselves. User-based allocation mechanisms require collective action institutions that have the authority to make decisions on water rights (Dinar et al. 1997).

The degree of efficiency that can be achieved in water allocation differs across these instruments. The following discussion will focus on the tax policy instruments, but many of these arguments also apply to the quota versions of these instruments.

A volumetric water tax targets the amount of water the farmer applies to the field. As outlined earlier, however, what matters from a social efficiency point of view is the amount of water consumed or irretrievably lost in the course of irrigation. When return flows are partially recoverable, volumetric water taxes will not be able to take account of crop-specific differences in field irrigation efficiency in a socially efficient way. The field irrigation efficiency would typically differ between rice and other crops because traditional rice production requires extra water for soaking the paddy fields.

[12] Non-volumetric taxes can also include taxes on other inputs than land. The implications of using taxes on other inputs to affect farmers' use of water have been studied by He (2004). Using agricultural sector models for Egypt and Morocco, she analyses the effect of using taxes on fertilizers, pesticides, and energy, as well as taxes on output, compared with the effect of using volumetric water pricing.

When return flows are partially or fully recoverable, a volumetric water tax scheme will therefore result in too heavy taxation of rice production, from a social efficiency point of view. If return flows are not recoverable, on the other hand, volumetric water taxes will in principle provide the socially optimal incentives for farmers' cropping pattern decisions.

Unlike volumetric water taxes, crop-specific land taxes would be able to account for crop-specific field irrigation efficiencies even when return flows are recoverable. Once the decision on cropping pattern has been made, however, crop-specific land taxes can no longer affect the farmer's use of water, because the marginal cost of applying more water to the same area is zero. Crop-specific land taxes will thus not induce farmers to adopt deficit-irrigation of the crop, which in some cases may be efficient from society's point of view, nor will they induce farmers to avoid misuse or overuse of water. In the case of crop-specific output taxes, there is a relationship between tax payments and water use, because yields tend to increase when water application increases (except in the case of overirrigation). It is not given, however, that a crop-specific output tax will lead the farmer to choose the socially optimal water-yield production technique (Gersfelt 2007).

In addition to these issues of how efficiently the different tax instruments can allocate water across crops and water-yield production techniques, there is also the issue of whether the policy instruments should be regionalized to capture regional differences in, for instance, crop water consumption rates, crop yields, field irrigation efficiency, and return flow recoverability, because basing tax rates on national averages for such variables can result in socially suboptimal allocation of water across regions (Gersfelt 2007).

The policy instruments differ not only in terms of their water allocation efficiency properties, but also in terms of their implementation costs. Although a given policy instrument may achieve a high degree of water allocation efficiency, high implementation costs may imply that this is not the most socially efficient choice of policy instrument for regulating farmers' use of irrigation water. Volumetric water taxes would require the ability to meter individual farmers' water diversions. As mentioned, this is not yet possible in the traditional irrigation system in the Old Lands, but in the future it may become possible in the areas covered by the IIP. Upgrading the entire irrigation infrastructure to allow for metering will require substantial investments, however, which would not only be costly, but also take a number of years to implement. Furthermore, even if meters are installed, it may be difficult to ensure metering of all farmers' water diversions. The reason is that if irrigation water is delivered in open canals, as is generally the case in Egypt, it may be difficult to prevent farmers located next to these canals from circumventing the meters by pumping the water straight from the canals and dodging the tax payments. This problem does not affect non-volumetric instruments like land taxes, because the tax in this case is levied on land use rather than on water.

In reality, implementing a volumetric water pricing system is also not simply a matter of getting the technology in place for metering farmers' water diversions. A regulatory framework must also be established, with procedures for measuring the amount of water delivered as well as procedures for partial deliveries, missed deliveries, excess deliveries, late deliveries, polluted deliveries, and so on. An administrative bureaucracy must be established to collect data on water deliveries to farmers and carry out the billing (Perry 2001). The establishment of such regulatory and administrative frameworks may be a significant barrier to the implementation of water policies in countries where regulatory structures and traditions are not yet strong and well developed.

Implementation of the non-volumetric policy instrument of crop-specific land taxes does not necessitate major investments in physical structures. Nonetheless, information must be collected on each farmer's allocation of land to different crops. Although collecting such information is not cost free, the implementation costs for land taxes are often deemed to be lower than the implementation costs for many of the other water policy instruments.

Implementing an output tax scheme requires information on output levels for each farmer. The cost of measuring these output levels will depend in part on the crop-marketing channels. In the special cases where the entire crop is marketed through a central state trading enterprise, measuring the level of output may be relatively inexpensive, resulting in low implementation costs. On the other hand, if some or all of the crop is either marketed through local informal markets or used for home consumption, then the costs of implementing an output pricing scheme can be very high. According to Tsur and Dinar, "the measurement of output can be as formidable as that of water" and examples of output pricing as a means for pricing water are rare (Tsur and Dinar 1997, 245).

As the preceding section has shown, each policy instrument has its pros and cons in terms of both efficiency and implementation costs. These aspects must all be considered and weighed against each other in the effort to design the most socially efficient policy schemes for regulating farmers' use of irrigation water.

## Assignment

Your assignment is to discuss the efficiency and distributional implications of using tax policy instruments versus quota policy instruments to regulate farmers' use of irrigation water. Then, based on the features of the Egyptian economy and irrigation system, design a policy strategy for regulating farmers' use of irrigation water in Egypt, considering economic efficiency aspects, implementation costs, and stakeholder issues.

## Additional Readings

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