IMPROVING IRRIGATION WATER ALLOCATION EFFICIENCY USING ALTERNATIVE POLICY OPTIONS IN EGYPT

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Abstract

This study provides an empirical perspective on alternative irrigation policies for allocating limited water to agricultural production in Egypt. Positive mathematical programming is used for model calibration. Three policy options for Egypt are tested: water pricing, water complementary input factor taxes, and output taxes. The results of the research show that: 1) water pricing needs to be much higher than the recovery cost in order to be effective in limiting irrigation water use; 2) at a higher tax rate, fertilizer and energy taxes are effective in reducing the irrigation water demand while maintaining adequate welfare levels; 3) a pesticide tax is less effective than fertilizer or energy taxes; and 4) an output tax on sugar cane and rice would decrease irrigation water demand substantially while allocating land to other crops which are less water intensive and have higher market values.

Introduction

Over the last few decades, the promotion of rational use of water resources and the adoption of appropriate irrigation policies to encourage water conservation has become an increasingly critical issue in many developing countries. According to a study conducted by the International Water Management Institute, many regions including Northern China, North Africa, and Northern Sub-Saharan Africa will encounter fresh water shortage problems by 2025 (Seckler et al).

The agricultural sector is the largest consumer of water in developing countries. Coupled with the growing demand for water and increasingly unstable water supply, access to irrigation water is steadily decreasing. One solution to overcome this obstacle at relatively affordable costs and in a timely manner is to promote water conservation; more specifically, the practice of efficient allocation of available water resources to more productive uses among different users. Water allocation efficiency[1] is generally considered very low in developing countries, despite the large contribution of irrigated agriculture towards reducing the problem of hunger (Seckler, Barker, and Amarasinghe). Successful conservation projects and increasing irrigation efficiency is regarded as a new way to meet future increasing water demand.

Nevertheless, there are many competing views held by economists and policy makers from different countries and regions about the best ways this issue should be addressed. Most stakeholders believe that access to water is an inalienable human right, a social necessity, and that water is essential for maintaining a stable and healthy social and

[1] Water allocation efficiency is often referred to the amount of irrigation water that should be allocated among crops in order to achieve the most profitable overall use. If large volumes of water are allocated to crops producing low value, the total amount of value generated will be low and the water allocation is inefficient.

economic environment for many regions. However, others tend to view water as a private good: one that should be allocated through competitive market pricing. Briscoe, Perry et al., and Hellegers further clarified the notion about treating water as an “economic good” as distinguished from valuing and charging for water. Economic efficiency is only one of the basic criteria for helping make good decisions about the optimal use and allocation of water among potential users if the choice is made based on a socio-economic trade-off composed of social equity and ecological sustainability (Hellegers). This argues that a multidisciplinary approach should be taken to address water allocation issues.

Invention and implementation of such policy options for allocating water to more productive uses remains a challenge in many countries. Sensitive physical, social, institutional, political and economic contexts of many regions and countries have left water pricing a debated policy option. Limited acceptable ranges of pricing have weakened the effectiveness of water pricing (Molle; De Fraiture and Parrey; Perry; Ogg and Gollehon). High transaction costs embodied in the implementation of water pricing has limited its benefits. Slow institutional change characterizes many developing countries that depend upon irrigation agriculture (Saleth and Dinar; Tsur and Dinar; Rosegrand and Binswanger; Sampath). Nevertheless, economic efficiency criteria are attractive to most economists. Focus has been on the belief that resource allocation efficiency is achieved by equating cross sector marginal benefits (Dinar and Loehman).

One obstacle facing water pricing policies in developing countries is lag effects of past water pricing policies. In many countries where irrigated agriculture plays an important role, farmers believe low or zero charges are justified. This belief is usually reflected in their political systems (Mohmoud Abu-Zeid). Many countries may also lack the tradition, experience, and appropriate institutions to price irrigation water, and some water scarce countries have adopted macroeconomic policies that have negative effects on agriculture in general and water in particular (Diao, Roe, and Doukkali). Most developing countries provide irrigation and domestic water supply systems at subsidized rates. By doing so they can secure water and food supplies, protect public health, and avoid opposition from farmers and urban poor to raising water prices (Mohmoud Abu-Zeid).

The research presented here addresses these issues by examining alternatives to water pricing that might provide another means of increasing water use efficiency in Egypt. The paper examines three strategic policy options using Agricultural Sector Model of Egypt (ASME) (Siam): 1) water pricing; 2) taxation on water complementary input factors; and 3) taxation on water intensive crop output.

Policy Options

Water Pricing

Water pricing methods (Tsur and Dinar) have covered: volumetric pricing, output pricing, area pricing, tiered pricing, two-part tariff pricing, and market pricing. Tsur and Dinar and Johansson examined in great detail the various pricing options available, and the contributions of these options to the goal of achieving economic efficiency of water use. Water pricing policy in this study refers to volumetric pricing mechanisms where irrigation water is priced based on consumed quantities. Just as the criterion of pricing any scarce resource, the main norm of pricing water is efficiency. With water pricing, it is assumed that farmers compare their marginal benefits with the marginal costs they face when deciding on change in irrigated crop patterns. If all farmers face the same price, every one of them will modify their water use to maximize the total profit from using available water. Therefore, effective water prices can affect users' allocation plans toward more profitable water application, hence achieving water allocation efficiency.

Some district analyses have demonstrated that similar pricing policies may have very different impacts under different conditions (Tsur et al.), as reflected in the shape (elasticity) of the derived demand curves. Farms with steep (inelastic) demand curves will be less responsive to price increases when policy makers or project designers do not have a clear understanding of the shape of demand and supply curves. Without this information, it is hard to find the most sensible price that will optimize water use. Tiwari and Dinar reviewed the World Bank's Irrigation and Drainage portfolio. They found that economic incentives are not adequately used in many water allocation projects. Many of the incentive measures adopted, such as water pricing mechanisms, are based on the "user pays" principle. But how far the adoption of these incentive measures will help to promote various facets of water use efficiency is uncertain in many of these projects.

Water Complementary Input Factors Tax

Strong complementarities between inputs (fertilizer, pesticide, and energy) and irrigation water have been recognized in agronomy and agricultural engineering. These inputs have a substantial impact on water productivity and farm-level decisions (Wichelns). Applying tax policy to adjust water complementary input factors might be a feasible instrument to manage irrigation water demand with the advantage of easier implementation than direct water price modification (Tsur and Dinar). It may be particularly attractive in Egypt where nearly all agriculture is irrigated.

Fertilizer

Dry water-soluble fertilizer must be dissolved into water before it can be applied (Burns). Feinerman demonstrated that a tax on nitrogen fertilizer will motivate farmers to adopt optimal time paths of nitrogen and irrigation water inputs to achieve a certain level of reduction on total nitrogen leaching. A more recent study by the IFA and FAO examined crop yield response to irrigation and fertilizer and farmers' decision response to fertilizer price from the analysis of experiment and survey data (IFA et al). They concluded that (1) fertilizer use may tend to increase as the average number of irrigations increases; (2) fertilizer use correlates positively with adequacy of irrigation supplies, and the marginal productivity of fertilizer is higher where households have access to adequate irrigation supplies; and (3) farmers respond to fertilizer prices when making decisions regarding fertilizer use, and farm-level credit constraints limit the use of fertilizer in some areas.

Pesticides

Repetto first looked at how pesticide subsidies interfered with farmers' judgments about pesticide use in nine key countries and how the subsidy policy in these countries has encouraged this potential harmful practice. Removing the distortion or increasing the price of pesticides could influence farmers' production decisions, and as a consequence affect the farmers' allocation of water resource. A case study in Costa Rica (Agne, Fleischer and Waibel) has shown that pesticide taxation can achieve significant reductions of pesticide use. However, most of the research on excessive pesticide use has centered on the health and environmental issues caused by careless application or over use of pesticide, and providing agricultural producers with adequate incentives to use less pesticides. Very little attention has been given to how pesticide prices affect crop patterns with respect to irrigation water allocation.

Energy

Irrigation often requires considerable amounts of electricity or diesel fuel for pumping water. Many countries, including the United States, China, Morocco, Iran, Mexico and Egypt, use ground water intensively in their agricultural sectors. Electricity subsidies have contributed substantially to the rate of increase in crop yields following the Green Revolution by providing farmers with an affordable and reliable water source in these regions.

Water –Intensive Output Tax

Water-Intensive output taxes applied to high water-consuming and low value crops would influence the production level of such crops. Output taxes do not directly target water consumption, but have an indirect effect on crop patterns. To reduce tax liability, farmers often switch to other crops not taxed or put land into fallow. These strategies change the production of water consuming crops and intend to meet the goals of decreasing the demand for irrigation water. Clearly, in this case, an output tax is economically equivalent to a price reduction for the crop.

Characteristics of Egypt's Irrigated Agriculture

The Egyptian economy depends heavily on the agricultural sector, which functions as a source to support non-agricultural sector growth. In 2001, the Nile River supplied about 57.5 billion of cubic meters of water to Egypt. About 80% of this water was used in agriculture. There are about 3.3 million ha (7.85 million Feddan[2]) of agricultural land in Egypt. More than 90% of this land lies within the Nile basin and delta. Only about 2% of the agricultural land is rain fed. There are three cropping seasons in Egypt (Siam): winter (November-May), summer (April-October) and Nili (July-October). The main winter crops are wheat, berseem (Egyptian clover) and broad beans. Among summer crops, maize, rice and cotton are dominant. Vegetable crops such as tomato and potato are planted in all three seasons.

Farmers do not have to pay for their irrigation water. The country faces water scarcity due to increasing irrigation and industrial demand. Water administration is very centralized. A FAO report on Egypt (FAO, 2000, P41-42) stated the water policy concerns and that water pricing only has minimal impact on water conservation, although it is needed to raise financial resources to develop and maintain the huge water infrastructure. The report also indicated that there is no general strategy or model that could be used for cost recovery policy for Egypt to meet the revenue needs of the system, distribute the cost equitably, provide incentives for efficient use of water and capital, keep the tariff rate structure simple so it can be well understood and implemented, and protect the environment.

However, irrigation cost recovery is an important process to capture revenue for irrigation suppliers. Perry reviewed the actual costs incurred for operating and maintaining the infrastructure for water delivery and disposal in Egypt. His calculations are mainly based on the updated separable costs and remaining benefit (SCRB) approach. Table 1 presents representative results of the operation and maintenance cost for agricultural use of water calculated by Perry. The cost recovery of the irrigation water used in old land is

[2] 1 Feddan = 0.42 ha

about 11.696 LE/000M^3 which is much lower than the marginal value 56 LE/000M^3 obtained by Hazell et al. In this research, the cost recovery price is used as one of the water pricing levels to simulate the optimal solution on crop mix to maximize producer and consumer surplus under the water pricing policy.

Research Methodology

Agricultural Sector Model of Egypt (ASME)

Agricultural sector models are used as tools for analyzing quantitative economic problems in the agricultural sector in many studies (Jabara and Thompson; Hazell and Pomareda; Fajardo, McCarl and Thompson; Britz et al.). Such models are designed to analyze policy impacts on agriculture and therefore provide scenarios or suggestions to policy decision makers.

The Agricultural Sector Model of Egypt (ASME) (Siam) used in this research is a static partial equilibrium model in which social welfare in the form of consumer and producer surplus from agriculture based commodities are maximized subject to various constraints including resource, technical, and policy constraints. To achieve maximized welfare, an equilibrium demand and supply is required. Demand and supply balance of the agricultural products are the key equations to solve for activity levels.

The data set includes 1999 national and regional levels of land, labor, water resource availability and requirements, yields and fodder byproducts. The production of 27 crop commodities and 5 animal commodities in 8 regions are included. The ASME has updated prices and cropping patterns to 2001. The updated data is used as the base to calibrate the model.

Positive Mathematical Programming (PMP)

The ASME has been calibrated by the authors using Positive Mathematical Programming (PMP) to generate decision behavior when simulating impacts on the variables of interest under different policy options. The general PMP set up is:

$$
\begin{aligned}
&Max \quad \mathbf{p'x} - \mathbf{c'x} \\
&s.t. \\
&\mathbf{Ax} \le \mathbf{b} \qquad [\boldsymbol{\pi}] \\
&\mathbf{x} \le \mathbf{x}_0 \qquad [\boldsymbol{\lambda}] \\
&\mathbf{x} \ge \mathbf{0}
\end{aligned}
$$

Where **p** is the *n* by 1 vector of commodity prices; **c** is the *n* by 1 vector of costs levels for each **x**; $\mathbf{x}_0$ is *n* by 1 vector of observed activity levels; $\boldsymbol{\pi}$ are dual variables of the resource constraints; $\boldsymbol{\lambda}$ are the dual variables of the calibration constraints which are employed to specify a nonlinear objective function such that the marginal cost of the activities are equal to their respective prices at the base activity levels $\mathbf{x}_0$. Given that the implied variable cost function is convex in all activity levels, the solution to the resulting programming problem is a "boundary point, which is the combination of binding constraints and first order conditions" (Howitt, 1995, p.330).

When a quadratic cost function is employed, the general formula of this cost function is specified as: $C^* = \mathbf{c'x} + \frac{1}{2}\mathbf{x'Qx}$; *c* is an *n by 1* vector of parameters associated with the linear term; **Q** is *n* by *n* symmetric, positive semi-definite matrix of parameters associated with the quadratic term. Let q_{ii} be the *n* diagonal elements of **Q**. It can then be calculated $q_{ii} = \frac{\lambda_i}{x_i^0} \quad \forall \quad i = 1,...,n.$ The final nonlinear programming problem that is calibrated to the exact base year activity levels becomes *max* $\mathbf{p'x} - (\mathbf{c'x} + \frac{1}{2}\mathbf{x'Qx})$ under the constraints $\mathbf{Ax} \le \mathbf{b}$ [$\boldsymbol{\pi}$] and $\mathbf{x} \ge \mathbf{0}$.

Derived Demand Curve for Irrigation Water

Derivation of demand curves is necessary to evaluate any water pricing policy. Demand curves illustrate the relationship between the willingness to pay for water and the water capacity of a given region. They may provide reasonable and feasible scales while setting up pricing policies for curtailing water demand.

Water demand functions have been derived using limited information via mathematical programming models (Shunway; Kulshreshtha and Tewari; Chakravorty and Roumasset; Bontemps and Couture). The scheme to obtain such a demand function is as: (a) For a given output price, estimate the quantity of water maximizing the profit of the agricultural sector; (b) vary the level of water quantities to deduce the shadow prices under different levels of water; (c) plot the derived demand curve over quantity and the corresponding shadow price to derive the demand function.

Crop production is assumed to be Leontief technology. Optimal crop production is calculated under various resource constraints and prevailing input-output prices. The water shadow price (λ) constraint is the marginal value of irrigation water. The derived demand for water is determined by solving the producer's maximization problem:

$$Max \quad \sum_{j=1}^{m} L_j \pi_j \tag{1}$$

$$s.t. \quad \pi_j = p_j y_j - \sum_{i=1}^{n} r_i z_{ij} \tag{2}$$

$$\sum_{j=1}^{m} L_j \le L \tag{3}$$

$$\sum_{j=1}^{m} L_j a_j \le W : [\lambda] \tag{4}$$

$$\sum_{j=1}^{m} b_{ij} L_j \le Z_i \tag{5}$$

$$L_j \ge 0 \tag{6}$$

Where L_j is the land allocated to crop *j*; y_j is yield of crop *j*; a_j is coefficient between water and yield of crop *j*; z_{ij} is quantity of other inputs *i* required for crop *j* per unit land; b_{ij} is coefficient between other inputs *i* and yield of crop *j*; p_j is price for output crop *j*; r_j is price vector for input factor *i* ; Z_i is available input levels for input factor *i* ; π_j is the unit land return on crop *j* ; λ is the water shadow price.

Equation (1) is the objective function of the producer's profit maximizing problem. Equation (2) defines the unit land returns on crop *j*, and equation (3) is the available land constraint. Equation (4) is the constraint on available irrigation water. The levels of the constraint are varied between the interval [0, *W**], where *W** is the maximum water capacity in the country. Each iteration yields a new water shadow price (λ). This shadow value is used to find derived demand for water at every level of *W*. By successively solving the producer's maximization problem this way, the derived demand for water for a given country can be traced. Equation (5) is a constraint for other input factors, and equation (6) is the non-negativity constraint on land.

Scenario Design

Three major scenarios are simulated using the modified ASME model: (1) a water pricing policy; (2) an input tax policy; and (3) an output tax policy. Table 2 summarizes these scenarios. The water pricing scenario observes the effects under different water pricing levels (cost recovery, and three shadow price levels). The input factor tax scenario includes three sub-scenarios: Nitrogen Fertilizer (N-Fertilizer), Pesticides, and Energy. The output tax scenario taxes paddy (rice) and sugar cane production since these crops are irrigation water intensive and have lower profits level among all other crops in Egypt.

The results of the policy simulation are presented in three categories: 1) the extent to which complementary input taxes and high water-consuming crop output taxes can be used as a proxy for water pricing; 2) farmers' response in crop production under different policy scenarios; 3) the effects of policy measures on changes in consumer and producer welfare gains.

The welfare measurement for this research is composed of consumer and producer surplus to agricultural commodities consumed by households, including crop and crop-based commodities and livestock commodities. These goods are mainly primary goods. Consumer and producer surplus represents how much benefit consumers and producers can extract at equilibrium. It is a well used measure for welfare change under different policy options giving an overall base for ranking preferences amongst a series of policies.

Water conservation is measured by the decreasing rate of demand for irrigation water after implementing a certain policy. Water demand is based on the crop pattern and water requirements for each crop. Water demand due to technology change is reflected by the yield response to deficit irrigation water usage on most of the crops. Therefore, two factors will affect water conservation: reduction in the production of water intensive crops and less water used on these crops.

Land reallocation and crop commodity production level is another important aspect that reflects farmer behavior in response to different policy alternatives. It can provide a trace of where the input factors, including water and fertilizer, are allocated, and how much a difference a specific policy can make on influencing farmers' input decision. It is also an indicator for agricultural policy makers and irrigation water managers while looking at any effectiveness of feasible policies.

Results

Water Pricing Policy Scenario

The demand for irrigation water in Egypt is inelastic when the price is low according to a derived demand curve for irrigation water (Figure 1). The irrigation water is the actual amount of water received by field crops. It is the amount of water used for agricultural irrigation after taking off the effect of conveyance efficiency, evaporation loss and the rainfall capacity. The shadow prices were deduced from different irrigation water constraints.

Table 3 gives the welfare change and irrigation water demand changes when using different water pricing levels. The first price level is 0.011696 LE/M^3 which is the cost recovery price calculated by Perry in 1996. The second, third and fourth price levels are the deduced shadow price levels found by changing the irrigation water constraint to less than the binding level by 5%, 10% and 20% respectively. The results show that demand for irrigation water is inelastic when water price is set low. To reduce irrigation water by 10%, the water price has to be at least 0.083 LE/M^3, which is about seven times as much as the cost recovery price. This induces a decrease in welfare by 5.63%.

Crop production changes per thousand tons (000t) and percentage (%) to its base level are reported in table 4. The production level decreased on almost all crops except citrus, which is fixed in the model. The largest change happens with berseem (Egyptian clover), maize, paddy (rice), sugar beet and sugar cane when water price increases from 0 to 0.17 LE/M^3. Sugar cane and paddy (rice) rank the highest two crops in using irrigation water per unit are in Egypt. However profitability for these crops is lower than tomato, potato and other vegetables. Berseem, maize and sugar beet may not use as much irrigation water as sugar cane and paddy production, but their profitability are in the relatively low ranks.

Table 5 describes the reductions in irrigation water. When the water price level is 0.01169 LE/M^3, the total irrigation water reduction is about1.83% of the base level. The reduction mainly comes from long berseem (-0.24%), summer maize (-0.16%), paddy (-0.21%) and sugar cane (-0.66%).

As water price increases, these crops are also the main source of irrigation water reduction. At the water price level 0.083 LE/M^3, summer maize, paddy, and sugar cane production contribute most to the deduction of irrigation water demand. The irrigation water demand reduction in summer maize accounts for 1.16% of the total, paddy accounts for 1.72%, and sugar cane accounts for 2.45%. At the price level of 0.17 LE/M^3, the irrigation water usage falls by 19.79%. The contribution of long berseem to this irrigation water reduction level is 1.18%, summer maize 2.36%, paddy 3.54%, sugar cane 5.06%, and wheat 1.59%.

Taxation on N-Fertilizer, Pesticides and Energy

Different tax levels on water complementary input factors including nitrogen fertilizer (N-fertilizer), pesticides and energy were simulated to find the best levy rate options to approximate the solution under a water pricing scheme.

N-fertilizer scenario results are presented in table 6 and table 7. The tax rate range for N-fertilizer ranges from 0% (base level) to 300%. N-fertilizer tax will affect the cropping decision and hence the demand for irrigation water. However, until the price of N-fertilizer increases by more than 50%, there are no appreciable changes in reduction of irrigation water use. When the N-fertilizer tax increases by 300%, the welfare decreases

8.55%. The demand for irrigation water decreases by 11.24% at this tax level (Table 6). The prominent changes in crop production are from sugar cane and sugar beet as the tax rate on N-fertilizer increases. This is reasonable because these crops comparatively need more N-fertilizer input than other crops in Egypt.

Soybean production also decreased as the N-fertilizer cost increases. Soybean production in Egypt uses N-fertilizer, although nitrogen fertilizer is not needed in most situations if it is properly inoculated. However, the N-fertilizer has to be used in Egypt because there is a deficient in nitrogen in the sandy and clay soils and low nitrogen use efficiency, 20% in some places, and never exceeds 50% (Ferguson et al.).

Soybean production in Egypt has been very low (about 15 thousand tons in 2001). Table 7 shows that irrigation water reduction will not be affected much by soybean, but by wheat, sugar cane, sugar beet, paddy, summer maize, and Nili maize. Summer vegetables and tomato production also decrease as the tax level increases. However, the irrigation water for winter vegetables increases because the increasing price of N-fertilizer encouraged more land to be used to produce winter vegetables which consume less N-fertilizer and water.

In the pesticide tax scenario, changing the pesticides cost has limited effects on both welfare level and irrigation water demand (Table 8). When pesticides cost increases 200%, the irrigation water demand only decreases by -2.35%, while the welfare level decreases by -3.85%. To obtain a higher reduction in irrigation water demand, pesticide cost should be even higher. At the 300% tax level, the welfare level decreases by 5.72%. However, irrigation water demand is only 3.18% less than the base level.

From the perspective of crop production, the most affected crop is sugar beet. Almost no noticeable reduction occurred with sugar cane when the tax rate ranges from 0 to 50%. Most of the other crops are affected by about the same magnitude as the pesticide tax rate increase since the cost of pesticide per unit land on most of the crops in Egypt are similar. Pesticide taxes decreases the production of tomatoes and vegetables as well.

According to Table 9, the contribution of irrigation water reduction comes most from paddy production and almost equally from the rest of the main crops in Egypt. Even at the 300% tax level, sugar cane only contributes 0.09% to the total reduction of irrigation water.

Results from the energy tax scenario are summarized in Table 10. "Energy price" here refers to the water pumping costs used in crop production. Comparing with pesticide scenario, table 10 shows that irrigation water demand decreases in a higher rate in this scenario as the pumping costs increases. About 10% of irrigation water reduction happened when energy tax is as high as 300%, and the welfare level decreases 6.64% from the base level. Increasing of pumping costs affects most the production of sugar beet, sugar cane, maize and soybean. Fava bean, lentil, maize, paddy, sesame, sorghum, and wheat production also decrease, although not as much as sugar beet and sugar cane. The high market value crops, such as potato, onion, tomato and other vegetables change less compared to other crops even when the pumping cost is increased by 300%. There are negligible effects on cotton production.

At the 300% energy tax level, the total 9.47% reduction of irrigation water is mainly composed of water use decreasing from sugar cane (-2.37%), paddy (-2.01%), summer maize (-1.28%), Nili maize (-0.68%), long berseem (-0.67%), and wheat (-0.81%) (Table

11). A similar result patterns happen at the 75% to 200% energy tax level. Other than these staple crops, water consumption of rest of the crops will not be affected very much.

Taxation on Sugar cane and Paddy

Taxation on sugar cane and paddy production decreases irrigation water demand as expected. Increasing the tax rate from 5% to 50%, the welfare level will change from -0.53% to -3.97% while the irrigation water demand will change from -1.11% to -13.91% (Table 12).

Production reduction only happens with sugar cane and paddy. However, the production of profitable crops, such as lentil, increases up to 26.58% along with the increasing tax on sugar cane and paddy. A slight increase also happens with wheat and barley production.

The main contributions to irrigation water reduction are from sugar cane and paddy. Although winter vegetable and wheat demands more irrigation water as the output tax rate increases, the change in demand for water is very small. Wheat only needs 0.07% more of the total base irrigation water and winter vegetable will need only 0.28% more of the total base irrigation level, even the output tax rate is 50% (Table 13).

At the output tax level of 40%, total irrigation water reduction decreases 10.92%. The main contribution to this irrigation water deduction are from sugar cane (-5.88%) and paddy (-5.49%) (Table 13). Except for a slight decrease in long berseem, Nili vegetable and barley, the rest of the crops increase irrigation water demand by 0.45%.

Conclusions

Water pricing policy works well in reducing the irrigation water use in Egypt when the water price level is high. Cost recovery price levels may help with financial scarcity problems. However, it is not very effective in limiting irrigation water demand. Not all the water complementary input factor taxes will work well in Egypt. Increasing N-fertilizer and energy costs up to 200%-300% of the current level will affect the irrigation water demand significantly without decreasing very much welfare, although this level of input tax rate may not be reasonable or realistic. A pesticide tax may not be a good driver in decreasing irrigation water demand and keeping the welfare level similar in Egypt since higher pesticide cost will not affect the water intensive crops substantially. The output tax tool may work better compared with input factor tax. For a detailed comparison of these policy scenarios in welfare and reduction of irrigation water demand, please see Table 14.

The research undertaken here is very important given the lack of information on the subject of irrigation policy regarding water complementary input factors and high water-consuming crop. The results have shown that it is a beneficial area of research for Egypt and should receive more attention. However, taxation policy on input and output factors policies are intervention tools that affect not only production, but agriculture as a whole. In a long run, price, market condition, cropping patterns, production technologies will all experience adjustment. Policy scenario outcomes in reality will not be as smooth as in our results. Effects on certain markets and the implications of international trade are left to other studies since this study only uses a partial equilibrium model and centers on farmers' decision making based on input and output data, and crop production budget structure.

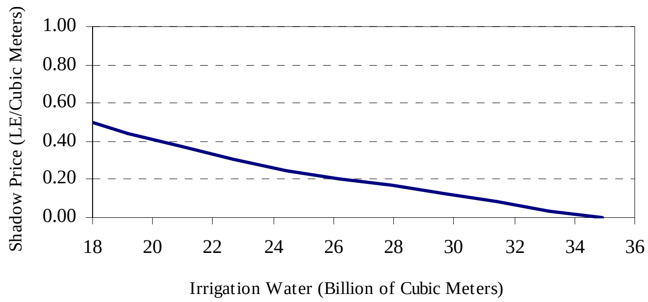

Figure 1. Derived Demand Curve for Irrigation Water

Table 1 Operation and Maintenance (O&M) Cost for Water Supply in Egypt

Sector	**Cost**		
	US $	LE	Exchange Rate 1$ = 3.4 LE
Old Lands Agriculture	3.44	11.696	
New Lands Agriculture	3.34	11.356	

Source:Perry (1996)

Table 2 Description of policy scenarios in Egypt

Scenarios	Water(1)	Water (2)	Water (3)	Water (4)	N- Fertilizer	Pesticides	Energy	Paddy(Rice)	Sugar Cane
Water Pricing	√	√	√	√					
Input Factor Tax					√	√	√		
Output Tax								√	√

Water (1): Using cost recovery price level calculated by Perry in 1996
Water (2): Using shadow price at the 5% reduction of irrigation water
Water (3): Using shadow price at the 10% reduction of irrigation water
Water (4): Using shadow price at the 20% reduction of irrigation water

Table 3 Welfare and Irrigation Water Demand Changes under Different Water Pricing Levels.

Water Price level	**Welfare**		**Irrigation Water Demand**	
LE/M3	level *million LE*	Change *%*	level *bcm*	Change *%*
Pw = 0	48.7		34.9	
Pw = 0.01169	48.3	-0.83%	34.28	-1.83%
Pw = 0.036	47.47	-2.52%	33.26	-4.75%
Pw = 0.083	45.95	-5.63%	31.43	-10.01%
Pw = 0.17	43.37	-10.93%	28.01	-19.79%

bcm : billions of cubic meters
pw: water pricing level

Table 4 Crop Production Levels and Percentage Changes from the Base under Different Water Price Levels.

Crop Production	Base	Pw= 0.01169 LE/M3		Pw = 0.036 LE/M3		Pw =0.083 LE/M3		Pw =0.17 LE/M3	
	000t	*000t*	*%*	*000t*	*%*	*000t*	*%*	*000t*	*%*
Barley	93.990	-0.86	-0.92%	-1.91	-2.04%	-4.68	-4.98%	-10.22	-10.88%
Berseem	61732.416	-286.77	-0.46%	-792.38	-1.28%	-1896.89	-3.07%	-3985.50	-6.46%
Citrus	6076.431	-	-	-	-	-	-	-	-
Fava Bean	424.551	-9.57	-2.25%	-22.71	-5.35%	-54.13	-12.75%	-84.87	-19.99%
Flax	67.940	-0.12	-0.17%	-0.36	-0.52%	-0.92	-1.35%	-1.88	-2.77%
Ground Nut	207.000	-1.82	-0.88%	-4.87	-2.35%	-11.64	-5.62%	-23.05	-11.13%
Legumes	34.987	-0.41	-1.17%	-0.95	-2.70%	-2.77	-7.91%	-6.52	-18.63%
Lentils	3.764	0.01	0.13%	0.03	0.80%	-0.20	-5.37%	-1.44	-38.12%
Maize	6906.005	-84.45	-1.22%	-264.41	-3.83%	-611.81	-8.86%	-1187.34	-17.19%
Onion	796.569	-5.88	-0.74%	-15.74	-1.98%	-36.13	-4.54%	-72.34	-9.08%
Paddy	5225.863	-64.44	-1.23%	-200.78	-3.84%	-543.44	-10.40%	-1113.47	-21.31%
Potato	1086.311	-2.96	-0.27%	-9.12	-0.84%	-20.97	-1.93%	-41.12	-3.79%
Cotton (G45)	0.077	0.00	-0.88%	0.00	-2.60%	0.00	-5.19%	-0.01	-10.39%
Cotton (G70)	77.835	-0.74	-0.95%	-2.27	-2.92%	-5.23	-6.72%	-10.72	-13.77%
Cotton (G88)	13.821	-0.12	-0.83%	-0.36	-2.57%	-0.82	-5.92%	-1.68	-12.13%
Cotton (G80)	88.406	-1.57	-1.77%	-4.86	-5.49%	-11.23	-12.70%	-21.20	-23.97%
Cotton (G83)	39.079	-0.59	-1.50%	-1.81	-4.62%	-4.17	-10.66%	-8.53	-21.83%
Cotton (G85)	88.532	-0.92	-1.04%	-2.86	-3.23%	-7.19	-8.12%	-14.73	-16.63%
Cotton (G86)	132.095	-0.98	-0.74%	-3.02	-2.29%	-6.97	-5.28%	-14.29	-10.82%
Cotton (G89)	153.815	-1.39	-0.90%	-4.31	-2.80%	-11.07	-7.20%	-22.68	-14.74%
Sesame	32.989	-0.47	-1.43%	-1.46	-4.42%	-3.36	-10.17%	-6.72	-20.37%
Sugarbeet	2857.714	-172.25	-6.03%	-509.67	-17.83%	-1201.74	-42.05%	-2438.96	-85.35%
Sugarcane	15387.614	-506.90	-3.29%	-1559.41	-10.13%	-3802.32	-24.71%	-8575.94	-55.73%
Sorghum	792.039	-10.57	-1.33%	-33.05	-4.17%	-75.50	-9.53%	-151.31	-19.10%
Soybean	14.847	-0.62	-4.18%	-1.90	-12.76%	-4.44	-29.90%	-8.26	-55.63%
Tomato	6290.013	-20.04	-0.32%	-55.15	-0.88%	-127.24	-2.02%	-264.00	-4.20%
Vegetables	11007.709	-27.29	-0.25%	-73.33	-0.67%	-161.43	-1.47%	-320.77	-2.91%
Wheat	6369.155	-54.20	-0.85%	-138.31	-2.17%	-346.77	-5.44%	-777.66	-12.21%

Citrus production is fixed in the model

Table 5 Decomposition of Irrigation Water Demand Reduction at Different Water Price Levels

Crop Item	Irrigation Water Demand (Base Level)	Pw = 0.01169 LE/M3		Pw = 0.036 LE/M3		Pw =0.083 LE/M3		Pw =0.17 LE/M3	
	mcm	*mcm*	*%*	*mcm*	*%*	*mcm*	*%*	*mcm*	*%*
Citrus	4114.46	-	-	-	-	-	-	-27.44	-0.08%
Favabean	370.69	-9.14	-0.03%	-21.75	-0.06%	-50.50	-0.14%	-79.74	-0.23%
Cotton (G80)	355.20	-6.30	-0.02%	-19.55	-0.06%	-45.19	-0.13%	-85.09	-0.24%
Cotton (G86)	444.57	-3.31	-0.01%	-10.18	-0.03%	-23.46	-0.07%	-48.10	-0.14%
Cotton (G89)	500.15	-4.86	-0.01%	-15.12	-0.04%	-39.82	-0.11%	-81.58	-0.23%
Groundnut	553.42	-3.97	-0.01%	-60.31	-0.17%	-80.49	-0.23%	-200.59	-0.57%
Long berseem	3999.04	-84.43	-0.24%	-122.01	-0.35%	-193.59	-0.55%	-410.34	-1.18%
Nili maize	619.43	-17.25	-0.05%	-59.38	-0.17%	-121.72	-0.35%	-252.33	-0.72%
Paddy	5617.22	-72.16	-0.21%	-224.50	-0.64%	-599.70	-1.72%	-1235.84	-3.54%
Short berseem (winter)	554.15	-7.34	-0.02%	-24.57	-0.07%	-38.43	-0.11%	-75.65	-0.22%
Sugar cane	3053.27	-229.75	-0.66%	-429.20	-1.23%	-855.85	-2.45%	-1767.45	-5.06%
Summer maize	4709.17	-54.34	-0.16%	-165.04	-0.47%	-403.52	-1.16%	-825.30	-2.36%
Summer sorghum	922.92	-11.89	-0.03%	-35.93	-0.10%	-83.77	-0.24%	-175.26	-0.50%
Summer tomato	601.35	-7.35	-0.02%	-25.36	-0.07%	-54.61	-0.16%	-110.16	-0.32%
Summer vegetables	1090.42	-8.87	-0.03%	-18.95	-0.05%	-44.61	-0.13%	-88.81	-0.25%
Wheat	4158.97	-38.22	-0.11%	-85.78	-0.25%	-230.69	-0.66%	-556.49	-1.59%
Winter vegetables	710.50	16.36	0.05%	-130.91	-0.37%	-213.58	-0.61%	-227.33	-0.65%
Others	2543.81	-95.67	-0.27%	-209.29	-0.60%	-414.35	-1.19%	-661.49	-1.89%
Total	34918.73	-638.47	-1.83%	-1657.82	-4.75%	-3493.87	-10.01%	-6908.98	-19.79%

mcm: million cubic meters

%: the percentage change of irrigation water demand on the base level of total irrigation water demand for all crops

Irrigation water: rainfall not included

Paddy: 125 days growing season paddy

Others: crop which consums less than 1% of the total irrigation water at the base level is grouped in "others"

Table 6 Welfare, Irrigation Water Demand, and Crop Production Level Change from the Base for N-Fertilizer Scenario.

N-Fertilizer Tax Level	Base	25%	50%	75%	100%	200%	300%
		Welfare and Irrigation Water Demand Change from the Base (percentage)					
Welfare: Consumer and Producer Surplus	48.692 Billion LE	-0.76	-1.52	-2.26	-3.00	-5.84	-8.55
Irrigation Water Demand	34.919 *bcm*	-0.99	-2.01	-2.88	-3.77	-7.45	-11.24
Crop Items	Base *000 ton*	Crop Production Change from the Base (percentage)					
Barley	93.990	-0.12	-0.13	-0.05	-0.01	0.25	-0.33
Berseem	61732.416	0.09	0.17	0.27	0.36	0.65	0.69
Citrus	6076.431	-	-	-	-	-	-
Fava Bean	424.551	-0.53	-0.96	-1.25	-1.66	-3.52	-7.20
Flax	67.940	-0.25	-0.51	-0.76	-1.02	-2.12	-3.18
Ground Nut	207.000	-0.47	-0.89	-1.26	-1.62	-3.09	-4.67
Legumes	34.987	-0.15	-0.10	0.12	0.34	0.97	-0.55
Lentils	3.764	1.75	3.92	6.18	8.41	15.81	10.43
Maize	6906.005	-1.39	-2.79	-4.20	-5.60	-11.32	-17.00
Onion	796.569	-0.82	-1.63	-2.44	-3.25	-6.43	-9.74
Paddy	5225.863	-0.36	-0.97	-1.45	-1.93	-4.88	-7.33
Potato	1086.311	-0.75	-1.53	-2.30	-3.07	-6.22	-9.33
Cotton (G45)	0.077	-0.69	-1.16	-1.63	-2.10	-3.98	-5.86
Cotton (G70)	77.835	-0.67	-1.35	-2.02	-2.70	-5.39	-8.09
Cotton (G88)	13.821	-0.60	-1.19	-1.78	-2.38	-4.75	-7.12
Cotton (G80)	88.406	-1.53	-3.04	-4.56	-6.09	-12.19	-18.31
Cotton (G83)	39.079	-1.39	-2.77	-4.16	-5.54	-11.09	-16.63
Cotton (G85)	88.532	-0.74	-1.49	-2.24	-2.99	-6.42	-9.63
Cotton (G86)	132.095	-0.53	-1.06	-1.59	-2.12	-4.23	-6.35
Cotton (G89)	153.815	-0.59	-1.20	-1.80	-2.40	-5.29	-7.94
Sesame	32.989	-0.74	-1.49	-2.23	-2.98	-5.95	-8.94
Sugarbeet	2857.714	-12.59	-25.10	-37.45	-49.83	-94.27	-97.26
Sugarcane	15387.614	-3.19	-6.31	-9.42	-12.54	-25.33	-40.78
Sorghum	792.039	-1.05	-2.12	-3.18	-4.26	-8.33	-12.32
Soybean	14.847	-2.28	-4.54	-6.81	-9.07	-18.13	-27.09
Tomato	6290.013	-0.75	-1.51	-2.25	-2.99	-5.95	-8.99
Vegetables	11007.709	-0.23	-0.45	-0.67	-0.89	-1.77	-2.71
Wheat	6369.155	-1.13	-2.23	-3.28	-4.34	-8.67	-13.86

Table 7 Decomposition of Irrigation Water Demand Reduction at Different N-fertilizer Tax Level.

N-fertilizer Tax Level	***Base***	**75%**		**100%**		**200%**		**300%**	
	mcm	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*
Citrus	4114.461	-	-	-	-	-	-	-	-
Favabean	370.693	-3.41	-0.01	-4.41	-0.01	-9.32	-0.03	-22.60	-0.06
Groundnut	553.419	-5.97	-0.02	-7.97	-0.02	-15.98	-0.05	-24.80	-0.07
Long berseem	3999.037	-52.38	-0.15	-48.26	-0.14	-32.90	-0.09	-31.18	-0.09
Nili maize	619.427	-70.52	-0.20	-94.91	-0.27	-187.86	-0.54	-286.62	-0.82
Summer maize	4709.168	-151.62	-0.43	-201.79	-0.58	-413.13	-1.18	-621.18	-1.78
Paddy	5617.223	-81.29	-0.23	-108.39	-0.31	-271.26	-0.78	-406.67	-1.16
Short berseem (winter)	554.147	-3.64	-0.01	-6.84	-0.02	-7.04	-0.02	-7.28	-0.02
Sugar cane	3053.274	-287.73	-0.82	-382.84	-1.10	-773.18	-2.21	-1246.83	-3.57
Cotton (G80)	355.198	-16.23	-0.05	-21.67	-0.06	-43.37	-0.12	-65.12	-0.19
Cotton (G86)	444.568	-7.06	-0.02	-9.41	-0.03	-18.81	-0.05	-28.23	-0.08
Cotton (G89)	500.153	-8.85	-0.03	-11.80	-0.03	-26.88	-0.08	-40.33	-0.12
Summer sorghum	922.921	-24.67	-0.07	-32.78	-0.09	-67.63	-0.19	-103.53	-0.30
Summer tomato	601.352	-16.61	-0.05	-23.46	-0.07	-46.97	-0.13	-67.92	-0.19
Summer vegetables	1090.415	-17.59	-0.05	-21.28	-0.06	-36.93	-0.11	-53.49	-0.15
Winter vegetables	710.496	24.94	0.07	24.50	0.07	22.66	0.06	34.63	0.10
Wheat	4158.972	-117.30	-0.34	-152.77	-0.44	-298.72	-0.86	-504.33	-1.44
Others	2543.81	-166.17	-0.48	-210.91	-0.60	-372.93	-1.07	-450.62	-1.29
Total	**34918.73**	-1006.11	**-2.88**	-1314.97	**-3.77**	-2600.22	**-7.45**	-3926.09	**-11.24**

Table 8 Welfare, Irrigation Water Demand and Crop Production change for the pesticide tax scenario.

Pesticide Tax Level	**Base**		**25%**	**50%**	**75%**	**100%**	**200%**	**300%**
			Welfare and Irrigation Water Demand Change from the Base (percentage)					
Welfare: Consumer and Producer Surplus	48.692	Billion LE	-0.49	-0.98	-1.46	-1.95	-3.85	-5.72
Irrigation Water Demand	34.919	*bcm*	-0.19	-0.46	-0.81	-1.19	-2.35	-3.18
	Base	*000 ton*	Crop Production Change from the Base (percentage)					
Barley	93.990		0.05	-0.06	-0.21	-0.27	-0.65	-0.89
Berseem	61732.416		0.04	0.04	0.05	0.07	0.07	0.12
Citrus	6076.431		-	-	-	-	-	-
Fava Bean	424.551		-1.58	-3.34	-5.25	-6.82	-14.33	-18.57
Flax	67.940		-0.06	-0.12	-0.18	-0.24	-0.49	-0.74
Ground Nut	207.000		-0.04	-0.17	-0.43	-0.67	-1.30	-1.91
Legumes	34.987		0.15	0.22	0.10	-0.11	-0.17	-0.24
Lentils	3.764		-0.08	-0.37	-0.71	-0.97	-2.11	-3.39
Maize	6906.005		-0.09	-0.31	-0.50	-0.80	-1.57	-2.36
Onion	796.569		-0.47	-1.02	-1.54	-2.15	-4.31	-6.45
Paddy	5225.863		-0.05	-0.35	-0.73	-0.98	-1.95	-2.97
Potato	1086.311		-0.58	-1.19	-1.79	-2.43	-4.86	-7.30
Cotton (G45)	0.077		-0.46	-0.70	-0.94	-1.18	-2.15	-3.11
Cotton (G70)	77.835		-0.35	-0.69	-1.04	-1.38	-2.77	-4.15
Cotton (G88)	13.821		-0.31	-0.61	-0.92	-1.22	-2.44	-3.66
Cotton (G80)	88.406		-0.42	-0.90	-1.29	-2.33	-4.65	-6.96
Cotton (G83)	39.079		-0.50	-1.02	-1.54	-2.07	-4.12	-6.16
Cotton (G85)	88.532		-0.24	-0.77	-1.17	-1.56	-3.12	-4.70
Cotton (G86)	132.095		-0.27	-0.54	-0.81	-1.09	-2.17	-3.26
Cotton (G89)	153.815		-0.32	-0.66	-1.01	-1.36	-2.72	-4.09
Sesame	32.989		0.13	0.12	0.01	-0.12	-0.24	-0.35
Sugarbeet	2857.714		-11.59	-23.32	-34.78	-46.22	-91.77	-97.02
Sugarcane	15387.614		0.01	-0.05	-0.10	-0.31	-0.64	-0.98
Sorghum	792.039		-0.08	-0.13	-0.19	-0.30	-0.58	-0.86
Soybean	14.847		0.08	-0.09	0.09	-1.75	-3.48	-5.20
Tomato	6290.013		-0.69	-1.40	-2.15	-2.88	-5.76	-8.62
Vegetables	11007.709		-0.27	-0.56	-0.87	-1.17	-2.36	-3.53
Wheat	6369.155		-0.13	-0.36	-0.59	-0.84	-1.75	-2.60

Table 9 Irrigation Water Demand Decomposition and Changes under Different Pesticide Tax Levels

Pesticide Tax Level	***Base***	**75%**		**100%**		**200%**		**300%**	
	mcm	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*
Citrus	4114.461	-	-	-	-	-	-	-	-
Favabean	370.693	-19.47	-0.06	-25.38	-0.07	-53.20	-0.15	-68.69	-0.20
Groundnut	553.419	-1.27	-	-2.57	-0.01	-5.97	-0.02	-9.30	-0.03
Long berseem	3999.037	-6.43	-0.02	-29.21	-0.08	-49.13	-0.14	-62.22	-0.18
Nili maize	619.427	-15.06	-0.04	-21.22	-0.06	-42.70	-0.12	-65.02	-0.19
Summer maize	4709.168	-8.28	-0.02	-18.28	-0.05	-35.54	-0.10	-52.88	-0.15
Paddy	5617.223	-41.11	-0.12	-55.28	-0.16	-110.29	-0.32	-167.80	-0.48
Short berseem (winter)	554.147	0.67	-	1.54	-	-0.50	-	-0.63	-
Sugar cane	3053.274	-3.71	-0.01	-9.89	-0.03	-20.20	-0.06	-30.74	-0.09
Cotton (G80)	355.198	-4.56	-0.01	-8.28	-0.02	-16.55	-0.05	-24.75	-0.07
Cotton (G86)	444.568	-3.62	-0.01	-4.83	-0.01	-9.66	-0.03	-14.49	-0.04
Cotton (G89)	500.153	-5.50	-0.02	-7.37	-0.02	-14.74	-0.04	-22.25	-0.06
Summer sorghum	922.921	-0.44	-	-1.03	-	-1.99	-0.01	-2.79	-0.01
Summer tomato	601.352	-18.35	-0.05	-23.07	-0.07	-52.01	-0.15	-76.07	-0.22
Summer vegetables	1090.415	-18.46	-0.05	-23.18	-0.07	-42.05	-0.12	-60.15	-0.17
Winter vegetables	710.496	-5.65	-0.02	1.50	-	0.13	-	-3.06	-0.01
Wheat	4158.972	-21.27	-0.06	-32.49	-0.09	-66.05	-0.19	-97.61	-0.28
Others	2543.81	-111.69	-0.32	-157.15	-0.45	-300.98	-0.86	-350.10	-1.00
Total	**34918.73**	-284.18	**-0.81**	-416.16	**-1.19**	-821.43	**-2.35**	-1108.55	**-3.17**

Table 10 Welfare, irrigation water demand and crop production level change for the energy tax scenario.

Energy Tax Level	**Base**	**25%**	**50%**	**75%**	**100%**	**200%**	**300%**
		Welfare and Irrigation Water Demand Change from the Base (percentage)					
Welfare: Consumer and Producer Surplus	48.692 Billion LE	-0.58	-1.16	-1.73	-2.30	-4.51	-6.64
Irrigation Water Demand	34.919 *bcm*	-0.79	-1.62	-2.41	-3.11	-6.19	-9.47
	Base *000 ton*	Crop Production Change from the Base (percentage)					
Barley	93.990	-0.30	-0.57	-0.70	-0.89	-1.59	-2.91
Berseem	61732.416	-0.30	-0.65	-0.93	-1.26	-2.60	-4.06
Citrus	6076.431	-	-	-	-	-	-
Fava Bean	424.551	-2.01	-4.08	-5.66	-7.80	-15.86	-19.62
Flax	67.940	-0.20	-0.40	-0.59	-0.80	-1.69	-2.54
Ground Nut	207.000	-0.51	-1.06	-1.50	-1.95	-3.74	-5.59
Legumes	34.987	-0.13	-0.43	-0.36	-0.31	-0.32	-2.30
Lentils	3.764	0.38	0.96	1.80	2.54	4.07	-7.17
Maize	6906.005	-0.86	-2.01	-3.02	-4.03	-8.20	-12.32
Onion	796.569	-0.17	-0.51	-0.74	-0.99	-1.92	-2.94
Paddy	5225.863	-0.87	-1.75	-2.62	-3.50	-8.19	-12.30
Potato	1086.311	-0.19	-0.49	-0.74	-0.99	-2.09	-3.15
Cotton (G45)	0.077	-0.22	-0.22	-0.22	-0.22	-0.21	-0.22
Cotton (G70)	77.835	-	-	-	-	-	-
Cotton (G88)	13.821	-	-	-	-	-	-
Cotton (G80)	88.406	0.53	0.02	0.02	0.02	0.03	0.02
Cotton (G83)	39.079	-	-	-	-	0.01	-
Cotton (G85)	88.532	0.07	0.13	0.20	0.26	-	-
Cotton (G86)	132.095	-	-	-	-	0.01	-
Cotton (G89)	153.815	0.08	0.14	0.22	0.29	-	-
Sesame	32.989	-0.65	-1.51	-2.27	-3.02	-6.04	-9.07
Sugarbeet	2857.714	-6.24	-12.64	-18.92	-25.13	-51.11	-76.71
Sugarcane	15387.614	-1.89	-4.04	-6.00	-7.98	-16.21	-27.11
Sorghum	792.039	-0.90	-1.87	-2.81	-3.75	-7.42	-11.20
Soybean	14.847	-2.02	-7.00	-10.49	-13.98	-27.93	-41.80
Tomato	6290.013	-0.36	-0.75	-1.11	-1.47	-2.91	-4.46
Vegetables	11007.709	-0.16	-0.36	-0.51	-0.69	-1.37	-2.11
Wheat	6369.155	-0.58	-1.27	-1.79	-2.38	-4.76	-7.92

Table 11 Irrigation Water Demand Decomposition and Changes at Different Energy Tax Level

Energy Tax Level	***Base***	**75%**		**100%**		**200%**		**300%**	
	mcm	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*
Citrus	4114.461	-	-	-	-	-	-	-	-
Favabean	370.693	-21.25	-0.06	-29.12	-0.08	-58.95	-0.17	-73.65	-0.21
Groundnut	553.419	-7.63	-0.02	-10.20	-0.03	-20.44	-0.06	-31.02	-0.09
Long berseem	3999.037	-107.15	-0.31	-120.00	-0.34	-176.52	-0.51	-233.41	-0.67
Nili maize	619.427	-58.70	-0.17	-79.25	-0.23	-153.91	-0.44	-236.64	-0.68
Summer maize	4709.168	-108.10	-0.31	-143.66	-0.41	-298.44	-0.85	-448.36	-1.28
Paddy	5617.223	-151.27	-0.43	-201.72	-0.58	-467.04	-1.34	-700.83	-2.01
Short berseem (winter)	554.147	-12.60	-0.04	-17.61	-0.05	-28.12	-0.08	-37.96	-0.11
Sugar cane	3053.274	-182.68	-0.52	-242.93	-0.70	-493.39	-1.41	-827.14	-2.37
Cotton (G80)	355.198	0.08	-	0.08	-	0.11	-	0.08	-
Cotton (G86)	444.568	0.01	-	0.01	-	0.02	-	-	-
Cotton (G89)	500.153	1.45	-	1.93	0.01	0.01	-	0.01	-
Summer sorghum	922.921	-27.04	-0.08	-35.93	-0.10	-72.52	-0.21	-108.46	-0.31
Summer tomato	601.352	-8.19	-0.02	-13.20	-0.04	-28.02	-0.08	-38.53	-0.11
Summer vegetables	1090.415	-14.64	-0.04	-17.98	-0.05	-30.53	-0.09	-42.64	-0.12
Winter vegetables	710.496	22.40	0.06	20.97	0.06	15.55	0.04	32.59	0.09
Wheat	4158.972	-63.30	-0.18	-80.82	-0.23	-155.20	-0.44	-282.92	-0.81
Others	2543.81	-100.68	-0.29	-115.43	-0.33	-194.39	-0.56	-278.58	-0.80
Total	**34918.73**	-839.31	**-2.40**	-1084.85	**-3.11**	-2161.76	**-6.19**	-3307.48	**-9.47**

Table 12 Welfare, Irrigation Water Demand and Crop Production Level Change for the Output Tax Scenario.

Output Tax Level	**Base**	**5%**	**10%**	**20%**	**30%**	**40%**	**50%**
		Welfare and Irrigation Water Demand Change from the Base (percentage)					
Welfare: Consumer and Producer Surplus	48.692 Billion LE	-0.53	-1.03	-1.94	-2.74	-3.41	-3.97
Irrigation Water Demand	34.919 *bcm*	-1.11	-2.37	-5.21	-7.96	-10.92	-13.91
	Base *000 ton*	Crop Production Change from the Base (percentage)					
Barley	93.990	0.26	0.39	0.71	0.86	0.86	0.86
Berseem	61732.416	0.16	0.28	0.36	0.43	0.43	0.43
Citrus	6076.431	-	-	-	-	-	-
Fava Bean	424.551	0.97	1.88	2.68	3.11	3.11	3.12
Flax	67.940	0.04	0.08	-	-	-	-
Ground Nut	207.000	0.06	0.08	0.08	0.10	0.10	0.10
Legumes	34.987	0.92	1.64	3.17	3.85	3.85	3.85
Lentils	3.764	5.67	11.59	22.01	26.58	26.58	26.58
Maize	6906.005	0.19	0.18	0.03	0.04	0.04	0.04
Onion	796.569	0.09	0.06	0.08	0.12	0.11	0.12
Paddy	5225.863	-3.83	-7.71	-17.08	-25.62	-34.16	-42.70
Potato	1086.311	0.08	0.09	0.02	0.02	0.02	0.03
Cotton (G45)	0.077	-0.22	-0.21	-0.22	-0.22	-0.22	-0.22
Cotton (G70)	77.835	-	-	-	-	-	-
Cotton (G88)	13.821	-	-	-	-	-	-
Cotton (G80)	88.406	0.41	-	-	-	-	-
Cotton (G83)	39.079	-	-	-	-	-	-
Cotton (G85)	88.532	0.19	0.36	-	-	-	-
Cotton (G86)	132.095	-	0.01	-	-	-	-
Cotton (G89)	153.815	0.21	0.40	-	-	-	-
Sesame	32.989	0.11	0.07	0.08	0.09	0.09	0.09
Sugarbeet	2857.714	0.62	1.10	0.27	0.30	0.30	0.30
Sugarcane	15387.614	-7.79	-15.73	-31.74	-48.97	-67.16	-85.34
Sorghum	792.039	0.02	0.01	0.01	0.01	0.01	0.01
Soybean	14.847	1.24	0.11	-0.01	-0.02	-0.02	-0.02
Tomato	6290.013	0.06	0.09	0.15	0.18	0.18	0.18
Vegetables	11007.709	0.05	0.06	0.08	0.10	0.10	0.10
Wheat	6369.155	0.41	0.75	1.20	1.44	1.44	1.44

Table 13 Irrigation Water Demand Reduction Decomposition under Different Output Tax Level.

Output Tax Level	***Base***	**20%**		**30%**		**40%**		**50%**	
	mcm	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*	*Change from Base (mcm)*	*% of Base Total*
Citrus	4114.461	-	-	-	-	-	-	-	-
Favabean	370.693	12.52	0.04	14.61	0.04	14.62	0.04	14.63	0.04
Groundnut	553.419	1.65	-	1.77	0.01	1.77	0.01	1.78	0.01
Long berseem	3999.037	17.40	0.05	21.00	0.06	21.05	0.06	21.11	0.06
Nili maize	619.427	3.17	0.01	3.19	0.01	3.21	0.01	3.24	0.01
Summer maize	4709.168	-1.31	-	-1.58	-	-1.53	-	-1.51	-
Paddy	5617.223	-958.02	-2.74	-1437.28	-4.12	-1916.23	-5.49	-2395.16	-6.86
Short berseem (winter)	554.147	3.76	0.01	4.48	0.01	4.48	0.01	4.48	0.01
Sugar cane	3053.274	-969.37	-2.78	-1496.38	-4.29	-2053.22	-5.88	-2610.05	-7.47
Cotton (G80)	355.198	-	-	-	-	-	-	-	-
Cotton (G86)	444.568	-	-	-	-	-	-	-	-
Cotton (G89)	500.153	-	-	-	-	-	-	-	-
Summer sorghum	922.921	-0.06	-	-0.08	-	-0.08	-	-0.08	-
Summer tomato	601.352	0.18	-	-0.02	-	-0.01	-	-0.01	-
Summer vegetables	1090.415	-3.28	-0.01	-3.59	-0.01	-3.96	-0.01	-3.60	-0.01
Winter vegetables	710.496	1.36	0.00	23.23	0.07	23.23	0.07	23.23	0.07
Wheat	4158.972	82.23	0.24	99.36	0.28	99.35	0.28	99.34	0.28
Others	2543.81	-8.48	-0.02	-6.70	-0.02	-5.34	-0.02	-14.39	-0.04
Total	**34918.73**	-1818.25	**-5.21**	-2777.97	**-7.96**	-3812.65	**-10.92**	-4857.01	**-13.91**

Table 14 Summary of Welfare and Irrigation Water Demand Changes (in percentage) for All Scenarios

Scenarios	Welfare	Irrigation Water Demand
	billion LE	*bcm*
Base	48.7	34.9
Water Pricing		
Water (1)	-0.83%	-1.83%
Water (2)	-2.52%	-4.75%
Water (3)	-5.63%	-10.01%
Water (4)	-10.93%	-19.79%
Fertilizer Tax		
25%	-0.76%	-0.99%
50%	-1.52%	-2.01%
75%	-2.26%	-2.88%
100%	-3.00%	-3.77%
200%	-5.84%	-7.45%
300%	-8.55%	-11.24%
Pesticide Tax		
25%	-0.49%	-0.19%
50%	-0.98%	-0.46%
75%	-1.46%	-0.81%
100%	-1.95%	-1.19%
200%	-3.85%	-2.35%
300%	-5.72%	-3.18%
Energy Tax		
25%	-0.58%	-0.79%
50%	-1.16%	-1.62%
75%	-1.73%	-2.41%
100%	-2.30%	-3.11%
200%	-4.51%	-6.19%
300%	-6.64%	-9.47%
Output Tax		
5%	-0.53%	-1.11%
10%	-1.03%	-2.37%
20%	-1.94%	-5.21%
30%	-2.74%	-7.96%
40%	-3.41%	-10.92%
50%	-3.97%	-13.91%

Water (1): Using cost recovery price level calculated by Perry in 1996
Water (2): Using shadow price at the 5% deduction of irrigation water
Water (3): Using shadow price at the 10% deduction of irrigation water
Water (4): Using shadow price at the 20% deduction of irrigation water

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