The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Bulletin Number 02-1 October 2002

ECONOMIC DEVELOPMENT CENTER

ECONOMY-WIDE BENEFITS FROM ESTABLISHING WATER USER-RIGHT MARKETS IN A SPATIALLY HETEROGENEOUS AGRICULTURAL ECONOMY

XINSHEN DIAO
TERRY ROE
RACHID DOUKKALI

ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Applied Economics, St. Paul

UNIVERSITY OF MINNESOTA

Economy-Wide Benefits From Establishing Water User-Right Markets In A Spatially Heterogeneous Agricultural Economy

Xinshen Diao, Terry Roe, and Rachid Doukkali
International Food Policy Research Institute,
University of Minneosta, and
Institut Hassan II, Morocco, respectively.

October 3, 2002

Abstract

This paper analyzes the economy-wide gains obtainable from the allocation of surface irrigation water to its most productive use, and evaluates a decentralized mechanism for achieving this result in a spatially heterogeneous environment. The focus country for the analysis is Morocco. The analysis is based on a general equilibrium model that, in addition to the rest of the economy, captures 83 agricultural production activities, 66 of which are in seven separately identified water districts that span the entire country. The results suggest that a decentralized water trading mechanism could increase agricultural output by 8.3 percent, affect the rental rates of other agricultural inputs at the national level, including labor, and have economy-wide effects that entail modest declines in the cost of living, an increase in aggregate consumption, and expansion of international trade.

Corresponding Author:
Terry Roe, Department of Applied Economics, University of Minnesota
1994 Burford Ave., St. Paul MN 55108
troe@umn.edu

1 Introduction

Inventing and implementing social mechanisms for allocating irrigation water to more productive uses remains a challenge in both developed and developing countries. Part of the difficulty is due to the problem of establishing property rights to water (Dinar et al, 1998, Gleick et al, 2002). Another part is due to the relatively high fixed costs of dams and canals associated with surface water which raises the issue of who pays and should marginal cost pricing for water be abandoned (Dinar and Subramanian, 1997, Thoban, 1997, Dinar, 2002). Another difficulty arises from the negative externality that ground water extraction imposes on the extraction of water by others (Diao and Roe, 1997, Tsur and Zemel, 1997). Embodied in each these difficulties is the heterogeneity of water availability and use within any one country. This heterogeneity makes difficult the formulation of a uniform water policy, and tends to necessitate a set of policies with each taking into account the particular spatial water and crop peculiarities and historical practices that vary by region. At the same time, policies must recognize that the various regions are inter-linked, and that they compete for economy wide resources so that a water policy in one region impacts other regions that compete for these resources.

Nevertheless, the need to overcome these difficulties is becoming ever more important. The International Water Management Institute (Sekler et al. 1999) for example has projected that by 2025 most regions in a broad swath from North China across Asia to North Africa and northern Sub-Saharan Africa will experience either absolute or severe water scarcity. In the majority of these countries, it is also the case that irrigated agriculture remains a major sector both in terms of its share in GDP and the proportion of a country's poor that reside in the sector.

The general purpose of this paper is to obtain insights into the potential economy-wide gains obtainable to irrigation water when it is allocated to its most productive use, and to evaluate the mechanism for achieving this result in an environment where considerable spatial heterogeneity in water availability and use exists. The heterogeneity encourages a more decentralized mechanism for allocating water while also requiring that policy makers take into account the indirect effect that policies in own and other irrigation districts have on the costs of other resources employed in agriculture, such as hired labor and capital. The intensity of water use, relative to other inputs, varies by region due to differences in climate, soil characteristics and water availability. This variability can greatly affect the returns to water, the degree to which water policy on one region has indirect, though no less important, effects on other resources, and thus the effectiveness of water policy to allocate water to its most productive use in one region of a country in contrast to another.

The effect of water policy on other resources is an important determinant of region's competitiveness in the production of a crop relative to other regions. Understanding the economics of the spatial diversity also helps to target those regions that are likely to gain the most from reform, thus helping to prioritize an already complex policy making process. The mechanism for reallocating water is also important for obvious reasons, but of key importance here, is the choice of a mechanism that might best take account of heterogeneity among irrigation districts, and one that is likely to meet the least resistance to implement among farmers. Many authors (e.g., Young, 1986, Easter et al, 1998, and Lauw and Schalkwyk, 2002 for the case of South Africa) suggest the need to rely upon some water pricing mechanism. Tisdell and Ward (2002) conclude from their study of Northern Victoria, Australia, that auctioning surface water among farmers is successful in allocating water to more productive uses.

The country chosen for this analysis is Morocco. This choice is based on its spatial diversity, the availability of farm level data, and previous studies upon which to build (e.g., Doukkali, 1997, Diao and Roe 2002). Of the approximately 15.8 billion cubic meters of water mobilized in an average year, about 83 percent is surface water that is regulated by nine regional agricultural development authorities (ORMVA) with about 498,617 hectares of land equipped for and under irrigation in 1996-97. Regional authorities assess farmers a fee for water that is generally lower than the water's productivity, and consequently, water allocation must be administered. The gap between water's productivity and the fee charged implies that farmers capture a rent to their water assignment. Allowing the water authority to auction water to the highest bidder would cause farmers to forego this rent, and thus they can be expected to resist this method of allocating water to its most productive use. The water assignments are made at the beginning of the crop year, and sometimes adjusted during the year depending on rainfall and water supplies from snow accumulated in mountain ranges. Agriculture is relatively large, accounting for about 15 percent of the country's total value added and about 47 percent of the population classified as non-urban.

The approach is to develop a computable general equilibrium model for the entire country with particular attention given to modeling the agriculture of seven major irrigation regions and the perimeters within each region. Each of the regions is linked to up and down stream markets, and competes with the rest of the economy for economy-wide resources. The empirical framework is used to provide empirical estimates of the shadow price of water in each perimeter of the seven major ORMVAs, given the country's current water policy, and to conduct an analysis of a water user-rights market among farmers in each of the seven regions.

The results show considerable diversity in the productivity of water both within and between irrigation perimeters and districts. The creation of a water user-rights market in which farmers can rent in or out to other farmers some of their water user-rights has the potential of greatly increasing the productivity of water. The results suggest that such a mechanism could increase agricultural output in seven ORMVAs by 8.3 percent, to have noticeable economy wide effects that entail lowering the cost of living, increasing foreign trade, and internalizing rents to farmers from the reallocation of water. A user-rights market also appears to have desirable effects on equity among farmers.

The paper is organized by first laying out the conceptual framework that explains the key economic forces affecting the differences in the shadow price of water by region. It also defines a water user-rights market, how the creation of such a market might affect the allocation of water, the resulting rewards to property-right owners, as well as serving to guide the interpretation of the empirical results. Then, the nature of the data and empirical model upon which it is based are discussed followed by the presentation of results.

2 The conceptual framework

The basic economic forces deriving the empirical results can be explained by narrowing our focus to a two sector (indexed j = a, b) economy that only produces and consumes agricultural goods using two economy wide factors, labor L, and capital K, given water assignments T_a and T_b . The water authority's assignments of water are taken as given initially. We first characterize the equilibrium conditions given these assignments. This corresponds to the *base* solution of the empirical model. Next, we define the equilibrium in which farmers are given property rights to the assignment which they are then permitted to rent in or out. The second part shows the conditions determining how the resulting market prices of water depart from the shadow values associated with the assignments. It turns out that market prices for water can be greater or less than these shadow prices. While efficiency rises overall, the returns to water, post assignment of water rights, can rise for some and fall for other farmers.

2.1 Primitives of the model

Let

$$y_j = f^j\left(L_j, K_j; T_j\right) = A_j L_j^{\beta_{1j}} K_j^{\beta_{2j}} T_j^{1-\beta_{1j}-\beta_{2j}}, \quad j = a, b \tag{1}$$

characterize sector level production functions where L_j and K_j denote labor and capital, and T_j denotes the water assignment to the j-th sector. Given perfect competition in each sector, the economy-wide GDP function can be expressed as

$$GDP = G\left(p_a, p_b, L, K, T_a, T_b\right) \equiv \tag{2}$$

$$\underset{(L_a,L_b,K_a,K_b)}{Max}\left\{\sum_{j=a,b} P_j A_j L_j^{\beta_{1j}} K_j^{\beta_{2j}} T_j^{1-\beta_{1j}-\beta_{2j}} \quad | L \geq \sum_{j=a,b} L_j, \quad K \geq \sum_{j=a,b} K_j, \quad T \geq \sum_{j=a,b} T_j\right\}$$

given that the assignments of water exhausts total supplies.

The corresponding sector GDP functions can be expressed as

$$G^j\left(p_j, w, r\right) T_j \equiv \underset{(L_j,K_j)}{Max}\left\{P_j A_j L_j^{\beta_{1j}} K_j^{\beta_{2j}} T_j^{1-\beta_{1j}-\beta_{2j}} - wL_j - rK_j\right\} \tag{3}$$

Notice that the shadow price of water is given by

$$\pi_j = G^j\left(p_j, w, r\right) \tag{4}$$

The economy-wide GDP function equals the sum of the sector GDP plus payments to labor and capital

$$GDP = G\left(p_a, p_b, L, K, T_a, T_b\right) = \sum_{j=a,b} \left(G^j\left(p_j, w, r\right) T_j + wL_j + rK_j\right) \quad (5)$$

Properties of the GDP function are well known (Woodland, 1982, p.127-131). For example the Hessian submatrix G_{pp} is positive semi-definite, due to convexity in prices, while the factor sub-matrix G_{vv} is negative semi-definite, due to GDP being non-decreasing in factor endowments.

The *base* solution of the empirical model is typified here by rental rate values $\{w^o, r^o\}$ such that markets for labor and capital clear,

$$\frac{\partial G^a\left(p_a, w, r\right) T_a}{\partial w} + \frac{\partial G^b\left(p_b, w, r\right) T_b}{\partial w} = -L$$
$$\frac{\partial G^a\left(p_a, w, r\right) T_a}{\partial r} + \frac{\partial G^b\left(p_b, w, r\right) T_b}{\partial r} = -K$$

The resulting shadow prices of water are

$$\pi_j^o = G^j\left(p_j, w^o, r^o\right) \quad (6)$$

The experiment performed is to grant farmers user-rights to their respective water assignments. They are permitted to rent water in or out, subject to the exhaustion of total water supply, T. Then, the equilibrium conditions can be re-written as the existence of values $\{w^*, r^*, t^*\}$ such that

$$\begin{aligned}
\frac{\partial G^a\left(p_a, w, r\right)\left(T-t\right)}{\partial w} + \frac{\partial G^b\left(p_b, w, r\right)\left(t\right)}{\partial w} &= -L \\
\frac{\partial G^a\left(p_a, w, r\right)\left(T-t\right)}{\partial r} + \frac{\partial G^b\left(p_b, w, r\right) t}{\partial r} &= -K \\
G^a\left(p_a, w, r\right) - G^b\left(p_b, w, r\right) &= 0
\end{aligned}$$

Where trade in water t equates the marginal value product of water among sectors, i.e.

$$\pi_a^* = G^a(p_a, w^*, r^*) = G^b(p_b, w^*, r^*) = \pi_b^*. \quad (7)$$

The amount of water transacted must be such that

$$0 \leq t \leq T$$

and shadow prices must be positive.

It now becomes apparent that the change in the shadow price of water relative to the base, i.e., (π_j^*/π_j^o) has to do with, first, how the reallocation of water causes change in the rental rates w, r, of the other resources, and then, how the change in these rates affect π_a relative to π_b. We now turn to this task.

2.2 Comparative statics of shadow prices

First, we show the effect of changes in water allocation on the rental rates of labor and capital. Note that rental rates are given by the gradient of the economy-wide GDP function with respect to the factor endowments L and K,

$$w = \frac{\partial G(\cdot)}{\partial L}, \quad r = \frac{\partial G(\cdot)}{\partial K}$$

Differentiating these functions with respect to the water assignment, and requiring the water constraint to hold, we can obtain the rate of change in factor rental rates as a function of the change in water allocation,

$$\hat{w} = \varepsilon_{T_a}^{w} \hat{T}_a - \varepsilon_{T_b}^{w} \hat{T}_b \tag{8}$$

$$\hat{r} = \varepsilon_{T_a}^{r} \hat{T}_a - \varepsilon_{T_b}^{r} \hat{T}_b \tag{9}$$

The "^" notation denotes the rate of change in the respective variable and $\varepsilon_{T_a}^{w}$ are elasticities. The Hessian of the GDP function implies

$$\varepsilon_{T_j}^{i} \geq 0, \ i = w, r, \ j = a, b$$

As (8) and (9) suggest, the signs of the change in the rental rates of labor and capital are indeterminate without knowledge of the initial water assignment, and the relative magnitude of the elasticities.

Suppose that sector b was initially assigned an insufficient amount of water so that, post water market reform, water flows to sector b. That is, $\hat{T}_a$

≤ 0. Then, the change in both factor rental rates $(\hat{w}, \hat{r})$ are positive if sector b is both labor and capital intensive *relative* to sector a. In this case,

$$\varepsilon^i_{T_b} \geq \varepsilon^i_{T_a}, \; i = w, r$$

For a Cobb-Douglas technology (1), this implies the following cost shares: $\beta_{1b} = wL_b/TC_b > \beta_{1a} = wL_a/TC_a$, and $\beta_{2b} = rL_b/TC_b > \beta_{2a} = rL_a/TC_a$.

The intuition, which carries over to the empirical analysis, is that sector b, now having more water, desires to also employ more labor and capital than the other sector is willing to release at the previous (pre-reform) rental rates for labor and capital. Thus, for the labor and capital markets to clear, their rental rates must rise.

More generally, for a given reallocation, $\hat{T}_a \leq 0$, four cases are possible:

1 : Sector a L and K intensive	$\beta_{1a} > \beta_{1b}$	$\beta_{2a} > \beta_{2b}$	$(\hat{w}, \hat{r}) \leq 0$
2 : Sector a L intensive, b K intensive	$\beta_{1a} > \beta_{1b}$	$\beta_{2a} < \beta_{2b}$	$\hat{w} \leq 0, \hat{r} \geq 0$
3 : Sector b L intensive, a K intensive	$\beta_{1a} < \beta_{1b}$	$\beta_{2a} > \beta_{2b}$	$\hat{w} \geq 0, \hat{r} \leq 0$
4 : Sector b L and K intensive	$\beta_{1a} < \beta_{1b}$	$\beta_{2a} < \beta_{2b}$	$(\hat{w}, \hat{r}) \geq 0$

The signs are reversed if, post reform, $\hat{T}_a \geq 0$.

We now consider the effect of these changes in labor and capital rental rates on the equilibrium shadow prices of water. The shadow price of water must also satisfy the market clearing condition for water given above. Thus, using $G^j(p_j, w, r)$, the change in the j-th sector's shadow price of water is given by

$$\hat{\pi}_j = \frac{\partial G^j(\cdot)}{\partial w}\frac{w}{\pi_j}\hat{w} + \frac{\partial G^j(\cdot)}{\partial r}\frac{r}{\pi_j}\hat{r}$$

or, more generally,

$$\hat{\pi}_j = \varepsilon^{\pi_j}_w \hat{w} + \varepsilon^{\pi_j}_r \hat{r} \tag{10}$$

From Hotelling's lemma, the elasticities are

$$\varepsilon^{\pi_j}_w = \frac{-\beta_{1j}}{1 - \beta_{1j} - \beta_{2j}} = -\frac{wL_j}{\pi_j T_j}, \quad \varepsilon^{\pi_j}_r = \frac{-\beta_{2j}}{1 - \beta_{1j} - \beta_{2j}} = -\frac{rK_j}{\pi_j T_j}$$

Sector j is said to be more labor than capital intensive if β_{1j} is larger that β_{2j}. This tells us that we can predict the change in the water shadow price if we know how the sign of the rental rates for labor and capital vary for changes in the water assignment.

More generally, substituting (8) and (9) into the above equation, we obtain

$$\hat{\pi}_j = \varepsilon_w^{\pi_j}\left(\varepsilon_{T_a}^w \hat{T}_a - \varepsilon_{T_b}^w \hat{T}_b\right) + \varepsilon_r^{\pi_j}\left(\varepsilon_{T_a}^r \hat{T}_a - \varepsilon_{T_b}^r \hat{T}_b\right) \tag{11}$$

In summary, for an initial water assignment resulting where, post water market reform, $\hat{T}_a \leq 0$, we have four possible cases, two of which are determinate, and two of which are indeterminate.

They are:

1 : Sector a L and K intensive	$(\hat{w}, \hat{r}) \leq 0$	$\pi_a^* \geq \pi_a^o$	$\pi_b^* \geq \pi_b^o$
2 : Sector a L intensive, b K intensive	$\hat{w} \leq 0, \hat{r} \geq 0$	indeterminate	indeterminate
3 : Sector b L intensive, a K intensive	$\hat{w} \geq 0, \hat{r} \leq 0$	indeterminate	indeterminate
4 : Sector b L and K intensive	$(\hat{w}, \hat{r}) \geq 0$	$\pi_a^* \leq \pi_a^o$	$\pi_a^* \leq \pi_a^o$

The two determinate cases occur when the rental rates of labor and capital move in the same direction, either both rise or both fall. The indeterminate cases occur when the rental rates of labor and capital move in the opposite directions. In the indeterminate cases, it is likely that the shadow price of water for one sector falls relative to the base while the other rises relative to its former base, i.e.

$$\pi_a^* \geq (\leq)\, \pi_a^o, \quad \pi_b^* \leq (\geq)\, \pi_b^o$$

Thus, starting with a very simple framework, we have shown that post reform the market prices of water can be greater or less than their pre-reform values, and that these effects work through the prices of factors of production whose productivities, and hence rental rates, are affected by the reallocation of water. While this discussion identifies the major forces determining the empirical results, the empirical model is far more complicated. For instance, goods produced in the domestic economy are presumed not to be perfect substitutes for imported goods in the same category. Consequently, the presence of a water market can cause changes in the prices faced by farmers so that in some circumstance it is possible for these forces to dominate the effects discussed in this section. We now turn to a discussion of the empirical framework.

3 The applied general equilibrium model and data

The structure and parameters of the empirical model exploit two basic data sources. The national level data on employment, trade, non-farm production and resource flows are taken from a Moroccan social accounting matrix (SAM). The second source is detailed input-output data on crop production and water use at the farm level. These data include farms inside and outside (typically rainfed) of the country's major irrigation districts. The data inside the districts are obtained from each of the country's water authorities, ORMVA. The Moroccan economy is disaggregated into 88 production activities, which produce 49 commodities and employ eight primary inputs. On the demand side, there are five private household groups and one public group. The non-agricultural component of the economy is captured by six activities (83-88). Since the European Union (EU) is a major trading partner, Morocco's trade patterns between the rest of the world and the EU are identified separately. There are five different policy instruments included in the data, including taxes, subsidies, tariffs, payments for water, among others.

Thus, of the 88 production activities, 83 are in agriculture or agriculture-related, including 66 in crop production activities, five in livestock, and 11 in processing agriculture, both up and down stream from the farm firm. To capture the spatial nature of irrigated agriculture, 66 crop production activities are further distinguished according to whether they are within or outside the seven ORMVAs. Among the 33 activities within the water authority perimeters, 21 are irrigated crop production and 11 are rain-fed. The 66 crop production activities produce 23 primary agricultural products, which implies that all crop products are jointly produced by different activities within or outside the ORMVAs. For instance, soft wheat is produced in both irrigated and in dry land areas, and in different regions of the country. Thus, this product is associated with a different production function (activity) depending upon where and how the crop is produced. Because water is either costly or presently impossible to transport between perimeters in a given ORMVA, the seven ORMVAs are further sub-divided into 20 perimeters. This data set provides us with farm level information on the water charge fees, cropping mix, water and land allocation, employment of labor and capital and intermediate input use by crop and, obviously, by perimeter. Both sets of data were developed by Doukkali in conjunction with his students and colleagues.

There are three representative farm types in each perimeter. Outside the ORMVA, that is, for the rest of agriculture, there is only one representative farm type engaged in 31 different production activities. In other words, 621 crop and livestock production activities (calculated as 31 x 20 + 1) are modeled with three different farm categories within each perimeter, and outside the perimeter, virtually the same array of crops is produced but with no special attention given to farm type. Thus, hard wheat can be produced by farmers within perimeters or outside each of the seven ORMVAs, in irrigation or rain-fed areas, which together, total a maximum of 42 wheat production activities.

Each representative farmer is assumed to maximize profit by choosing intermediate inputs, labor, capital, and land. For farmers residing in a perimeter managed by an ORMVA, they are presumed to take as given the farm – crop level water quota that is assigned by the respective ORMVA. Output and input prices are given for individual producers but are affected by the market equilibrium within the economy. Farm level production functions are assumed to be constant returns to scale in primary inputs (labor, capital, land, and water) with a constant elasticity substitution (CES) form. The intensities of intermediate goods are in fixed proportion to output.

Inter-sectoral labor markets are notoriously difficult to model. Consequently, labor is specified as either rural or urban. Rural labor can seek employment anywhere in agriculture (including primary and processing agriculture), but not in urban labor markets. In other words, we restrict rural workers from being employed in the other non-agricultural sectors (which are urban based). Outside the ORMVA areas, capital and land are "mobile" among all the agricultural sectors in the sense that they can be allocated to the production of any of the identified crops (including livestock). Within a particular perimeter of a given ORMVA, capital and land can be allocated to any crop activity produced in the perimeter, but this capital and land cannot be allocated to production activities in another perimeter. Land is distinguished as irrigated and rain-fed. The supply of irrigated land is fixed, i.e., we do not consider infrastructure investments to increase the size of the perimeter.

Irrigated water is employed in the production of crops both within and outside the ORMVA areas. The use of water by the urban sector and by non-crop agricultural production is omitted from the analysis. Water is mobile within a perimeter but not mobile across perimeters. There is no water mobility between ORMVAs, nor from an ORMVA to regions outside an ORMVA. Focus is placed on the water within the ORMVAs, and not on private irrigated lands outside of the water authority districts. Included in the analysis is the water charge assessed on farmers in the district by authorities as given in the data base.

The water charge is presumed to be imposed by the method of volumetric pricing[1]. This rate is generally viewed as sufficient to cover operation and maintenance costs (Doukkali, 1997). As the water charge is less than the price the marginal users are willing to pay, the distribution of water must be administered. When the quota of water assigned to farmers is below the demand for water at the given water charge rate, then, implicitly, the shadow price for water is positive. Depending upon the marginal product of water allocated to various crops and water availability within a perimeter, the shadow price will vary accordingly, even though the ORMVA charges the same rate to different farmers.

The share of government charges in water's total contribution to value-added to production at the farm level varies from 80 to 20 percent across perimeters. The difference between the shadow price of water and the government's charge accrues as a benefit (rent) to farmers, i.e., this is a part of farmer's profit. For each individual farmer, as the intensity of water use varies by crop, benefits related to growing various crops vary from an estimated less than one percent to more than 60 percent of the value-added to production. Thus, considerable heterogeneity appears to exist across farmers, perimeters and regions in the intensity of water use in production.

[1] In 1997, the water charge to farmers takes into account a minimum consumption of 3000 cubic meters. By law (1969 Agriculture Investment Code), farmers that have more than 5 hectares are supposed to pay for the initial investment. Nevertheless, the actual pricing of water is close to a volumetric charge.

Finally, given the above structure and data, the model's parameters are calibrated in such a way that a "base solution" to the model reproduces exactly the "data" upon which the model is based. All other solutions to the model are compared to this base.

4 Simulation analysis – getting water price right

Using the SAM to calibrate the model, and then solving the model for the existing pre-water market reform policy, results in estimates of the pre-water market reform shadow prices, i.e., the shadow prices associated with the various district water assignments to farmers. These values are referred to as the base. Other than these values, no new information is provided since the model and calibration process are designed to reproduce the base data exactly. As indicated, the next step is to grant farmers rights to the assignment, and allow them to rent in/out some or all of their assignment. As shown in Section 2, this results in equating the marginal value product of water in its various uses *within* each perimeter of *each* ORMVA (note, *not* between perimeters or between ORMVAs.) A farmer's entitlement to water user-rights are assumed to be determined by the water quota assigned to them by the water authority according as indicated by the data.

4.1 Where does the water go?

Following the reasoning of the theoretical model, the first question to ask is: which activities is the water allocated from and which activities is it allocated to? As expected, trade in water user-rights causes some (not all) water to be re-allocated away from crops yielding a relatively low return (i.e., low shadow price in the *base*) to those crops whose shadow price of water in the *base* is relatively high. The larger a perimeter's standard deviation in the *base* water shadow price cross crops, the larger the volume of water that tends to re-allocated to equate shadow prices (i.e., to equate the marginal value product of water among activities within a perimeter).

However, as noted in Section 2, when water is re-allocated across crops, it may cause prices for other inputs, such as wage and capital rental rates, to change, as the production of different crops have different factor intensities in the use of water and other inputs, i.e., some inputs are more important in the production of some crops than others.

Not considered in the theoretical section is that the prices for output may also change due to different trade dependencies across sectors. The lower the ratio of the exports to total supply in a sector, the higher the sector's production is constrained by domestic demand. These factors also affect water allocation such that for a region with a multiple crop-mix, water may not go to the crops with a high base shadow price. The applied general equilibrium model allows us to measure where the water goes and how much water has to be re-allocated in order to improve water efficiency.

Table 1 displays two results. The first column reports the standard deviation in *base* water shadow prices for various crops in each perimeter. In terms of the theory section, these are the standard deviation of the base shadow values π_j^0. The second column reports results from solving the model when farmers are given user-rights to their water assignment which they can rent in or out within the perimeter of each of the seven ORMVAs. In terms of the theory section, these are the values $\hat{T}_j$ appearing in equation (11). The amount of water reallocated is expressed as a percent of the water assignment reported in the base data for each perimeter.

A simple cross-section linear regression shows that there exists a significantly positive correlation between the standard deviation in the water shadow price and the amount of water re-allocated. That is to say, a large deviation in water shadow prices implies that the current water assignment is relatively far away from the assignment that would otherwise equate the marginal value product of water among alternative uses within a perimeter. The larger the deviation observed in water shadow prices, the greater the incentive to trade in water user-rights, and thus, the larger the percentage of the total water that is likely to be traded.

The highest percent of total perimeter water reallocated is slightly more than 60 percent. This result occurs in the Haouz irrigation district's Perimeter 2 where the standard deviation in shadow price of water is 3.97. This deviation is the highest of all perimeters. The lowest ratio of re-allocated water over a perimeter's total water supply is 3.5 percent, which occurs the Gharb, Perimeter 1. The deviation in water shadow price in this case is only 0.35 (table 1). With a few exceptions, the results suggest that trade in water user-rights causes water to be re-allocated away from crops with a low water shadow price and to those crops with a high shadow price.

Patterns within regions can also be observed. In most perimeters, the base year water shadow prices are relatively high in the production of vegetables and fruit crops and low in grain, sugar and other industrial crops. The introduction of a water market causes a re-allocation of water away from the mentioned crops and towards the production vegetables and fruits, which in turn, leads to a decline in grain and industrial crop production (table 2). However, this does not mean that producers of grain and industrial crops experience a decline in income. Instead, their income rises because they find it more profitable to "rent out" some of their water user-rights to producers of fruits and vegetables (or increase fruit and vegetable production themselves) than to allocate this water to production of the protected crops.

To what extent does the reallocation of water in the various regions cause a change in production in the rain-fed areas? Declines in grain, sugar and other industrial crop production mainly occur in the irrigated area, while the same crop produced in the rain-fed areas either does not fall or falls only slightly (second part of table 2). There are two reasons to explain this. First, there is only an indirect effect of the water policy reform on the production of rain-fed crops. The indirect effect mainly comes from change in the prices for other inputs, such as wages, and capital rental rates, as well as some change in output prices. As water is allocated more efficiently within perimeters, the productivity of other resources is also affected, and most of these effects are positive. The result is an increase in the price of these other resources. This rise in prices of some inputs has larger negative effects on crops that employ them intensively relative to other crops. Hence, producers in the rain-fed areas face slightly higher prices for some – but not all - inputs used in their crop production. The second reason is that choices in the cropping mix are relatively limited for the dry-land area, so that farmers are limited to a smaller group of possible crops. Moreover, these dry-land crops are also produced in the other regions outside the seven ORMVAs. The change in the total output by crops at the national level is much smaller than the change at the ORMVA level (table 3).

Overall, tables 2 and 3 suggest that the effects of water re-allocation tend to cause an increase in fruit and vegetables production, and to lower the level of cereal and industrial crop production. Or, stated differently, the pre-reform water assignments appears to have favor the latter crops, even though these are crops for which Morocco is import competing.

4.2 What is the market price for water?

We now focus attention on the price of water, by perimeter, that results after a water market in user-rights is introduced. These results are reported as the percent difference between the water market price, post reform, and the average shadow price of water pre-reform (see the Water column, table 4). The theory section noted the conditions causing the market price for water to be higher or lower than the shadow price based on the water assignment, and the conditions whereby the market price would lie somewhere between the high and low shadow prices observed base. The empirical results show that, for almost all perimeters, the price of water after the introduction of a water user-rights market lies within a range that is bounded by the highest and lowest shadow price for water observed in the base year. Given the standard deviations reported in table 1, this implies that most farmers have an incentive to engage in water trading.

The market price for water is still different across perimeters as we assume that infrastructure is not in place to channel water from one perimeter to the other, and hence a water market price is spatially confined to and determined locally within each perimeter. For some perimeters in which the supply of water is relatively large, or the cropping mix is less water-intensive, the market price for water may be relatively low, while for the other perimeters which are relatively water scarce, or the production structure is more water-intensive, the market price of water can be high.

Table 4 also reports the change in the returns to capital and land, which are assumed to be mobile within a perimeter but not across perimeters. Effectively, perimeter capital and land are the perimeter's sector specific resource and are thus components of farm profits. We expect the change in water policy to affect the returns to these resources.

Among the 20 perimeters included in the study, there are 16 in which the market price for water post-reform is higher than the average returns to water pre-reform. This result implies that, at the perimeter level, water's productivity rises, on average, (i.e., the marginal value product of water rises post reform relative to the average marginal value product of water pre-reform) due to the introduction of trade in water user-rights. Moreover, a cross-section regression shows that the magnitude of the rise in water productivity is closely related to the amount of water re-allocated due to the reform, i.e., the larger the amount of water re-allocated post reform, the larger the rise in water productivity. Table 4 shows that the two highest increases in the water productivity are observed in Haouz, Perimeter 2 (52%) and Moulouya, Perimeter 3 (37%), where more than 60 and 50 percent of water, respectively, is re-allocated (see table 1) post reform.

Whether the water market price post-reform is higher (lower) than the average return to water pre-reform highly depends on whether water moves away from growing some crops that are less (more) water-intensive to growing other crops that are more (less) water-intensive. More intuitively, as water moves from crops that are less water intensive to crops that are more water intensive, those giving up water tend release more non-water resources from production at the old rental rates of these resources than the water intensive crops can profitably employ at the old rental rates. Thus, market pressures cause the rental rates of these other resources to fall, which, as shown in the theory section, tends to raise the shadow price of water.

We choose an ORMVA – Souss Massa to illustrate this important point (see table 5). In both Perimeters 1 and 2, the largest decline in water demand is in fodder production, ranging from 37 to 89 percent of water being re-allocated from these crops. The largest increase in water demand is in the category, other vegetable production (ranging from 42 to 93 percent of the water being re-allocated to these crops). Fodder production is more water intensive than is vegetable production (as indicated by the data which shows water's share in total value added). Fodder production uses more water in Perimeter 1 than in Perimeter 2, and vegetables employ less water in Perimeter 1 than in Perimeter 2. Thus, as water is allocated to vegetables in Perimeter 1, vegetable producers also need to employ other resources. This need in turn causes the rental rates of other perimeter resources to rise (see table 4). This places downward pressures on the rise in water's shadow price with the end result that the market price of water is –12.58 percent of the average shadow price pre-water market reform. We see this same tendency for the case of Perimeter 3, but in this case the prices of other inputs rise by relatively small amounts so that the price of water is only slightly different

(3.65 percent) than the pre-reform average. In the case of Perimeter 2, the post-reform price of water is 6.87 percent higher than the average shadow price, pre-reform. We see from table 4 that the rental rate of capital rose by 2.6 percent, and thus, the 6.78 percent rise is *not* the result we expect from the simple theory alone. However, we find that rural wages fall slightly, as do the prices of some other intermediate inputs. This case thus illustrates the point that the reallocation of water has major impacts on the prices of other inputs, which in turn has a major influence on the resulting market price of water.

4.3 Will a market for water benefit rural labor, or other factors of production?

The empirical model treats the market for rural labor as sector-wide factor, i.e., labor can move among all agricultural and agriculture-related production activities (but cannot move into the six urban based manufacturing and service sector activities). After introducing the water user-rights trade, the efficiency in water use is improved. The increase in production of those crops that employ more water post-reform also employ more labor. The seven ORMVAs in total increase labor demand by about 1.13% relative to the level observed in the data (table 6, the last column). However, not all ORMVAs nor all perimeters experience an increase in labor demand. Due to differences in cropping-mix and the amount of water re-allocated post-reform, there are two ORMVAs in which there are net labor outflows. At the perimeter level, only Souss Massa experiences a rise in the demand for labor in all of its perimeters. In the case of the other six ORMVAs, there is at least one perimeter in which labor demand falls (table 6).

Labor flows are affected by differences in crop-mix among perimeters. In general, if a perimeter's water is re-allocated away from growing more labor-intensive crops into less labor-intensive crops, then a labor outflow from the perimeter should be observed. This downward pressure on wages encourages some labor to search for employment elsewhere. The opposite situation occurs when water is re-allocated away from growing less labor-intensive crops and toward more labor intensive crops. In table 7, we calculate labor's average contribution to total value-added for two groups of crops in the perimeter. One group includes the crops employing more water, post-reform and the other group are crops employing less water. In the case of Doukkala, Perimeter 1, water moves toward crops for which labor accounts for a relatively small share of total costs (4.81 percent), compared to the crops giving up water in which labor costs account for 30.96 percent of total cost. In this case, the crops receiving water have the need to increase employment, but to a smaller amount than the crops giving up water. Thus, total employment of labor in this perimeter declines by about 2.87 percent (table 6).

What is the effect of reform on rural labor employed in the rest of agriculture? The results suggest that water re-allocation will cause the rural labor wage rate to decline slightly (0.81 percent, table 8). The net change in labor employed, by crop, is shown in (table 9).

The explanation for this change is the same as given above for other factors of production. Labor accounts for about 15 percent of total value-added in the seven ORMVA's crop production, while it accounts for about 22 percent of total value-added in the rest of the economy's primary agriculture. As there is a much smaller contribution from water to the value-added in crop production in the rest of economy, labor's share in total value added is logically higher in the rest of economy than that in the irrigated regions. As irrigated regions compete for labor after water is more efficiently allocated, labor has been released from the more labor-intensive activities to the less intensive. Thus, the rural labor wage rate declines, albeit by the relatively small amount of 0.81 percent. Clearly, this result is specific to the Moroccan case as it depends upon the initial water assignments.

Capital rental rates and returns to land are also affected by the re-allocation of water (table 4). As capital and land can only move across crops within a perimeter, the direction and magnitude of change in capital rental rates and returns to land varies across regions. Again, the driving force yielding this result is the differences in factor intensity across crops. For example, as tree crops are relatively capital-intensive (but less land-intensive), the re-allocation of water to these crops causes the capital rental rate to rise while returns to irrigated land tends to decline.

4.4 Effects of water reform on equity, the rest of the economy, and foreign trade

Even though the seven ORMVAs only account for 10 percent of agriculture's total GDP, the re-allocation of water within the perimeters has noticeable economy-wide effects. To show the basic effects, we draw upon selected aggregate economic indicators at the national level. These indicators are reported in table 10.

As farmers in the various ORMVAs become more competitive due to the more productive use of water, and thus compete for factors of production with farmers in the rest of agriculture, the real output in the rest of agriculture declines slightly (by 0.01 percent). As the positive impact of water reform in the irrigated regions dominates the negative impact to the rest of economy in terms of output, economy-wide GDP increases by 0.17 percent, and even the cost of living declines slightly, by 0.07 percent. This aggregate welfare gain is also captured by the increase in consumer's total consumption, which rises by 0.25 percent. In other words, water reform in a sector that comprises about 10 percent of agricultural GDP, benefits the entire economy. This amounts to a "free" gain in total welfare without the use of additional resources.

In terms of rural and urban income, the results suggest that urban income will rise, in real terms, slightly more than the increase in the total rural income (0.2% vs. 0.16%). The main reason is due to the slight decline in the rural wage rate and in the cost of living. Rural non-wage income, i.e., incomes earned by those farmers who own capital, land, and water user-rights, increases by 0.46%, while total wage income declines by 0.66%. These results imply that a water market may not necessarily make better off those rural workers that do not own assets other than their labor, such as land, and machinery. Moreover, for the farmers who own different amounts of land and capital, the impact of the reform is also different. Data show that the small farmer group (those owning less land and capital than those in the medium and large farmer groups) has to depend to a greater degree on wage income earned from employment either in non-farm activities or on the large farms. Thus, as a group, small farmers' income only rises by 0.17%, while income rises by 0.39% and 0.37% for the medium and large farmer groups, respectively.

Water policy reform also affects the country's trade profile (table 11). Given the static property of the model, the total trade deficit has treated as given, i.e., fixed (this is a common feature of static general equilibrium analysis). However, trade shares with the EU and the rest of world, as well as the structure of the trade, is affected by the water policy. The results reported in table 10 suggest that the percent change from the base in Morocco's total trade with EU rises by almost 3%, especially the surplus in agricultural trade, (rises by more than 6%). It is well known that the EU is a major destination for Moroccan vegetable and fruit exports in which Morocco has a comparative advantage. As more water is re-allocated to vegetable and fruit production in the irrigated regions, exports of these commodities rise.

Table 11 reports the change in exports by commodity group. We observed that crop exports, especially exports to the EU, increase the most (more than 3 percent). As domestic production of wheat, sugar and other industrial crops, in which Morocco tends not to hold a comparative advantage, declines due to water being re-allocated away from them, their imports rise. Thus, total crop and total agricultural imports rise by 0.71 and 0.85 percent, respectively (table 11). An implication is that foreign and domestic barriers to agricultural trade are likely to be an important determinant of the shadow price of water.

Further, it is almost surely the case that changes in the other economy-wide policies will affect the structure of trade to a greater degree than water policy alone. This in turn would be expected to further affect water allocation and hence the structure of crop production, as well as the entire economy. Analysis on the relationship between water policy reform and trade liberalization is the focus of a forthcoming paper.

5 Concluding Remarks

The growing scarcity of water in low income countries places increased pressures for developing mechanisms to allocate water to its most productive uses. This paper considers water allocation in the context of a spatially heterogeneous irrigated agriculture, the benefits from establishing property rights to this water, and the sector and economy-wide effects that can potentially accrue by permitting users to rent in/out their rights to water. The design of a national water policy is made difficult by the spatial heterogeneity of agriculture. Property rights matter because they influence the motivation farmers have to use water efficiently, and to determine which farmers can use water more efficiently than others. The sector and economy-wide effects matter because changing water policies affect the prices of other economy wide resources, such as labor and agricultural capital, while at the national level, they can affect the level of exports, imports, and even the cost of living, as measured by the consumer price index, because food tends to be a relatively large share of total consumption expenditures in low income countries. Ignoring these influences is to greatly underestimate the economic rewards from allocating water to its most productive uses.

To provide insights into these factors, we develop a detailed economy-wide model of the Moroccan economy with major attention given to seven irrigated regions whose water supplies and distribution are managed by seven water authorities, each of which contains at least two irrigation perimeters. Of the 88 production activities modeled, 82 are in agriculture or agriculture-related activities, including 66 in crop production, five in livestock, and 11 in processing agriculture, both up and down stream from the farm firm. The 66 crop production activities are further distinguished by being within or outside the seven ORMVAs. Among the 33 activities within (or outside) the water authority perimeters, 21 are irrigated crop production and 11 are rain-fed. The 66 crop production activities produce 23 primary agricultural products, some of which are produced in irrigated agriculture, as well as in rain-fed areas. The intent of this detail is to capture the spatial heterogeneity of irrigated agriculture.

Given policies in place, as depicted in the data, including the water assignments made by the water authorities within each perimeter, the model is solved so as to reproduce the base data, as well as to provide estimates of the shadow price of water for each water assignment to each crop in each perimeter of each of the seven ORMVAs. The level and disparity in shadow prices provides insights into the degree to which current policy allocates water to the most productive crops.

Then, the assumption is made that farmers are given the user-rights to their historic water assignments. In this case, they can choose to allocate water as they have in the past and internalize, as part of their profits, the shadow price of water. Or, they can choose to rent out to or in from other farmers in the perimeter some or all of their water, and receive as compensation the resulting market rental price of water in that perimeter. This is the mechanism by which the property rights to water is modeled, and how trade in water user-rights leads to the allocation of water so as to equate the marginal value product of water in its alternative uses within each perimeter.

The results are quite profound. They suggest that such a mechanism could increase agricultural output within the seven ORMVAs by 8.3 percent. Most likely, this estimate is conservative because some of the higher income stream will surely be invested into new agricultural capital, and growth in trade should encourage growth in the imports of intermediate capital goods that will help foster growth in agriculture and the rest of the economy.

The results suggest that output of fruits and vegetables increase the most, while the production of wheat and fodder tends to decline. Water reform is shown to have economy-wide effects, to place downward pressure on the cost of living, to increase net agricultural trade, and to increase rural farm income. The effect on rural wages is slightly negative, but income of small, medium and larger farms increase. Thus the creation of a water market appears to have positive implications to equity among farmers. The market price of water, relative to the average shadow price of water pre-water market reform, rises in 16 of the 20 irrigation perimeters contained in the seven ORMVAs detailed in the model. The increase ranges from a low of 1 percent to a high of almost 52 percent, while the declines in the four remaining perimeters range from a –0.27 percent to about –25 percent. The allocation of water to its most productive use also tends to raise the productivity of other resources, and hence their rental rates, such as agricultural capital and land that is specific to a perimeter.

While numerous technical and institutional difficulties exist to creating markets for water in almost any country, the potential economic benefits from the allocation of irrigation water to its most productive uses appears to be not only substantial to the rural economy but to the broader economy as well. This study also makes clear the need to evaluate water policy in a broader content than just irrigated agriculture, and particularly so in countries where agriculture consumes a majority of disposable water supplies.

References

Diao, X., T. Roe, Water Scarcity in Developing Countries: Linking Water Markets to Macro-Economic Reforms in "Guidelines for Pricing Irrigation Water Based on Efficiency, Implementation Cost and Equity Consideration," World Bank Final Project Report, A. Dinar, Principal Supervisor, forthcoming, 2002

Dinar, A., T. K. Balakrishnam, and J. Wambia, Political economy and political risks of institutional reforms in the water sectors, paper presented at the World Bank Workshop "*the Political Economy of Water Pricing Implementation.*" World Bank, Washington, DC , 1998.

Dinar, A., in "Guidelines for Pricing Irrigation Water Based on Efficiency, Implementation Cost and Equity Consideration," World Bank Final Project Report, forthcoming, 2002

Dinar, A., and A. Subramanian, Water pricing experiences, an international perspective, *World Bank Technical Paper* 386, 1997.

Doukkali, R. Economic analysis of second stage of structural adjustment in Morocco: gains from first and second best policy instrument, unpublished thesis submitted to University of Minnesota, St. Paul, MN (1997).

Easter, K., M. Rosegrant, and A. Dinar. *Markets for Water: Potential and Performance,* Boston: Kluwer Academic Press, 1998.

Gleick, P., G. Wolff, E. Chalecki, and R. Reyes, The New Economy of Water: The Risks and Benefits of Globalization and Privatization of Fresh Water, Pacific Institute for Studies in Development, Environment, and Security, Feb. 2002

Louw, D. B. and H. D. van Schalkwyk. Efficiency of Water Allocation in South Africa: Water Markets as an Alternative, Paper presented at the conference "Irrigation Water Policies: Micro and Macro Considerations, Agadir, Morocco, 15-17, June 2002

Roe, T and X. Diao, The Strategic Interdependence of a Shared Water Aquifer: A General Equilibrium Analysis, in *Decentralization and Coordination of Water Resource Management,* Parker, D and Y. Tsur, editors, 1997

Seckler, David, D. Molden and Randy Baker. 1999 *Water Scarcity in the Twenty-First Century,* International Journal of Water Resource Management 15:1/2:29-42.

Tisdell, John, and John Ward. An Experimental Evaluation of Water Markets in Australia, Paper presented at the conference "Irrigation Water

Policies: Micro and Macro Considerations, Agadir, Morocco, 15-17, June 2002.

Thoban, M, Formal water markets: why, when, and how to introduce tradable water rights, *The World Bank Research Observer* **12**(2): 161-179 1997.

Tsur, Y. and A. Zemel. On Event Uncertainty and Renewable Resource Management, in *Decentralization and Coordination of Water Resource Management,* Parker, D and Y. Tsur, editors, 1997

Woodland, A.D. International Trade and Resource Allocation, North-Holland Pub. Coo, Amsterdam, NY, Oxford, 1982.

Young, R. Why Are There So Few Transactions Among Water Users, *American Journal of Agricultural Economics,* Vol. 68(5): 1143-1151.

Table 1. Standard deviation in water shadow price and water re-allocation

		Standard Deviation of water shadow price*	Water re-allocation**
Doukkala	PER1	5.91	31.44
	PER2	1.26	27.50
Gharb	PER1	0.35	3.47
	PER2	1.13	24.01
	PER3	0.63	39.50
Haouz	PER1	0.64	22.31
	PER2	3.97	63.94
	PER3	0.54	29.29
Loukkos	PER1	2.34	21.20
	PER2	0.90	20.96
	PER3	2.30	34.40
Moulouya	PER1	0.59	11.01
	PER2	1.11	32.35
	PER3	1.22	50.74
	PER4	0.55	17.00
Souss_Massa	PER1	1.53	31.80
	PER2	0.67	37.25
	PER3	0.78	13.59
Tadla	PER1	0.82	36.50
	PER2	0.92	36.94

* Standard deviation is calculated within each perimeter using base year's data

** Percent of total water supply for each perimeter after introducing water use-rights market

Table 2. Change in the seven ORMVAs' total supply by crop

	Hard whea	Soft wheat	Barley	Other cereal	Pulses	Fodder	Sugar beet
Irrigated							
Base level	495.99	1232.98	76.87	72.21	115.69	520.19	823.61
% change from base	-16.29	-15.57	-24.86	-30.04	-16.15	16.47	-14.25

	Sugar cane	Other ind. crops	Tomato	Potato	Pepper	Green bean	Melon
Base level	316.68	179.74	774.08	241.67	67.12	24.78	50.67
% change from base	-8.43	-22.13	-9.04	18.87	34.22	42.42	57.71

	Cucumber	Zucchini	Other vegetables	Olives	Citrus	Apricots	Other fruit trees
Base level	0.17	3.13	604.97	345.48	1580.87	77.43	1344.45
% change from base	100.89	15.01	72.68	93.26	3.27	3.47	-0.05

Rain-fed

	Hard whea	Soft wheat	Barley	Other cereal	Pulses	Fodder	Sugar beet
Base level	127.50	48.39	31.16	0.24	13.46	2.93	1.99
% change from base	-0.82	-0.39	-0.58	-2.39	0.56	-4.12	4.62

	Other ind. crops	vegetables	Olives	Other fruit trees
Base level	0.22	1.31	0.00	4.92
% change from base	3.70	-13.67	-0.58	3.61

Table 3. Change in crop output at the national level

	Hard whea	Soft wheat	Barley	Other cereal	Pulses	Fodder	Sugar beet	Sugar cane
Base level	3424.07	7813.48	3886.54	449.81	1229.90	1752.18	990.89	316.68
% change from base	-0.24	-0.13	0.20	-0.78	0.32	0.01	-8.45	-8.43

	Other ind. crops	Tomato	Potato	Pepper	Green bean	Melon	Cucumber	Zucchini
Base level	1715.60	2177.97	551.89	250.59	128.71	155.50	21.87	39.73
% change from base	0.18	-2.38	5.29	4.05	4.90	13.65	1.29	1.16

	Straw-berry	Other vegetables	Olives	Citrus	Apricots	Peach & nectarine	Other fruit trees
Base level	240.68	7977.98	2057.30	3229.28	213.35	182.79	6004.97
% change from base	0.43	1.29	6.04	3.10	0.72	0.87	0.69

Table 4. Change in water price, capital rental rate, and returns to land
In per cent change relative to base

ORMVA	Perimeter	Water*	Capital	Irrigated land	Rain-fed land
Doukkala	PER1	-24.89	4.64	-13.44	0.03
	PER2	18.98	-0.06	3.32	1.42
Gharb	PER1	2.24	1.85	2.11	0.21
	PER2	20.47	1.96	5.59	1.36
	PER3	18.54	0.08	-0.27	-6.85
Haouz	PER1	-2.3	5.77	-16.23	-0.62
	PER2	51.88	72.52	-42.54	-6.16
	PER3	20.5	-12.09	-2	3.96
Loukkos	PER1	-0.27	6.24	-3	-7.67
	PER2	9.79	8.03	-0.34	0
	PER3	15.68	9.18	3.61	1.2
Moulouya	PER1	2.78	-0.38	-8.6	0.78
	PER2	15.25	5.29	-5.26	0
	PER3	37.05	6.43	-6.16	0
	PER4	1.02	0.36	-6.75	0
Souss_Mass	PER1	-12.58	17.63	4.91	-4.27
	PER2	6.87	2.6	15.84	0.51
	PER3	3.65	-0.26	2.74	0.82
Tadla	PER1	26.51	-3.07	-1.08	0.76
	PER2	30.98	-6.39	11.06	1.9

Source: model results

* Comparison between water market price post-reform with average returns pre-reform

Table 5. Relationship between water market price and water-intensivity of crop production
-- The case of Souss Massa

	Perimeter 1	Perimeter 2	Perimeter 3
Crop with the largest decline in water demand	Fodder	Fodder	Fodder
% in total re-allocated water	89.20	37.30	47.90
Crop with the largest increase in water demand	vegetables	vegetables	Olive trees
% in total re-allocated water	68.70	93.00	42.20
Share of water in crop value-added*			
Fodder	71.55	58.42	56.61
Other vegetables	24.35	39.78	24.54
Olive trees			69.61
Water market price relative to the average return to water	-12.58	6.87	3.65

Source: * from data and all others from model results
** Water market price is from post reform and average returns to water is from pre-reform.

Table 6.Labor re-allocation by regions, Percent change from base labor supply

	DOUK	GHAR	HAOU	LOUK	MOUL	SOUS	TADL	Total***
PER1*	-2.87	-2.10	-6.72	-1.15	1.89	6.56	5.42	
PER2*	8.70	5.57	-22.72	10.70	3.03	1.61	-1.47	
PER3*		27.18	-3.59	14.27	-0.26	1.12		
PER4*					-3.78			
Total**	1.73	10.53	-7.22	3.08	1.26	1.81	-0.09	1.13

*Increase/decrease in labor demand relative to the base labor supply at the perimeter level.
**Increase/decrease in labor demand relative to the base at the ORMVA level.
***Increase in total labor demand relative to the base labor supply over all ORMVAs.

Table 7. Average share of labor in total value-added for two groups of crops

ORMVA	Perimeter	Crops water moves into	Crops water moves out of
Doukkala	PER1	4.81	30.96
	PER2	25.72	13.73
Gharb	PER1	17.04	6.42
	PER2	14.09	9.88
	PER3	18.15	4.40
Haouz	PER1	21.68	39.07
	PER2	10.74	49.08
	PER3	17.65	35.50
Loukkos	PER1	13.39	13.87
	PER2	5.33	5.45
	PER3	20.59	17.39
Moulouya	PER1	15.73	10.93
	PER2	24.01	27.91
	PER3	12.63	22.77
	PER4	14.87	17.65
Souss_Massa	PER1	15.73	13.23
	PER2	10.95	12.57
	PER3	8.98	6.08
Tadla	PER1	22.02	22.31
	PER2	25.77	24.08

Table 8. Change in the prices for economy-wide factors
-- percent change from the base

Capital in crop production	0.39
Capital in livestock production	0.33
Other capital	0.09
Rural wage	-0.81
Urban wage	0.04

Table 9. Labor re-allocation by crops

percent change from labor demand by crop in the base

Irrigated	Hard wheat	Soft wheat	Barley	Other cereal	Pulses	Fodder	Sugar beet
	-11.08	-15.19	-17.91	-38.19	-16.14	6.74	-7.97
	Sugar cane	Other ind. crops	Tomato	Potato	Pepper	Green bean	Melon
	-1.96	-18.10	-5.98	0.87	15.67	16.68	20.69
	Cucumber	Zucchini	Other vegetables	Olives	Citrus	Apricots	Other fruit trees
	71.46	11.89	26.65	47.46	3.40	0.95	-3.96
Rain-fed	Hard wheat	Soft wheat	Barley	Other cereal	Pulses	Fodder	Sugar beet
	0.92	1.07	-0.03	-0.70	1.57	-5.23	6.83
	Other ind. crops	vegetables	Olives	Other fruit trees			
	3.73	-11.77	-4.60	3.56			

Table 10. Change in selected macroeconomic indicators

	Base (Million Dh)	Percent change from base
All perimeters' real output	6740.72	8.27
All nonperimeters' real output	275652.84	-0.01
GDP at expenditure with base pric	323781.40	0.17
Total consumption	26294.07	0.25
Real exchange rate (base is 1)		-0.02
Consumer price index (base is 1)		-0.07
Total rural income*	69594.21	0.16
Total farm nonwage income	51146.19	0.46
Rural wage income	18448.02	-0.66
Small farm total income	18313.44	0.24
Medium farm total income	20651.45	0.45
Large farm total income	16853.77	0.44
Total urban income	204659.27	0.20
Urban wage income	92145.91	0.17
Total trade deficit/surplus**	10641.40	
with EU (surplus)	-3932.45	2.76
with rest of the world (deficit)	14573.85	0.74
Total ag trade deficit/surplus	888.06	-21.27
with EU (surplus)	-3530.47	6.54
with rest of the world (deficit)	4418.53	0.95
Total nonag trade deficit/surplus	9753.34	1.94
with EU (surplus)	-401.97	-30.49
with rest of the world (deficit)	10155.31	0.65

All prices are normalized to the base level.

*Incomes are normalized by consumer price index.

** Total trade deficit holds constant in the scenario.

Table 11. Effects on Trade by commodity group

	Base (Million Dh)	Percent change from base
Total crop exports	4,127	3.01
exports to EU	3,007	3.25
exports to rest of the world	1,120	2.36
Total other primary ag exports	611	0.33
exports to EU	534	0.33
exports to rest of the world	78	0.32
Total processed ag exports	10,225	1.93
exports to EU	5,958	2.51
exports to rest of the world	4,267	1.12
Total agricultural exports	14,963	2.16
exports to EU	9,498	2.62
exports to rest of the world	5,465	1.37
Total crop imports	5,307	0.71
imports from EU	1,398	0.60
imports from rest of the world	3,909	0.75
Total other primary ag imports	2,726	0.06
imports from EU	1,723	0.04
imports from rest of the world	1,003	0.10
Total processed ag imports	7,818	1.22
imports from EU	2,847	0.32
imports from rest of the world	4,971	1.74
Total agricultural imports	15,851	0.85
exports to EU	5,968	0.30
exports to the rest of the world	9,883	1.18
Total nonagricultural exports	75,640	-0.16
exports to EU	48,835	-0.13
exports to rest of the world	26,806	-0.20
Total nonagricultural imports	85,394	0.08
imports from EU	48,433	0.12
imports from rest of the world	36,961	0.03

RECENT BULLETINS

95-6 Elamin H. Elbasha and Terry L. Roe. "Environment in Three Classes of Endogenous Growth Models." August 1995.

95-7 Gopinath Munisamy and Terry L. Roe, "Sources of Sectoral Growth in an Economy Wide Context: The Case of U.S. Agriculture." August 1995.

95-8 Gopinath Munisamy and Terry L. Roe, "General Equilibrium Analysis of Supply and Factor Returns in U.S. Agriculture, 1949-91." August 1995.

95-9 Douglas Golin, "Do Taxes on Large Farms Impede Growth?: Evidence from Ghana." 1995.

96-1 X. Diao, E.H. Elbasha, T.L. Roe, and E. Yeldan, "A Dynamic CGE Model: An Application of R&D-Based Endogenous Growth Model Theory." May 1996.

96-2 Munisamy Gopinath and Terry L. Roe, "R&D Spillovers: Evidence from U.S. Food Processing, Farm Machinery and Agriculture." October 1996.

96-3 Xinshen Diao and Agapi Somwaru, "Dynamic Gains and Losses from Trade Reform: An Intertemporal General Equilibrium Model of the United States and MERCOSUR." October 1996.

96-4 Vernon Ruttan, "Sources of Technical Change: Induced Innovation, Evolutionary Theory and Path Dependence." October 1996.

97-1 Hung-Lin Tao and Thomas Stinson, "An Alternative Measure of the Human Capital Stock." April 1997.

98-1 Xinshen Diao, Terry L. Roe, and A. Erinc Yeldan, "How Fiscal (Mis)-Management May Impede Trade Reform: Lessons From an Intertemporal, Multi-Sector General Equilibrium Model for Turkey." January 1998.

98-2 Xinshen Diao, Terry Roe, and Erinc Yeldan, "Strategic Policies and Growth: An Applied Model of R&D-Driven Endogenous Growth." March 1998

98-3 Anna Maria Siti Kawuryan, "Educational Achievement and Sectoral Transition in the Indonesian Labor Force." March 1998.

98-4 Vernon W. Ruttan, "Growth Economics and Development Economics: What Should Developmental Economists Learn (if anything) from the New Growth Theory?" April 1998.

98-5 Xinshen Diao and Terry Roe, "The Effect of Sequencing Trade and Water Market Reform on Interest Groups in Irrigated Agriculture: An Intertemporal Economy-Wide Analysis of the Moroccan Case." November 1998.

98-6 Willis Peterson, "Monetary Instability and Economic Growth." November 1998.

99-1 Pei-Chien Lin and Terry Roe, "Growth Theory and Accounting for Growth of the Taiwanese Economy." July 1999.

99-2 H. Colby, X. Diao, and A. Somwaru, "Sources of Growth and Supply Response: A Cross-Commodity Analysis of China's Grain Sector." July 1999.

00-1 Beatriz Gaitan and Ferdinand Pavel, "Is 'Getting the Prices right' Always Right? How Trade Liberalization Can Fail." March 2000.

00-2 Vernon W. Ruttan, "Imperialism and Competition in Anthropology, Sociology, Political Science and Economics: A Perspective from Development Economics." March 2000.

01-1 Xinshen Diao, Agapi Somwaru and Terry Roe. "A Global Analysis of Agricultural Trade Reform in WTO Member Countries." January 2001.

01-2 Hamid Mohtadi and Terry Roe. "Democracy, Rent Seeking, Public Spending and Growth." June 2001.

01-3 Paul Glewwe. "Schools, Skills and Economic Development: Education Policies, Student Learning and Socioeconomic Outcomes in Developing Countries." December 2001.