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FEEDBACK LINKS BETWEEN ECONOMY-WIDE AND FARM-LEVEL POLICIES: Application to Irrigation Water Management in Morocco

Terry Roe[1], Ariel Dinar[2], Yacov Tsur[3], Xinshen Diao[4]

ABSTRACT

This paper focuses on policy interventions for improving irrigation water allocation decisions by including both macro and micro considerations in a unified analytical CGE framework. The approach is demonstrated, using the case of Morocco, by analyzing selected policy (top-down and bottom-up) interventions and external shocks that affect the water sector. Both direct and indirect effects of these interventions are identified. The top-down (macro-to-micro) links are of a trade reform type. The bottom-up (micro-to-macro) links pertain to changes in farm water assignments and the possibility of water trading. We find that water productivity is strongly influenced by these policies, with the general equilibrium (indirect) effects modifying and sometimes reversing the partial equilibrium (direct) effects. We also find that the impacts of the two reforms we assessed are different, with trade reform having an absolute impact of a higher magnitude than the water reform. Finally, we show that the sequence of introducing the policy reforms has different consequences.

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[1]University of Minnesota, St Paul USA; [2]World Bank, Washington DC USA; [3]Hebrew University of Jerusalem Israel; [4]International Food Policy Research Institute, Washington DC USA.

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FEEDBACK LINKS BETWEEN
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With Application to Irrigation Water Management in Morocco

INTRODUCTION

Agriculture consumes the lion's share—between 75-90 percent—of annual renewable fresh water on earth. This is a sufficient reason for policy makers to focus their efforts on improved performance of water use in irrigated agriculture, especially when water scarcity becomes a crucial policy issue. The literature shows that governments use a plethora of policy interventions such as pricing, water right assignments and development of water trading schemes (e.g., Johnson et al., 2002; Dinar and Saleth, 2005, Tsur et al., 2004; Tiwari and Dinar, 2002) to address water productivity and equity issues. Most economic analyses of policy intervention in the irrigation sector address questions at the farm or regional level. Actual results of the various interventions vary, depending on the local institutional setups (Dinar and Mody, 2004).

While policy interventions at the farm and regional (micro) levels could lead to desirable results (Tsur et al. 2005), narrow considerations may also lead to a sub-optimal outcome from a social point of view. This point is demonstrated in recent findings from work on economy-wide considerations and linkages (Tsur et al. 2004). Because interactions among sectors and factors of production are evident, the linkages among micro and macro policy interventions are far more important and allow policy makers to better assess the outcome of their interventions.

Tsur et al. (2004, chapter 5) apply a CGE framework to Morocco's irrigation sector demonstrating the importance of macro-micro feedback effects by using water rights and international trade reforms. They find that reforms outside agriculture have major impacts on rural household income, and that water reforms that are designed without taking into account reforms outside irrigated agriculture may lower overall productivity of irrigation water. Diao et al. (2005) extend the model in Tsur et al. (2004) to include a detailed accounting of the agricultural sector in Morocco. They show the potential gains to the irrigation sector and the economy as a whole from allocating water to its most productive uses in an economy with considerable spatial heterogeneity in water availability and productivity. Their model includes seven water districts that span the entire irrigation economy in Morroco.

Most economic works on water policy and pricing and institutional reforms are partial in nature, in that they focus on small regions—mainly farms, water districts, and perimeters or irrigation projects (see the works listed in Table 1 of Johansson et al, 2001). However, efforts to reform water policy and improve water use efficiency from the perspective of the district alone, though necessary, are not sufficient. In fact, the national level efforts of macro economic policy reform are intricately and jointly linked to water policy at the micro (district, perimeter, farm) level. In the context of water policy interventions however, in addition to the works cited above, we are aware of only a few other CGE studies (e.g., Berck et al. 1991; Goldin and Ronald-Holst 1995; Diao and Roe 2000). Most CGE studies on water that have been reported in the literature treat irrigated agriculture as one sector/activity. Such structures are only appropriate in economies where physical (soil quality, water availability, etc.), economic and social conditions (crop mixes, proximity to markets, farm size, water delivery costs, etc…) are similar across regions.

However, when there are disparities among regions, a more detailed structure is needed to analyze the impacts of water policy interventions. This structure will provide in-

sights into the different regional impacts of national policy changes, such as changes in the production levels of export crops, the effect on small growers that typically supply local markets, and differences in the possible gains of establishing water markets in some regions relative to others. This is a major step in identifying differences in emphasis and priorities that the various regional water management authorities need to consider in a policy-change environment. These insights should also help reduce the resistance to policy reform, and if a piecemeal approach to policy reform is chosen, it helps to identify the regions that should receive higher priority than others. Diao et al. (2005) have further addressed the cross regional variance in conditions by developing a district-level framework to track down reforms in the water sector in a general equilibrium context.

Recognizing the importance of having the ability to assess different policy-linkage and performance interactions, the present paper considers policy interventions aimed at improving irrigation water allocation decisions by including both macro and micro considerations in a unified analytical framework. Our macro-micro approach shows how various levels of the economy are directly and indirectly linked to the irrigation sector. Macro-micro linkages figure heavily in water resource management for a number of reasons. First, irrigation water is a key input of production to agricultural crops whose prices are strongly influenced by domestic and trade policies, both directly and indirectly through the competition for economy-wide resources (labor, chemical and mechanical inputs). Second, the use of water resources typically entails external effects that extend beyond the individual user or district. Finally, as is typical of a spatial sector such as agriculture, variations in local conditions mean that national policies have differential local impacts so that the implementation of water allocation and distribution reforms depend on local conditions. Thus, it is critical that economy-wide to local linkages be considered since, for most countries, irrigated agriculture is not isolated to a single homogeneous perimeter.

The approach is demonstrated by analyzing selected policy interventions and external shocks that affect the water sector directly and indirectly. We include top-down and bottom-up policy interventions. Macro policies associated with removing various trade and domestic barriers to open up the economy are examples of top-down links affecting the irrigation sector indirectly; we refer to such a policy as a 'trade reform'. Water management policies at the farm-perimeter-district levels, such as assignment of water rights to farmers or different ways to price irrigation water (e.g., per area, volumetric, or market-based) are examples of bottom-up links that affect the irrigation sector directly. But after being adopted by a large number of farmers, they have indirect effects on the economy as a whole, which in turn feeds back (largely through factor markets) and affect the micro level; we call such policies 'water reforms'.

In addition to policy interventions, we also assess the impact of water projects (such as expanding areas under irrigation perimeters), and shocks to available farm water supply (either due to weather or the growth of metropolitan areas) on the economy. And finally, we show that the sequence of introducing policy reforms (water reforms and trade reforms that we include in the analysis) could be critically important. For example, implementing water markets when policy protects irrigated sugar and wheat producers, can lead to a Pareto inferior outcome by causing water to move from non-protected to protected activities. The analytical framework we propose can provide the sequence of reforms that lead to continually Pareto superior outcomes.

We start with laying out the conceptual framework that consists of a macro (Computable General Equilibrium—CGE) model and a farm-level model. We explain the links between the macro-level and micro-level models, present the analytical equations of the

model, and set our hypotheses. Then we provide a short overview on issues associated with irrigated agriculture in Morocco, where irrigated agriculture is an important sector of the economy. We highlight the associated linkages between macro- and micro-level policy interventions in the country. In the fourth section we report the empirical results of our analytical framework, applied to Morocco. Finally, we conclude with a set of generalizations and discuss need for additional work.

CONCEPTUAL FRAMEWORK

We begin by outlining the micro (farm, perimeter, district) model, describing micro level decisions and the economic environment in which they are made. We distinguish between those variables that are exogenous to micro level decisions and those that are endogenous. In this way feedback effects between the micro and macro levels are broken down to direct and indirect effects. Direct effects correspond to partial equilibrium effects (e.g., the effect of a ceteris paribus change in farm output prices on crop supply). Indirect effects are largely due to general equilibrium effects. The overall effect of a policy is the sum of direct and indirect effects. This dichotomy is important because in a general equilibrium framework the indirect effects tend to counter and, in some circumstances, dominate the direct effects. This conceptual approach has its analytical foundation in the LeChatelier principle (see for example Varian (1992, p47)), and has been applied in a number of studies (Binswanger 1989; and in the studies directed by Krueger, Schiff and Valdez 1991 on the political economy of agricultural price policy).

We developed a simple general equilibrium model of a two-sector economy with water and labor as inputs; the entire model can be found in Roe et al., (2004), and highlights of its main equations in a following section. Its purpose is to show how macro and microeconomic reforms (as illustrated by trade reforms and water reforms, respectively) affect factor prices (labor in this case) and the shadow price of water. We use this simple framework to illuminate the indirect (general equilibrium) effects on the micro (farm) model. The analysis shows that the importance (or intensity of use) of water and other resources in production are essential to understanding how a change in macroeconomic policy can cause the shadow price of water to rise or fall, and who benefits and who looses from reforms. These same forces are also essential to understanding how the reallocation of water to equate its marginal value product among alternative crops affects the rental rates of other resources, such as labor, capital and other economy-wide resources.

Micro-Macro Links

We first show the macro to micro linkage by considering an economy wide reform illustrated by a trade reform. Then, we focus on the direct effect on farm profits from a crop's water assignments, and the indirect feed-back effect when water assignments are changed for all farms. These two reforms are also considered in the empirical analysis, using data for Morocco.

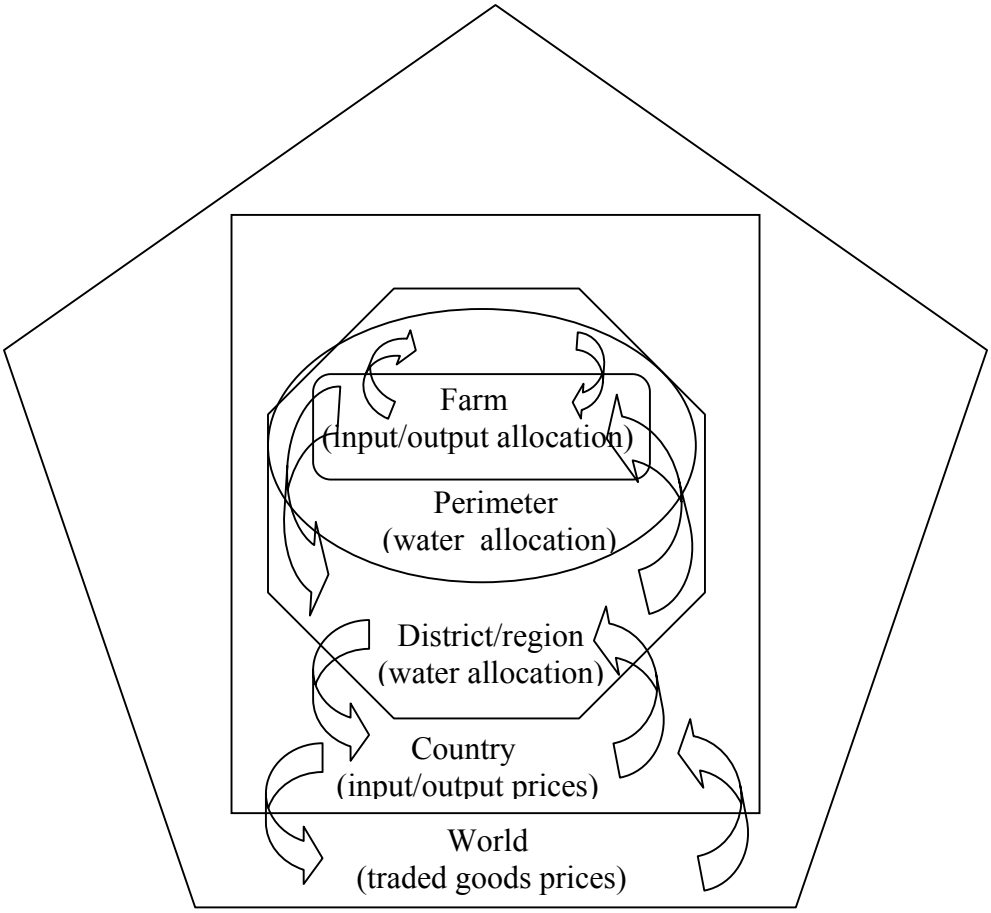
Micro (*farm, perimeter, district*): The basic decision making unit in a water economy is an irrigated-land farm operator. In the short run, farmers take the production technology, input prices and output prices as given and decide on input allocation—including irrigation water—and consequently on output supply. The overall quantity of water demanded at different water prices constitutes the (aggregate) demand for irrigation water. The supply is given by the marginal cost of water supply (the cost of supplying the next, marginal unit).

Irrigation water can be derived from local sources (a local aquifer, an adjacent stream flow or reservoir) or conveyed from external sources. Cheaper water is supplied first, thus the water supply curve begins with the marginal cost of supplying water from the cheapest source, switches to the second cheapest source when the first reaches its capacity limit and so on. Under certain institutional settings and/or geographic conditions the decision-making unit may be the water user association rather than the individual farmer.

Macro (*economy-wide*): The economy consists of many sectors that interact through markets to determine the prices of goods and services (including agricultural inputs and outputs). In addition, prices of traded inputs and outputs are set at the world market and are affected by domestic trade policy (quotas, tariffs and other trade barriers). Irrigators compete for inputs (water, capital, labor) with other sectors and their overall supply of agricultural products affects the prices of these products.

Macro-to-Micro links: We refer to three possible links. (i) Prices of purchased inputs and outputs, which are determined at the macro level and taken as given by farmers. These prices are sensitive to government policies (taxes and subsidies) and affect the derived demand for irrigation water. (ii) Trade policies (tariffs and other trade barriers) affect prices of traded agricultural inputs (fertilizer, pesticide, and seeds) and outputs. (iii) An important macro-to-micro link involves national or regional water projects (e.g., dams), which affect water supply constraints and the cost of water supply. This link may provide additional information about potential returns of using the scarce financial resources in the water sector.

Figure 1: Overview of micro-macro links



Micro-to-Macro links: These links include water allocation reforms at the micro level (perimeters, districts), such as changing water assignment rules, changing water pricing methods (e.g., from per area to volumetric pricing), or introducing institutions and mechanisms for trading water and water rights. Such reforms affect farmers' water (and other inputs) use and agricultural production. When applied in a number of regions these changes will affect input and output prices at the national level. The changing prices will then feed back, affecting the micro units (farms, perimeters). Figure 1 provides a schematic view of the micro-macro links.

In the following, we describe our analytical framework, which consists of a farm model and a macro model, with the former integrated into the latter. A more technical description of the model can be found in Roe et al. (2004).

Overview of the micro (farm) model

Farmers cultivate a number of crops and allocate inputs for each crop. These inputs include area planted, the monthly quantity of irrigation water (if necessary, also shorter periods for the peak-demand months), as well as fertilizer, machinery, pesticide, labor and other inputs. In their input allocation decisions, farmers take as given the prices of purchased inputs (labor, machinery, fertilizer, pesticide) and output, the production technology, the quantity of irrigable land, and the supply of irrigation water according to the water authority's assignment rules. The input decisions are chosen so as to maximize profit subject to the land and water constraints (and possibly other constraints such as crop rotation).

The resulting profit depends on the exogenous variables—input and output prices, farm size and water constraints. Shadow prices of water are derived as well and provide important information regarding efficiency and distribution of water in the economy.

Overview of the macro (economy) model

We discuss first the simplest possible general equilibrium open-economy *analytical* model to show the key linkages between macroeconomic reform as illustrated by trade reform, and sectoral changes as illustrated by water reform. Then, the model is discussed in a more generalized context by focusing on the nature equations that are necessary to link the macro (economy-wide) and micro (farm) analyses.

This analytical approach illustrates how the macro and micro empirical framework interlinks and will be used in the analysis. Agricultural goods are produced by two sectors (could be crops, farm types, regions), using labor and an assignment of water given by a water authority that exhausts total water supply. Commodity markets clear at given (world) prices, and the labor market clears at an endogenously determined wage rate. In this structure, the shadow price of water in each sector is unambiguously determined as the profits per unit of water used in each sector. Each sector's profits (or shadow price of water) are a function of the sectors output price, and wages. Wages in turn are a function of the economy's resource endowments, i.e., the amount of water assigned to each sector and world prices. Thus, by considering trade reform we can trace the impacts through the effects on wages, and the shadow price of water. By changing the sectoral allocation of water, wages change and so does the shadow price of water. A drought, for example, leads to a decrease in the total quantity of water, which impacts wages and again, the shadow prices of water in each sector. It can be shown that the magnitude and direction of change in the shadow price of water depends upon the initial water assignment, and the relative factor intensity of

labor and water in each sector's production function. These features are critically important to explain the 'behavior' of the large empirical model.

The effect of trade distortions on the shadow prices of water. Now, consider the case of a tariff imposed on an import competing good. A policy that changes (or lifts) the tariff will directly change the relative output prices and will indirectly affect demand for—hence prices of—inputs. The changes in input demand include irrigation water, hence the shadow price of water is likely to change too. We show in the Empirical Results section that after the trade reform, producers of one good can be made worse off in the sense that the total returns to their water assignment (i.e., their profits) may decline. If, however, prior to the trade reform a water market were introduced, then this will equate the shadow prices of water between the two sectors and the economy can be made better off. The key implication is that the sequencing of economic reform in a water economy can, as predicted by the theory of the second best, be critically important.

The effect of water market reforms on the shadow prices of water. Water market reform can have dramatic effects on the shadow prices of water. Consider the introduction of water markets within a system in which water is assigned for each crop at each month. If farmers can only relocate water between crops, the water market will equilibrate the shadow prices of water between crops. If farmers can also trade water between months or seasons, it will further equilibrate the monthly shadow prices of water. We show that depending on the importance of water relative to other inputs of production (or relative factor intensity), a market that equilibrates the marginal value product of water among its various uses can cause the shadow price of water to fall, remain unchanged or rise. The prices of all other factor inputs, such as labor, are also likely to change. If a water market reallocates water to labor intensive crops, then wages rise, thus benefiting the poor whose income depends on rural labor opportunities.

KEY ANALYTICAL RELATIONSHIPS IN THE MODEL

The key macro-micro linkages can be illustrated using a small and open, two sector economy (indexed $j = a, b$) that faces world market prices, p_a, p_b, and consumes and produces two agricultural goods using labor L and water H. We assume that a water authority assigns water to each sector in the amounts H_a and H_b such that total water is allocated

$$H = H_a + H_b$$

The sectoral production functions are given by

$$y_j = f^j\left(L_j, H_j\right), \quad j = a, b \qquad [1]$$

and assumed to be homogenous of degree one and non-decreasing in inputs $\left(L_j, H_j\right)$. Initially, the water authority's water assignment are taken as given. We also assume that the water charge is negligible. The economy's supply of labor L is allocated to the two sectors such that total demand equals supply,

$$L = L_a + L_b$$

At equilibrium, the economy's total gross domestic product ($GDP_{economy}$) is given by the value of gross output, which, due to homogeneity of degree one in production, also equals total factor rewards

$$GDP_{economy} = p_a y_a + p_b y_b = wL_a + \lambda_a H_a + wL_b + \lambda_a H_b \qquad [2]$$

where λ_a is the shadow price of water. Thus, the value added of sector *a* is $\lambda_a H_a$, and similarly for sector *b*.

It is useful to note that the water shadow price λ_j can be determined as a function of sectoral output price p_j and the wage rate *w*

$$G_j = \boldsymbol{\lambda}^j\left(p_j, w\right)H_j \equiv \underset{(L_j)}{Max}\left\{p_j f^j\left(L_j; H_j\right) - wL_j\right\},\ j = a, b \qquad [3]$$

where G_j is value added due by water, i.e., sector $j's$ GDP, and the shadow price of water is given by the function $\lambda_j = \boldsymbol{\lambda}^j\left(p_j, w\right)$. Using the envelope properties of $\boldsymbol{\lambda}^j\left(p_j, w\right)H_j$, the labor market equilibrium depicted in the right most diagram of the lower panel of figure 2 can be expressed as

$$-\frac{\partial \boldsymbol{\lambda}^a\left(p_a, w\right)H_a}{\partial w} - \frac{\partial \boldsymbol{\lambda}^b\left(p_b, w\right)H_b}{\partial w} = L \qquad [4]$$

where, given world prices p_j and water assignments H_j, the only endogenous variable is the wage rate, *w*.

It can be seen that the determinants of *w* depend upon exogenous variables, such as p_j, H_j, and L and the parameters of the technologies $f^j\left(L_j; H_j\right)$. The parameters determine the slopes of the labor demand curves. To ascertain the determinants of *w* we use the envelope properties of the economy-wide GDP function, defined as

$$GDP_{economy} = \mathbf{G}\left(p_a, p_b, H_a, H_b, L\right) \equiv \underset{(L_j)}{Max}\left\{\sum_j p_j f^j\left(L_j; H_j\right) \ \ \textbf{s.t.} \ \ \sum_j L_j \le L\right\}$$

to obtain

$$w = W\left(p_a, p_b, H_a, H_b, L\right) = \frac{\partial G(\cdot)}{\partial L} \qquad [5]$$

Expressing (20) in terms of elasticities, it can be shown that

$$\hat{w} = \sum_j \varepsilon^w_{p_j} \hat{p}_j + \sum_{i=T_a, T_b, L} \varepsilon^w_i \hat{v}_i \qquad [6]$$

where, "$\hat{}$" denotes rate of change, $\hat{w} = dw / w$, $\hat{p}_j = dp_j / p_j, \hat{v}_i = dv_i / v_i$, and $v_i = H_a, H_b, L$. From the homogeneity properties of $G(\cdot)$, the price elasticities, $\varepsilon^w_{p_j}$, sum to unity,

$$\sum_j \varepsilon^w_{p_j} = 1 \qquad [7]$$

and the endowment elasticities, ε^w_i, sum to zero

$$\sum_{i=H_a, H_b, L} \varepsilon^w_i = 0\,. \qquad [8]$$

In summary, equations [3] and [5] characterize the effects of changes in the exogenous variables $\left(p_a, p_b, H_a, H_b, L\right)$ on the shadow price of water and factor payments, in this simple case, wages. The logic of this structure provides insights into how trade reform, by altering output prices p_a, p_b, and water market reform, by altering water assignments

H_a, H_b, can affect the shadow price of water and returns to the economy-wide resource, labor. These same fundamental forces are embodied in the more detailed and complex empirical model, but nevertheless.

Finally, the analytical linkage between micro farm economy and the macro economy that allows the computation of the indirect effects of reform is the wage equation [5]. We now focus on this linkage.

Modeling feedback links

Let the farm profit function be denoted as

$$g = \mathbf{g}(P^A, W, h^1, \cdots, h^T, d) \qquad [9]$$

and recall that envelope properties of [9] imply the gradients of this equation with respect to the arguments, expressed in vector form, $P^A, W, h^1, \cdots, h^T, d$ yield, respectively, output supply of each crop $j \in I_M$, derived factor demand $i \in I_N$, the shadow price of water λ_t, in each month *t*, and the shadow price of land d_j planted to each crop *j*.

To illustrate, consider the removal of a tariff on the production of an agricultural import competing good, such as sugar. Clearly, we can use the mentioned envelope properties to evaluate this effect on supply, factor demand, and the farm level shadow price of water and land. For brevity, we focus mainly on farm profits [9].

Thus, we presume that the removal of a tariff on sugar (for which we let $j = 1$) causes a change in the price of sugar p_1 faced by farmers to fall. The **direct 'feed-down' effect** of this change on farm profits is given by:

$$\textit{direct effect} = \frac{y_1 p_1}{g}\hat{p}_1 = \frac{\left(\partial \mathbf{g}(\cdot)/\partial p_1\right)p_1}{g}\hat{p}_1 < 0. \qquad [10]$$

Of course, as all farmers respond to the a decline in the price of sugar, resources throughout the entire economy are reallocated, as illustrated by the labor market clearing condition [3], and wage rate equation [5]. In general, this reallocation causes a change in factor rental rates $\hat{w}_i$, $i \in I_N$, as well as a change in the prices of home goods, say $\hat{p}_j \quad j \in I_O$ had we included these in the macro model.

The **'total effect'** on farm profits from a change in the price of sugar is given by

$$\textit{total effect} = \frac{y_1 p_1}{g}\hat{p}_1 - \sum_{i \in I_N}\frac{x_i w_i}{g}\hat{w}_i = \frac{\left(\partial \mathbf{g}(\cdot)/\partial p_1\right)p_1}{g}\hat{p}_1 + \sum_{i \in I_N}\frac{\left(\partial \mathbf{g}(\cdot)/\partial w_i\right)w_i}{g}\hat{w}_i \;?\; 0 \qquad [11]$$

where, from [3] and we have

$$\hat{w}_i = \frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_1\right)p_1}{w_i}\hat{p}_1 + \sum_{j \in I_O}\frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_j\right)p_j}{w_i}\hat{p}_j, \;\; \forall i \in I_O$$

Substituting the appropriate terms from (34) for all $\hat{p}_j \in I_O$ yields

$$\hat{w}_i = \frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_1\right)p_1}{w_i}\hat{p}_1 + \sum_{j \in I_O}\frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_j\right)p_j}{w_i}\sum_{j \in I_O}\frac{\left(\partial \mathbf{P}^j(\cdot)/\partial p_1\right)p_1}{p_1}\hat{p}_1 \qquad [12]$$

Thus, the total effect is given by substituting [12] for all $\hat{w}_i$ in [11]. The sign of [11] is indeterminate due to adjustments in factor rental rates and the prices of home goods in the rest of the economy. The **indirect 'feed-up' effect** is given by the difference between [10] and [11] i.e.,

$$\textit{indirect effect} = -\sum_{i\in N}\frac{x_i w_i}{g}\left(\frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_1\right)p_1}{w_i}\hat{p}_1 + \sum_{j\in I_O}\frac{\left(\partial \mathbf{w}^i(\cdot)/\partial p_j\right)p_j}{w_i}\sum_{j\in I_O}\frac{\left(\partial \mathbf{P}^j(\cdot)/\partial p_1\right)p_1}{p_1}\hat{p}_1\right) \quad [13]$$

where the first term in $(\cdot)$ is the effect of a change in the price of sugar on factor prices w_i, and the second set of terms are the effect of a change in the price of sugar on all home goods that in turn affect the factor prices w_i.

The direct, [11], total, [12] and indirect effects [13] are computed empirically by linking the farm level model with the CGE model.

Notice that the monthly shadow price of assigned water at the farm level is given by $\lambda_t = \boldsymbol{\lambda}^t\left(P^A, W, h^1, \cdots, h^T, d\right) = \dfrac{\partial \mathbf{g}\left(P^A, W, h^1, \cdots, h^T, d\right)}{\partial h_t}$.

The logic of the above analysis applied to the function $\boldsymbol{\lambda}^t\left(P^A, W, h^1, \cdots, h^T, d\right)$ can also be used to determine the *direct, indirect and total effects* of macroeconomic reform on the productivity of water at the farm level. This is the nature of the analysis with the empirical model in later sections of this paper.

OVERVIEW OF RELEVANT POLICY ISSUES IN MOROCCO

We demonstrate the micro-macro linkage approach by applying it to the case of Morocco where irrigated agriculture is a major sector. Using Moroccan data we demonstrate the impacts of various policy interventions and external shocks.

Agriculture accounts for about 15 percent of Morocco's gross domestic product and employs about 40 percent of the country's labor force. Agricultural products account for an average of 19 percent of the country's total imports and about 18 percent of total exports. Of the 9.2 million hectares of arable land, ten percent is irrigated but the products from irrigated agriculture account for 75 percent of total primary and processed agricultural exports. Agriculture is a key sector in the domestic economy, and it is a major trade sector and thus prone to macro economic shocks and to the trade policies of the country's major trading partner, the European Union.

The irrigated sector consumes about 85 percent of the country's total available water supplies. Besides the uneven geographic distribution of Morocco's water resources, the country faces an uneven and erratic rainfall pattern with large year to year variation from the arid South to the Northern regions of the country. Per capita annual renewable water resources are estimated at 800 m^3, implying that Morocco is already a water stressed country. Morocco has invested heavily in developing its water resources, and is now reaching the physical limits of water availability from ground and surface sources (snow melt in the Atlas). The management of this critical resource for irrigation is carried out by nine administrative authorities (ORMVAs) in each of nine large scale irrigation schemes (regions), seven of which account for over 90 percent of the total irrigation water managed by public authority. The investment in and development of these irrigation districts has contributed in major ways to sustaining the income of rural areas, and employment opportunities. It is generally recognized that both economy wide and farm level policies are needed to increase water use efficiency.

Key Policy Issues. The potential trade arrangements of Morocco with the EU are likely to increase competition for cereals while increasing opportunities for the export of fruits and

vegetable products. Domestic policies support directly and indirectly the production of other commodities such as sugar, bananas, livestock and vegetable oils. Other policy barriers include adjustment in capital markets to encourage foreign direct investment, particularly in those sectors for which Morocco can compete in international markets. Irrigated fruit and vegetable products are among these sectors.

Closely linked to the macro economic issues is the question of policy to better allocate water within and among irrigated perimeters to maximize the returns to this scarce resource. This entails a reconsideration of how water is priced and allocated to farmers, concerns with the equity of this process and poverty reduction. Moreover, due to the uncertain temporal and spatial effects of weather, policy must also take into consideration the mechanisms by which these uncertainties can be managed, and particularly so in an environment of a continuing growth in non-farm water demand. The feedback links between economy wide (macro) and farm-perimeter-district level (micro) policies are presented in Table 1.

THE EMPIRICAL FRAMEWORK

The empirical framework is applied to the case of Morocco. In this section we provide highlights of the irrigated agriculture sector in Morocco and how it is modeled within the framework described earlier.

Key Features

Special features of the empirical framework include: (1) spatial identification of irrigation districts and the perimeters within each district, (2) linking the micro, farm-level model to the macro model within the irrigation district(s), (3) disaggregating the macroeconomic policy instruments, by separating the country's trade pattern between the EU—Morocco's major trading partner—and the rest of the world, and (4) modeling architecture designed to accommodate the availability of data depending upon the country to which it is applied. This architecture will allow application to other countries but will not be carried out here.

The spatial identification is particularly important because of the spatial heterogeneity of irrigated agriculture, the proximity of major metropolitan areas to some districts whose growth affects the scarcity of water in some regions relative to others, and the obstacles of transporting water over distance and elevation.

Finally, the architecture of the framework can be easily condensed or expanded to accommodate data availability. The CGE model is written in GAMS code, so changes in index definitions easily change the dimensionality of the model. The stand-alone farm model is currently in GAMS, and thus has the same flexibility (since the farm model is relatively small, spreadsheet solvers can also be used).

The basic structure of the macro-micro model

The Moroccan economy is disaggregated in the CGE model into 88 production activities, which produce 49 commodities and employ eight primary input including intermediate inputs produced in own and other sectors. 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 or sub-sectors. 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 macroeconomic policy instruments that are embedded in the data, including taxes, subsidies, tariffs, and payments for water.

Morocco's irrigated agriculture is organized in 9 water districts (ORMVAs), 2 of which are isolated inform the rest of the economy and we consider the remaining 7 ORMVAs. Among the 82 agricultural and agriculture-related production activities, 66 are in crop production, 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. Because water is either costly or presently impossible to transport between perimeters, the seven ORMVAs are further sub-divided into 20 perimeters.

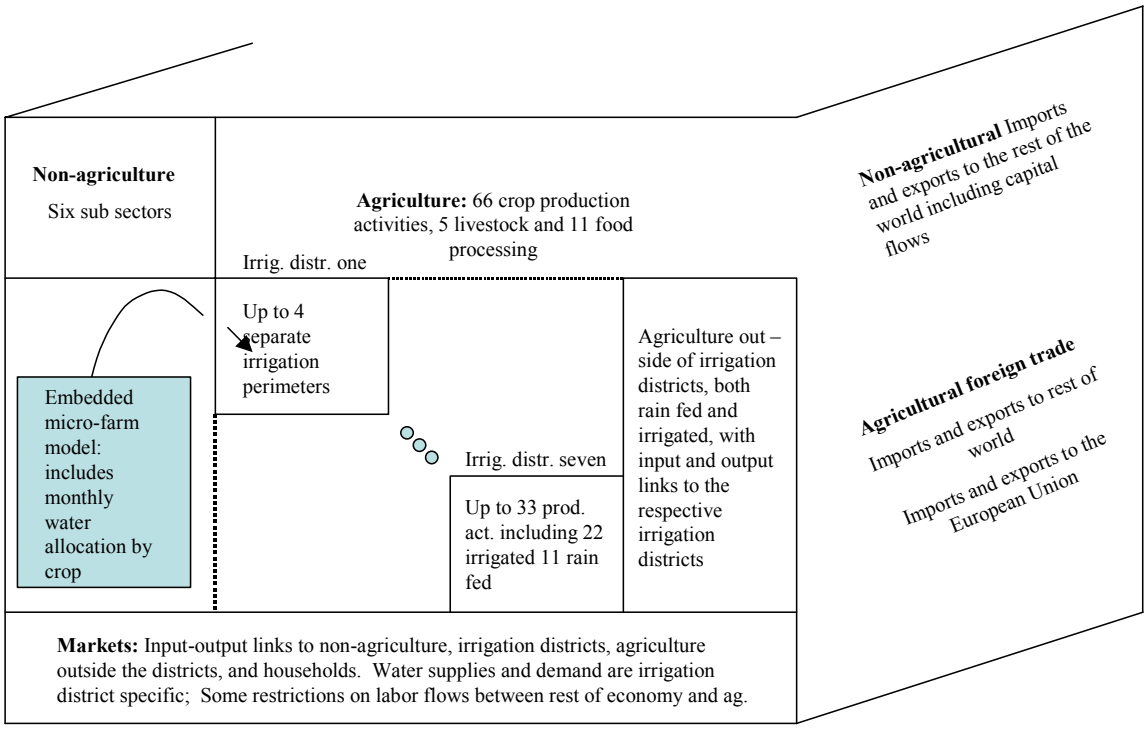
The data are organized into a social accounting matrix (SAM). The data include perimeter level information on water charge fees, cropping mix, water and land allocation by crop and area, employment of labor and capital and intermediate input use by crop. National level data on employment, trade, non-farm production and resource flows are also entered into the SAM. These data are used to calculate the parameters of the model.

Unlike a standard SAM that often includes only national level data, the Morocco SAM in this study is multi dimensional, taking into account crop production activities. A schematic presentation of the major features of the macro framework is presented in Figure 2.

Data for the farm model ('micro' model) are from the same data source as those for perimeters in the 'macro' model, i.e., each perimeter is aggregated from farm level data. For this reason, the production activities in the farm model are compatible with the 'macro' CGE model. For the analysis preformed here, the representative farm is chosen from the irrigated area, and hence, only irrigated crops are included in the farm model.

The farm model accounts for monthly water allocation by crop. Typically, the representative farm only grows some of the crops produced in the perimeter. Only a number of crops (10) are included in the farm model. Just as the case with the CGE model, the farm model is calibrated to the data in such a way that the solution of the farm model for the base period reproduces the observed farm data exactly.

Figure 2: Depiction of the major features of the general equilibrium model including sectoral and spatial disaggregation and embedded farm model



Note:
Households: six groups, four in agriculture, one non agriculture and public group**.**
Structure of Production: 88 activities; 49 commodities; up to eight primary factor inputs plus intermediate factors of production for each activity.
Policy Instruments: i taxes, subsidies, tariffs and water charges, quotas by region.

While the farm model only captures farmer's decision-making in production activities, the CGE model, as a general equilibrium model, captures inter-sectoral interactions of the decision making process in the economy. For this reason, prices, including prices for output and factors of production, are endogenously determined by the CGE model. Factor markets clear such that total available supplies of land, capital, and labor have to equal their respective demand. In the farm model, the representative farmer faces given prices for output and factors. The farm model treats the supply of land and monthly supplies of water as constraints. Otherwise, the farmer can hire labor, employ capital and use intermediate inputs at exogenously (to the farmer) given prices without supply side constraints. But these prices are endogenously determined in the economy wide markets. A schematic presentation of the major features of the farm-level model is given in Figure 3.
Figure 3: Illustration of the major features of farm level model

Production of ten irrigated crops;	Purchased & inter. inputs	Constraints
Annual crops Multiple-cropping	Production input/output relationships	Resource balance constraints
Production input/output relationships & resource allocation constraints		Family supplied inputs Monthly water assignments by crop

In principle, the farm model can be handled in two ways: full linkage, i.e., embedding the farm model into the CGE model, or top-down (stand-alone) linkage. The stand-alone linkage is illustrated in the analysis section of this paper. The full linkage treats the representative farm as a small part of the economy included in one of the perimeters. In the top-down linkage, the prices that are exogenous to the farm model are determined by the CGE model. When we shock the CGE model and prices change through this linkage, the farmers (in the farm model), facing different prices, adjust their production decision to maximize profits. These effects are separated into direct, indirect and total effects.

EMPIRICAL RESULTS

We conduct two sets of policy analysis to illustrate how the macro-micro linkage framework works for the case of Morocco. The first set of policies is at the macro level, and trade reform is chosen to illustrate the macro-to-micro analysis. These results appear in tables 2 to 9. The second set of policies is at the micro level, and water reform is chosen[1]. These results are reported also in tables 2 to 8.

Macro-to-micro effects of a trade reform

We use a full trade liberalization scenario as an illustration of a macroeconomic reform, and focus on the macro-micro linkage effects due to liberalizing both agriculture and non-agriculture sectors. We focus on demonstrating the methodology, and thus limit discussion to key results and their links to the farm level.

Macroeconomic effects. The trade reform (removing tariffs on the imports of all commodities, agricultural and non-agricultural) scenario is first conducted in the economy-wide (CGE) model. Removing trade protection causes all endogenous variables to change and the economy moves to a new equilibrium. Table 2 summarizes selected aggregate/macro eco-

[1]Morocco completed the negotiations with the EU and the US for bilateral free trade arrangements, and the potential impact of free trade agreements on agriculture is one of the most important concerns. In the meantime, the possible impact from on going WTO negotiations of agricultural reforms is also a major concern for the policy-makers. Thus, it is quite useful for us to choose trade reform as an illustration to show how the macro-micro linkage framework works for policy analysis.

nomic variables and their change. As predicted by the trade theory, the country as a whole benefits from the trade reform. Real GDP increases by 1.54 percent from its pre-reform level, and total consumption increases by 1.51 percent. A depreciation of the real exchange rate causes exports to increase. The resulting total exports to the EU, Morocco's major trade partner, increases by 11.26 percent and the agricultural component of exports increase by 38.93 percent. Morocco's agricultural import competing commodities, such as wheat, sugar, and other industrial crops, are highly protected. Removing protection increases the imports of these commodities.

Table 2 also reports the aggregate effect on agricultural production within and outside the irrigation perimeters. As we described in the previous section, the CGE model includes seven ORMVAs and 20 perimeters. Due to current data constraints, livestock production within perimeters has to be ignored (and is included in the outside perimeter agriculture). Total crop production within perimeters accounts for about 25 percent of national crop production. Due to the decline in the production of the protected crops (wheat, sugar, and other industrial crops), total agricultural output within the perimeters declines (by 2.3 percent). Crop production outside of the perimeters (mostly rain-fed agriculture) also declines, but only by 1 percent. However, these aggregate changes mask increases in the output of fruits and vegetables.

Trade reform generally results in more efficient allocation of resources. As output and input markets re-equilibrate following macroeconomic reform, we observe changes in output and factor prices (not presented). Most of the commodities for which prices have fallen received some form of trade protection. Tables 3 and 4 report changes in factor prices (wages and capital). In the CGE model, labor is an economy-wide factor, but capital is fixed at the perimeter level, i.e., capital can only move within a perimeter. Thus, the 'rental rate' of capital (e.g., farm structures, irrigation equipment) varies by perimeter. The slight decline in rural wages suggests that trade policy tended to protect those sectors of agriculture that are relatively labor intensive. This finding bears some important implications related to the debate on 'self sufficiency' policies of developing countries. Trade protection and water assignments are partially designed to encourage the production of staple crops in-house, and to secure jobs for the poor. Our analysis shows that the first objective comes at the expense of the second and policy makers need to consider the trade-off between the two.

Trade reform affects the shadow prices of water (i.e., the productivity of the authorities' water assignment), by crop and perimeter. For the protected crops, trade reform tends to lower the shadow price of water assigned by the respective ORMVA to these crops. As other input and home goods' prices re-equilibrate to this adjustment, the shadow prices adjust accordingly. In general for most perimeters, the shadow prices of the formerly protected crops are lower. However, since input prices faced by farmers are also generally somewhat lower after the trade reform (as we discuss below), the shadow price of water allocated to non-trade protected crops tends to rise.

Since farmers only pay a nominal water charge, changes in the shadow price of water translate directly into changes in farm profits. Equity implications in irrigated areas are also apparent. Farmers producing bananas, for example, tend to be of larger scale with relatively capital-intensive operations. These producers experience a decline in returns to water that is assigned by the water authority to these protected crops, while the smaller scale unprotected fruit and vegetable crop producers experience a rise in the shadow price of water assigned to their crops.

Farm level direct effects of output price changes. Table 5 reports the change in crop output from the farm model due to trade reform; these effects are separated into direct, indirect and

total. In response to the changes in output price, keeping everything else constant (i.e., considering only the direct effect), the farmer often reduces production of crops for which prices fall (e.g., wheat and sugar cane) and increases production of crops for which prices rise (e.g., water melon and potato). However, as sugar cane and soft wheat account for 42 and 24 percent, respectively, of farmland (not shown), reducing the production of these two crops releases an amount of land that can significantly increase the production of other crops, even those experiencing a price decline. Thus, although peanut prices fall, the farmer still decides to increase peanut production (by 1.7 percent for early peanut and 2.4 percent of the late peanuts) to assure the full employment of farm resources.

Farm level direct and indirect effects of changes in output prices. To capture the full effect of changes in output prices we allow prices for both crop outputs and purchased inputs (including intermediate inputs, labor, and capital) to change according to the results of the CGE model (see tables 3-4). In general, the indirect effect from declines in factor and intermediate input prices work in opposite direction to the direct effects discussed above. That is, the decline in some input prices help to countervail the decline in output prices due to the reform's direct effects. Thus, we observe that the decline in sugar cane production falls less (-5.4 percent, table 4) under the total effect scenario, and change in soft wheat production actually increases (+2.1 percent). However, for the other small crops, the total change in output is larger than (i.e., dominate) the direct effect. The decline in purchased input prices (intermediate inputs, labor, and capital) benefit farmer's production, and hence, induce the farmer to increase (or reduce less) each crop's production after the reform. Interestingly, due to differences in input intensity among crops, the demand for labor and capital, as well as land reallocation change differentially in response to reform interventions (table 5). This analysis then shows clearly the importance of linking and identifying the separate macro-micro effects on farm decisions.

Since farmers are heterogeneous, their supply response to the trade reform will also vary. For this reason, it is necessary for policy makers to distinguish between the aggregate (all farms) effect of trade reform on agricultural production and the distribution effect across farm types. This analysis can be done by using the economy-wide (CGE) model, in which not only the macro economic variables can be obtained, but also sector level (agriculture by crops) variables, such as changes in total supply of each crop, can be observed.

Due to the differential effect on crop production, crop and input prices and land holdings, trade reform impacts on farm incomes vary with farm size. In table 6, we report the income effect of trade reform by household groups in the CGE model. Due to our current data constraints, this income grouping does not distinguish between farmers in or outside the perimeters. The results show that small farmers incur the largest income loss due to the trade reform. As a group, small farmers' income declines by 17 percent. The urban household group benefits from the reform, and its income increases by 8.6 percent. These results reflect the fact that the non-farm sector of the economy is also negatively impacted by the country's current trade policy. This result, while at first may appear perplexing, is actually encouraging. It suggests that the basic economic forces of growth and development observed in successful economies, namely, the forces tending to pull from agriculture surplus labor to more productive opportunities in the non-primary agricultural part of the economy, are also strongly present in Morocco.

Micro-to-Macro links of water reforms

We now analyze how a water policy reform at the farm level has direct effects on the farm

firm, how these effects affect the broader economy when adopted in all perimeters, and then, how these adjustments feed-back (indirect effects) to affect the economy of the firm. In terms of the simple theoretical model, extending the reform of water policy from the firm to the national level is considered in terms of trades in water user rights. This type of national level reform will equate shadow prices within each perimeter. The results appear in tables 2-5 below.

Farm level direct effects of water reforms. Starting at the micro level, the reform analyzed is to relax the water authority's water assignment rule, which is the respective ORMVA's assignment of water by crop and month. To model such policy reform, we start from the farm model, and allow the farmer to equate the marginal cost of water across crops (by month) to maximize their production profit. Without considering the possible effect on other economic factors (i.e., holding all exogenous variables in the farm model constant), the farmer responds by reallocating water more efficiently, according to the marginal-value product-of-water rule. Thus, water moves out of the crop production in which the government has assigned an amount of water that causes the marginal value product of water in this crop to lie below that of other crops. Hence, the shadow prices (opportunity cost) of water for growing such crops (such as soft wheat and sugar cane) are lower than for those crops receiving a lower water assignment (e.g., strawberries and water melon).

The direct effect of reform at the farm level (results not shown) is to cause water allocated to the production of soft wheat and sugarcane to decline by 36.6 and by 3.7 percent, respectively. The water released from wheat and sugar cane is allocated to other crops. Except for the late peanuts, water allocation increases in all other crops. Water reallocation is accompanied by the reallocation of land as well as labor and capital (not shown). Moreover, although the direction of change in the reallocation of land and other inputs are consistent with water reallocation, due to the relative factor intensity of the resource employed in each crop and the water-land ratio, the magnitude of the changes in the other inputs is not in direct proportion to water reallocation.

For example, the water-land ratio is low in soft wheat, as the crop only needs to be irrigated for three consecutive months (March to May). The water-land ratio is very high for greenhouse products, such as strawberries, which are irrigated throughout the year. For these reasons, the magnitude of reduction in water demand in wheat is much larger than the reduction in land used in wheat production, while the magnitude of the increase in water demand for strawberries is much larger than the increased land allocate to strawberry production. Change in the allocation of water and land, and in the demand for other inputs results in a change in farmer's crop production. Comparing the results in table 5 for trade and water reforms, we observe that the change in the direction of sugar cane and wheat are consistent in both scenarios, implying that the trade policy and water policy often protect similar crops.

Herein is an important finding. This result suggests a path dependency to reform. For example, if water markets were created to allocate water to equate its marginal value product in all perimeters, in the absence of trade reform, it is likely that some water would be re-allocated from the unprotected to the protected crops, thus leading to a Pareto inferior outcome compared to the current, observed allocation. Instead, the Pareto superior path is to reform trade before water. The important feature of sequencing the reform's components is of special value in irrigated agriculture and deserves additional research. For instance, it is well known that the beneficiaries of policy change easily become entrenched to future reforms that lead to a decline in benefits of former policies. If the sequence of reform is a Pareto superior path, then either new reforms lead to no decrease in benefits, or if

benefits fall to a sub-group, they can, in principal, be compensated without another group being made worse off. Thus, a policy reform is easier to implement and likely to remain more sustainable if carried out in a particular sequence.

Finally, notice that the magnitude of the output change due to water reform is often larger than the change due to trade reform, indicating the importance of water policy to farmers' production decision.

Farm level direct and indirect effects of water reforms. If many farmers in a region (e.g., a perimeter or an ORMVA) participate in a water reform, the allocation of a perimeter's total disposable water supplies among crops and farm types is most likely to depart substantially from those of the water assignments. If, for example, the government were to grant to farmers the user rights to the ORMVA's previous assignment of water, some farmers may have the incentive to rent out some of their water to other farmers, or to rent in from others. In this case, a different combination of crops could be produced and different combinations and levels of resources could be employed at the farm level. These changes in turn will cause factor markets for labor and other purchased inputs to re-equilibrate.

For this reason, we use the economy-wide model (CGE) to simulate a similar water reform policy that might be carried out on a national basis. We could have chosen to consider such a policy only at the perimeter level of a single ORMVA, across perimeters in the same ORMVA or combinations thereof.

In contrast to the farm model, in which we assumed that the reform simply allowed farmers to reallocate monthly water assignments across crops rather than be constrained by the monthly and crop specific assignment, we assume that the government makes a water assignment, but then allows farmers to hold user-rights to this water. The rights allow trade among farmers and for the farmer to receive payments for water rented out up to the total water assignment. Effectively, this policy allows water to be reallocated by a perimeter-specific water market so that the water shadow price is equated among farmers and crops throughout the perimeter. Water trades are not allowed across perimeters due to technical limitations regarding water conveyance.

We assume that this policy is adopted for each perimeter in each of the seven ORMVAs. This policy will cause the economy to re-equilibrate, with new prices for labor and goods that are not traded in world markets (including some purchased inputs).

Table 3 report the change in wage due to such a water reform, while Table 4 presents changes in factor prices, which the farm takes as given. The difference between the total and direct effects gives the indirect effects of water reform. These results are reported in Table 5. In most cases, the indirect effects are of opposite sign to the direct effects.

Sugar cane illustrates the case where the indirect effects at the farm level dominate the direct effect of water re-allocation. It turns out that for the farmer represented by our data, the reallocation of water alone, all else constant, provides an incentive to *decrease* sugar production by 3.7 percent, but the indirect effects, through changes in purchased input prices and changes in the prices of home goods (sugar in this case is mostly traded in the domestic economy), provide an incentive to *increase* production by 6 percent. Since the indirect effect dominates the direct effect, the end result is that the farmer increases sugar production by about 1.36 percent. Thus, the total effect is to induce the farmer to reallocate water back to sugar cane production with the result that sugar production on this particular farm increases.

It is important to note that the farmer simulated in our farm model *does not* represent all farmers' decisions and that his decisions are constrained by the initial cropping system of his particular farm. At the aggregate level, sugar cane production and hence water allocation

actually declines (not shown). This result further indicates that it is not necessary for the economy-wide model and farm model to generate exactly the same result. This type of information should be of particular interest to policy makers.

Effects on the shadow prices of water. The total effect of water reform on the productivity of water in each of the seven ORMVA's, by perimeter, is reported in table 7. The values shown are the change in the shadow price due to the provision of water user rights that farmers may trade among themselves as a percent of the shadow price of water (as estimated by the model when calibrated to data) associated with water assignments in each perimeter of each ORMVA, by crop. The trading in water rights should equalize the shadow price of water. In an analytical model with multiple factor inputs, the change in the shadow prices of water is indeterminate.

Of the 20 perimeters, only four experienced a decrease in the shadow price of water due to water trade reform. The intuition explaining this result is that (a) given the initial water assignments, and (b) the reallocation of water among crops and farmers in all ORMVAs, together caused an increase in the prices of other factor inputs that the crops in these four perimeters employ relatively intensively. This caused the new shadow prices for the crops grown in these four perimeters to fall. In the case of Doukkala perimeter 1, sugar beats account for over 10 percent of total output, melons for about 8 percent and other tree crops for 12 percent. The allocation of water out of sugar beets, and the increase in other input prices simple caused the productivity water in the perimeter to fall in marginal value relative to the base as the prices of other inputs increased.

The other 16 perimeters experienced an increase in the shadow price of water relative to base. The largest increase, about 52 percent, occurred in perimeter 2 of the Haouz ORMVA. This increase occurred as water was allocated out of cereals and fodder production and into crops that are relatively more water intensive such as vegetables. This reallocation released more non-water resource from cereals and fodder production than could be profitability employed in other crop production and the pre-reform resource prices. The result was an increase in the shadow price of water in this perimeter.

The effect of reforming water policy on the macro economy and income distribution of household groups is shown in Table 2 (4^{th} column). Total agricultural output in the seven ORMVAs increases by 7.54 percent due to the water reform. This is a substantial increase in output that is obtained without the additional net use of resources. It can be seen that change in most other aggregate or economy-wide variables are modest. Such modest effects are due, in part, to restricting reform to the perimeter level, and holding urban demand for water constant. It must also be kept in mind that irrigated agriculture is a relatively small share of the total economy, although it employs a disproportionately larger share of the nation's rural work force.

Farm level effect due to combined trade and water reforms. In Table 8, we briefly assess and compare the overall effects of the two policy reforms. We use the effect on farmer's total revenue and net profit to represent the possible welfare gains/losses of the policy reforms for the modeled farm, recognizing that farms of different types and enterprises may experience different effects.

The results show that for this specific farmer who is heavily dependent on income from growing sugar cane and soft wheat, the trade reform leads to relatively large decline in output revenues and farm profits (defined as total production revenue minus all purchased inputs, thus equaling returns to farm specific resources). The direct effects of reform cause total production revenue and net profits fall by 15.7 and 50.7 percent, respectively. The indirect effects compensate the direct negative effects only marginally, by a positive one percent

on revenue and 10 percent on profits. Thus, the total effect of trade reform for this particular farm is a decline in revenue of 14.7 percent and a decline in profits of about 40.3 percent.

On the other hand, the farmer benefits from the water reform. In this case, the indirect effects are larger than the direct effects, and more importantly they operate in the same direction. The direct effect of the water reform is to increase revenue by 3.7 percent and profit by 16.5 percent. The total effect is a 9.6 percent or 35.6 percent increase on revenue or profit, respectively.

Putting the trade and water reforms 'together', the particular farm modeled is still made worse off (35.6% - 40.3 %), but the water reform can almost totally compensate the farmer for the losses incurred by the trade reform. This result illuminates the importance of taking a broader view on reforms. It also suggests that the chronological order at which the reforms are implemented is important. Farmers will be more agreeable of a combined trade and water reform when they know that the water reform will compensate some or all of their losses due to the trade reform.

CONCLUSIONS

The top-down (macro-to-micro) links considered in our analysis for Morocco are of a trade reform type. The bottom-up (micro-to-macro) links pertain to changes in farm water assignments and the possibility of water trading. For each policy we analyzed the direct, indirect and total effects. Water productivity is strongly influenced by these policies, with direct effects modified by general-equilibrium indirect effects and sometimes even reversed by them.

The impacts of the two reforms assessed are found to be different, with trade reform having an absolute impact of a higher magnitude than the water reform. Differences in relative and absolute magnitudes may differ, based on the institutional, economic, and physical conditions of the particular country analyzed.

The importance of packaging and sequencing reforms is an issue that deserves further research. Our analysis of the Moroccan economy reveals that this is an important factor affecting a successful implementation of any reform (See also Saleth and Dinar 2004, Chapter 10). The model developed here can be used to evaluate policy reforms in other situations, pending appropriate data, and is therefore of wide application. For example, various countries are in varying degrees of initial conditions and relative effectiveness of policy interventions. Applying the Micro-Macro approach to these countries will allow testing the hypotheses related to reform packaging and sequencing under different circumstances.

REFERENCES

Berck, P., S. Robinson, and G. Goldman (1991). The Use of CGE Models to Assess Water Policies. In: Dinar, A. and D. Zilberman, (Eds.), The economics and Management of Water and Drainage in Agriculture.

Binswanger, H. P. (1989). "The Policy Response of Agriculture," Proceedings of the World Bank Annual Conference on Development Economics.

Diao, X. and T. Roe. (2000). "The Win-Win Effect of Joint Water Market and Trade Reform on Interest Groups in Irrigated Agriculture in Morocco," in A. Dinar (ed.) The Political Economy of Water Pricing Reforms, Oxford University Press.

Diao, X., Roe, T., and Somwaru, A. (2002). Developing Country Interests in Agricultural Reforms Under the World Trade Organization. American Journal of Agricultural Economics,

Vol. 84, No. 3, August 2002, pp. 782-790.
Diao, Xinshen, Terry L. Roe, and Rachid Doukkali, (2005). Economy-Wide Gains from Decentralizing Water Allocation in a Spatially Heterogeneous Agricultural Economy. Environment and Development Economics (forthcoming).
Dinar, Ariel and Jyothsna Mody (2004). Irrigation Water Management Policies: Pricing and Allocation Principles and Implementation Experiences *Natural Resources Forum* 28:112-122.
Dinar, Ariel and R. Maria Saleth (2005). "Issues in Water Pricing Reforms: from Getting Correct Prices to Setting Appropriate Institutions". *International Yearbook of Environmental and Resource Economics in "New Horizons in Environmental Economics"*. Henk Folmer and Tom Tietenberg (Eds.), Edward Elgar Publishing, (In Press).
Goldin, I. and and D. Roland-Holst (1995). Economic Policies for Sustainable Resource Use in Morocco, in Ian Goldin and L. Alan Winters (eds), The Economics of Sustainable Development, Cambridge Univ Press.
Johansson, R. C., Y. Tsur, T. L. Roe, R. M. Doukkali and A. Dinar (2002). Pricing irrigation water: a review of theory and practice, Water Policy, 4, 173-199.
Krueger, A. O., M. Schiff and A. Valdes, Eitors (1991). The Political Economy of Agricultural Price Policy, Vol. 1, Johns Hopkins University Press.
Roe, T., Y. Tsur, A. Dinar and X. Diao (2004). Water Policy Analysis In General Equilibrium: A Framework Linking Economy-Wide and Farm Level Effects, Economic Development Center Working Paper No. A001, Department of Economics and Department of Applied Economics, University of Minnesota, April.
Saleth, R. Maria, and Ariel Dinar (2004) The Institutional Economics of Water, Cheltenham, UK: Edward Elgar Publishing and the World Bank.
Tiwari, Dirgha, and Ariel Dinar (2002). Balancing Future Food Demand and Water Supply: The Role of Economic Incentives in Irrigated Agriculture. *Quarterly Journal of International Agriculture*, 41(1/2):77-97.
Tsur, Y., T. L. Roe, R. M. Doukkali and A. Dinar (2004) Pricing Irrigation Water: Principles and Cases from Developing Countries, RFF Press: Washington, D.C..
Tsur, Yacov, Ariel Dinar, Rachid M. Doukkali and Terry L. Roe (2005). Irrigation Water Pricing: Policy Implications Based on International Comparison. Environment and Development Economics (forthcoming).
Varian, H. R. (1992) Microeconomic Analysis, Third edition, W. W. Norton & Co., Inc. NY New York.

Table 1: Policy and policy linkages in the analyzed countries

Key Policy Issues affecting the use and productivity of irrigation water		Likely Impacts	
Macro Policies	Micro Policies	Macro to Micro Linkage	Micro to Macro Linkage
1. Modification of policies (both Moroccan and European based) to allow Morocco better access to the EU-Market 2. Free trade agreement with the US on access to agricultural markets.	1. Change in farm-level and regional water policy: Institutions, water entitlements, water pricing. 2. Agricultural development policy: expansion in irrigation area, investment in water conveyance infrastructure, investment in farm-level irrigation technology/management, fertilizers and other input pricing.	The possible trade arrangements are likely to increase competition for cereals while increasing opportunities for the export of fruits and vegetable products.	Improved equity among small and large farms. Better inter-regional allocation of water to address regional relative advantages.

Table 2: Change in selected aggregate variables due to Trade reform and water reform, Economy-wide CGE results, in millions of Dirhams (MD)

Item	Base (million Dh)	% change from base[a]	
		Trade Reform	Water Reform
Real GDP	323,781	1.54	0.17
Real exchange rate	1.00	11.65	-0.12
Consumer price index	1.00	-5.62	-0.08
Total exports	90,603	12.01	0.32
Total exports with EU	58,333	11.26	0.43
Total exports with rest of the world	32,270	13.35	0.13
Agricultural exports	14,963	35.93	2.73
Agricultural exports with EU	9,498	38.53	3.30
Agricultural exports with rest of the world	5,465	31.40	1.73
Nonagricultural exports	75,640	7.28	-0.15
Nonagricultural exports with EU	48,835	5.96	-0.13
Nonagricultural exports with rest of the world	26,806	9.68	-0.20
Total crop output from all perimeters	6,471	2.28	7.54
Total crop output from all non-perimeters	27,160	-1.04	-0.27
Total agricultural output from all non-perimeters	60,711	-2.63	-0.06

[a]Base is normalized to 1.

Table 3: Changes (% from base) in wages for economy-wide labor due to trade and water reforms (CGE model)

	Trade reform	Water reform
Rural wage	-7.91	-0.56
Urban wage	8.23	-0.01

Table 4: Change (%) in capital returns from perimeter capital input due to trade and water reforms (CGE model)

ORMVA	Perimeter 1		Perimeter 2		Perimeter 3		Perimeter 4	
	Trade reform	Water reform	Trade reform	Water reform	Trade reform	Water reform	Trade reform	Water reform
Doukkala	-6.07	4.64	-32.72	-0.31				
Gharb	-23.19	-0.02	-25.99	3.45	-21.69	-6.38		
Hause	-6.36	7.81	-29.19	12.57	-22.93	-10.97		
Loukkos	-34.95	8.86	-42.37	12.03	-43.92	14.12		
Moulouia	4.06	-0.59	-29.16	4.07	-20.28	8.00	7.00	-1.60
Sous-Massa	-7.74	19.96	8.40	0.51	12.01	-1.99		
Tadla	-27.78	-3.15	-17.65	-0.44				

Table 5: Change (% from base) in farm production by crop after trade and water reforms (Farm model)

Crop	Initial level of production (Kg)	% change from base					
		Trade reform			Water reform		
		Direct effect	Total effect	Indirect effect	Direct effect	Total effect	Indirect effect
Peanut1	47.4	1.65	2.08	0.61	13.53	6.75	-6.39
Peanut2	29.3	2.40	2.97	0.85	-7.20	-15.22	-7.36
Soft wheat	72.2	-2.68	2.14	4.55	-8.14	-13.24	-5.20
Sugarcane	3918.7	-7.52	-5.44	2.09	-3.81	2.38	6.05
Strawberry	44.5	0.47	0.61	0.14	13.63	13.67	0.03
Melon	56.8	0.41	0.53	0.12	5.6	5.30	-0.30
Watermelon	46.2	1.63	1.90	0.27	76.25	73.03	-3.46
Pepper	26.8	1.11	1.60	0.50	41.31	39.69	-1.76
Potato1	160.2	1.16	1.65	0.50	6.57	5.47	-1.10
Potato2	101.6	1.23	1.73	0.51	7.25	1.03	-6.21

Table 6: Income effect of the trade reform on different household groups (CGE model)

Income Category[a]	Base (Million MD)	Change from Base (%)
Total rural income	69,594	-11.78
Farm non-wage income	55,819	-12.78
Rural wage income	13,776	-7.73
Small farm income	18,313	-16.95
Medium farm income	20,651	-13.07
Large farm income	16,854	-7.91
Urban income	204,659	8.62

Incomes are normalized by CPI.

Table 7: Percent change in the shadow prices of water relative to the pre water market shadow prices.

ORMVA	Perimeter	Change in shadow prices of water[a] (%)
Doukkala	Per1	-24.89
	Per2	18.98
Gharb	Per 1	2.24
	Per 2	20.47
	Per 3	18.54
Hause	Per 1	-2.30
	Per 2	51.88
	Per 3	20.50
Loukkos	Per 1	-0.27
	Per 2	9.79
	Per 3	15.68
Moulouya	Per 1	2.78
	Per 2	15.25
	Per 3	37.05
	Per 4	1.02
Souss Massa	Per 1	-12.58
	Per 2	6.87
	Per 3	3.65
Tadla	Per 1	26.51
	Per 3	30.98

[a]Comparison between water market price post water reform with average returns to water assignments pre-reform.

Table 8: Farm's total production revenue and profits (Farm model results)

	Output Revenue (MD)	Profits (MD)
Base (MD)	266,832	70,858
% change due to trade reform		
Direct effect	-15.73	-50.74
Total effect	-14.73	-40.28
Indirect effect	1.00	10.46
%change due to water reform		
Direct effect	3.68	16.50
Total effect	9.55	35.57
Indirect effect	5.86	19.06