Understanding the Direct and Indirect Effects of Water Policy for Better Policy Decision Making: An Application to Irrigation Water Management in Morocco

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An Application to Irrigation Water Management in Morocco

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INTRODUCTION

Irrigated agriculture is unique in its spatial dependency on land and water resources, its forward and backward linkages with the rest of the economy, it is almost always an international trade dependent sector, and its relative labor intensity in production suggests the potential for employing the poor and the potential for policy to ameliorate their living conditions. These differences with other sectors of the typical economy along with the difficulty of creating markets for water are arguably one of the main reasons that governments use a plethora of policy interventions such as complex water pricing mechanisms, 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. Only recently have some countries also realized that as a trade dependent sector, foreign trade, fiscal and monetary policies also impact the marginal product (or shadow price) of irrigation water.

A confounding but seldom recognized feature of water policy is the policy errors that arise from collective action. Since the lack of water markets typical require some form of collective action to determine and administer the rules for water allocation to farmers, the mentioned uniqueness of irrigated agriculture implies that water policies often have both direct and indirect effects, the latter of which often work in the opposite direction to the former. The problem arises because the process of collective action, as Douglas North (1990) has noted, typically involves a process that tends to place emphasis on the direct effects of a policy outcome. In other words, the constraints of collective action tend to be such that this process is not capable of "solving" the simultaneous equations of a real economy as a decentralized market mechanism can be characterized as being able to perform. Often, the indirect effects, i.e., those effects that come about as other product and factor markets respond to the policy change, work in the opposite direction to the direct effect, and occasionally, these effects dominate the direct effect. The result can be viewed as failure of the collective action process to incorporate all of the information needed to make policy choices that lead to intended outcomes. Moreover, the sequence of policy reform is important when, as in most economies, there is more than one policy causing distortions. In this case, the sequence of reform that leads to a sequence of Pareto Superior outcomes becomes problematical. The collective action process tends fail in choosing the best sequence because the scope is typically narrowed to a sector so that distortions elsewhere in the economy are ignored. In this second best environment, the indirect effects of reform can easily dominate the direct effects.

The paper is organized as follows. We first sketch the Moroccan economy, provide a non-technical overview of the methodology and then proceed with the analysis.

OVERVIEW OF RELEVANT POLICY ISSUES IN MOROCCO

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. Per capita annual renewable water resources are estimated at 800 m^3, implying that Morocco is already a water stressed country. 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. It is these seven regions and their respective irrigation perimeters that are identified in the empirical model and linked to the rest of the economy.

THE EMPIRICAL FRAMEWORK: 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. 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.

The basic structure of the macro-micro model

A schematic presentation of the major features of the macro framework is presented in

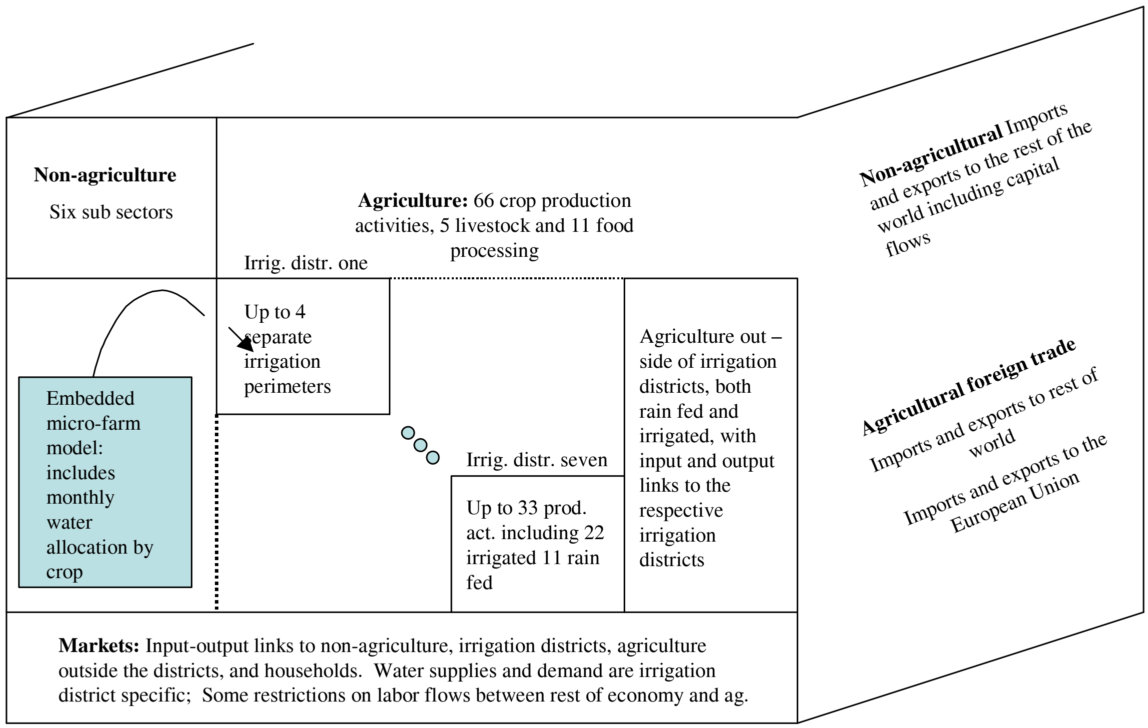
Figure 1. The Moroccan economy is disaggregated in the CGE model into 88 production activities, which produce 49 commodities and employ eight primary input including intermediate inputs produced in own and other sectors. On the demand side, there are five private household groups and one public group. 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 pattern 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 relatively small and isolated due to their desert location. We thus model the remaining 7 ORMVAs as spatially separate areas. 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.

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. The farm model *embedded in the CGE* 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.

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 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.

Figure 1: Depiction of the major features of the general equilibrium model including sectoral and spatial disaggregation and embedded farm model



EMPIRICAL RESULTS

We conduct two sets of policy analysis. The first set of policies is at the macro level, and trade reform is chosen to illustrate the direct-indirect macro-micro analysis. The second set of policies is at the micro level, and water reform is chosen. These results are reported in tables 1 to 7.

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.

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. Table 1 summarizes selected aggregate/macro economic 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 1 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. 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. Most of the commodities for which prices have fallen received some form of trade protection. Tables 2 and 3 report changes in factor prices (wages and capital). 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 were are relatively labor intensive.

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.

A key observation is that had the country pursued water reform prior to trade reform, producers of the protected import competing crops would have had an incentive to bid water away from those export competing crops in which the country has a comparative advantage.

Farmers producing bananas 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 4 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.

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 2-3). 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 3) 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 4).

This analysis then shows clearly the importance of linking and identifying the separate macro-micro effects on farm decisions.

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. The results appear in tables 1-4 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. 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. 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. Water reallocation is accompanied by the reallocation of land as well as labor and capital (not shown).Due to the relative factor intensity of resources employed in each crop, the magnitude of the changes in the other inputs is not in direct proportion to water reallocation.

Herein lies an important finding, as this result suggests a path dependency to reform as previous mentioned. If water markets were created to allocate water to equate its marginal value product in all perimeters, in the absence of trade reform 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. 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. If the country pursued water reform before pursuing trade reform, not only would the economy become more distorted and compensatory payments would also may not be possible. Thus, a policy reform is easier to implement and likely to remain more sustainable if carried out in a particular sequence.

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 reallocation of a perimeter's total disposable water supplies among crops and farm types will experience indirect effects due to changes in input market prices from re-equilibration.

In contrast to the farm model, we assume that the government assigns water as rights to each producer based on historic allocation and allows trading these rights among farmers. 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 a perimeter of an ORMVA. Water trades are not allowed across perimeters due to technical limitations regarding water conveyance.

Table 2 reports the change in wage due to such a water reform, while Table 3 presents changes in factor prices. These results are reported in Table 4. 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. 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.

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 6. 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 effect of reforming water policy on the macro economy and income distribution of household groups is shown in Table 1 (4th 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.

Farm level effect due to combined trade and water reforms. In Table 7, 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.

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 %). Importantly, the water reform almost totally compensates 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 AND IMPLICATIONS FOR MULTI-POLICY ANALYSIS

This paper focused on the total effects of policy change in a GE environment, but broke these effects into direct and indirect. Two types were considered, reforms that started at the top (trade) and those that start at the bottom, farm level water quota policy. We also showed that the sequence (trade reform then water reform, not the reverse) matters. Delineating these differences is important for policy analysis, and particularly so for irrigated sectors where spatial differences are pronounced and water markets tend to be problematical.

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Table 1: 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 2: 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 3: 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 4: 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 5: 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 6: 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 7: 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