Water Scarcity and Food Trade in the Middle Eastern and North African Countries

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EXTENDED ABSTRACT

The Middle Eastern and North African region (hereafter MENA) has been a focal area in the discussion on water scarcity and its impact on food security. This is not only because the region overall is poor in water resources and many countries are importing a large portion of food to meet the domestic demand, but also its strategic geographical location and sensitivity in the international politics.

The MENA region is dominated by an arid and semi-arid climate. Irrigation is of crucial importance for agricultural production. However, the lack of water resources has limited the expansion of irrigation, posing a constraint to food production. On the other hand, the continuous population growth has led to ever greater demand for food. Increasing amount of food has been imported to fill in domestic shortfalls. The import, in essence, reduces the water demand in domestic food production. Allan (1997) termed the food import for compensating the water scarcity as 'virtual water'.

This study investigates food trade patterns in relation to water resources availability in the MENA countries. Multi-variable regression analyses were conducted to estimate the effects of water scarcity and other factors on the food trade patterns in the region. Two model formulations are used for the analysis of water-food trade relations. Model I is a liner regression model that pools all the observations in the regression without considering country effects. Model II applies panel data following a fixed-effects formulation for country. In essence, Model I investigates the overall water-food trade relations in the region by assuming homogeneity across the countries. Model II takes into account the specific effects of individual countries on their food trade behaviour. Differences across the countries are captured in the constant terms.

Three points can be summarized from the results of Model I and Model II: 1) GDP per capita has strong influence on the level of the import of water intensive crops in the MENA countries (the result of Model I). High income countries already had a high import level at the beginning of the period observed and the level remained high over the years. This situation coincides with Allan's claim that the MENA countries had run out of water since the 1970s (1997). High income countries were able to afford more food import to compensate for water scarcity, whereas low income countries had low import affordability, and thus low level of food import; 2) Water resources availability is a dominant factor in explaining changes in the import of water intensive crops during the period observed (the result of Model II). In other words, the increase in food import experienced in the MENA countries during this period is closely related to the intensification of water scarcity. No significant relationship is found between water resources availability and the trade of fruits and vegetables, implying that water scarcity does not impose a major constraint to a country's export of these crops; 3) Irrigated area per capita is negatively related to the level of import of water intensive crops and positively related to the level of export of fruits and vegetables (result of Model I). However, its effect on the changes in the trade of these crops is in general modest or insignificant (result of Model II).

The European Union (EU) is the major food trade partner of the MENA countries, except for cereal. About 70% of the fruit export and 55% of the vegetable export of the region currently go to the EU market. Expanding the export of fruits and vegetables is conducive to improving the value of water use in the MENA countries. However, the expansion is constrained partly by the barriers in the destination markets, notably the EU.

The MENA countries are facing formidable challenges in safeguarding the food supply with diminishing per capita water resources in the coming years. Within the agricultural sector, exporting crops of high water use value, and importing part of cereal, vegetable oil and sugar are conducive to improving water use efficiency in the MENA countries. A greater openness of the exporting markets and improved international political relations across countries are necessary.

1. INTRODUCTION

The MENA region has been a focal area in the discussion on water scarcity and its impact on food security. This is not only because the region overall is poor in water resources and many countries are importing a large portion of food to meet the domestic demand, but also its strategic geographical location and sensitivity in the international politics.

The MENA region is dominated by an arid and semi-arid climate. Irrigation is of crucial importance for agricultural production. However, the lack of water resources has limited the expansion of irrigation, posing a constraint to food production. The ratio of water withdrawal to water resources availability reflects the water use intensity in a country. Most of the MENA countries currently have a ratio over 40%, the water criticality threshold suggested by Alcamo and Henrichs (2002). Some even exceed 100%, indicating that they are using more water than the renewable water resources available to them. This is primarily related to the mining of non-renewable fossil groundwater, and to a lesser extent, the use of recycled waste water and desalinated seawater (Yang and Zehnder, 2002). Irrigation is the largest user of water. On the regional average, about 90% of the water withdrawal is used for this purpose (FAO, 2004b).

On the other hand, the continuous population growth has led to ever greater demand for food. Increasing amount of food has been imported to fill in domestic shortfalls. The import, in essence, reduces the water demand in domestic food production. Allan (1997) termed the food import for compensating the water scarcity as 'virtual water'.

The present study zooms into the MENA countries to investigate in detail the water and food trade relations and disparities across countries and among different food crops. Effects of other factors, particularly the national income, on food import in the MENA countries are also examined. Multi-variable regression models are formulated to investigate factors explaining the magnitude and changes in the trade of different food commodities during the past two decades. The major trade partners of the MENA countries are investigated. The implications of trade policies in the destination markets, particularly the EU, for the export of vegetables and fruits of the MENA countries are also elaborated.

Eleven countries in the MENA region are included in this study: Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Syria, Tunisia and Turkey. West Bank and Gaza Strip are ignored due to the lack of data. Five groups of food commodities are considered: cereal, vegetable oil, sugar, fruit and vegetable, for their close relevance to water use and the importance for food security. Data for water resources availability, crop production, domestic supply and trade are primarily from AQUASTAT and FAOSTAT, the databases of the Food and Agriculture Organisation of the United Nations (FAOa). Items included in each group of crops can be found in the Food Balance Sheet of FAOSTAT. For the analysis of food trade partners, the data are from COMTRADE, adatabase of the United Nations (UNSD, 2004). Meat trade is not considered in this study for the following reasons: part of the cereal import is for animal feed; difficulty in determining water use for animal production; relatively small volume of meat trade in the MENA countries; and a modest portion of meat consumption in the dietary energy intake. Except for Cyprus and Israel, animal products only account for between 5-10% of the total dietary energy intake in the MENA countries (FAO, 2004b).

2. TRENDS IN FOOD PRODUCTION AND TRADE

The past two decades has seen a continuous increase in total food consumption in the MENA countries. On the production side, the growth has failed to keep pace with the demand, leading to an increase in food import (Figure 1).

For convenience, we define the ratio of import to total domestic supply of a crop as the import dependence of that crop. Likewise, the ratio of export to total domestic supply of a crop is the export dependence of that crop.

Cereal grains are the staple food and provide 50%-60% of the dietary energy in the MENA countries (FAO, 2004a). Over the period observed, cereal import increased in parallel with the production in the region. The import dependence of cereal remained at about 35%. An upward trend is also seen in the import of vegetable oil and sugar. Compared with cereal, the import dependences of vegetable oil and sugar are higher: 45% and 60%, respectively. There was a large increase in the import dependence of vegetable oil during the period observed, while the import dependence of sugar was relatively stable.

The MENA region as a whole is a net exporter of fruits and vegetables. However, the quantity of export is only a small fraction of the production in the region. In contrast to the rigid increase in the import of cereal, vegetable oil and sugar, the export of fruits and vegetables had been rather static over the years, despite a relatively large increase in the production.

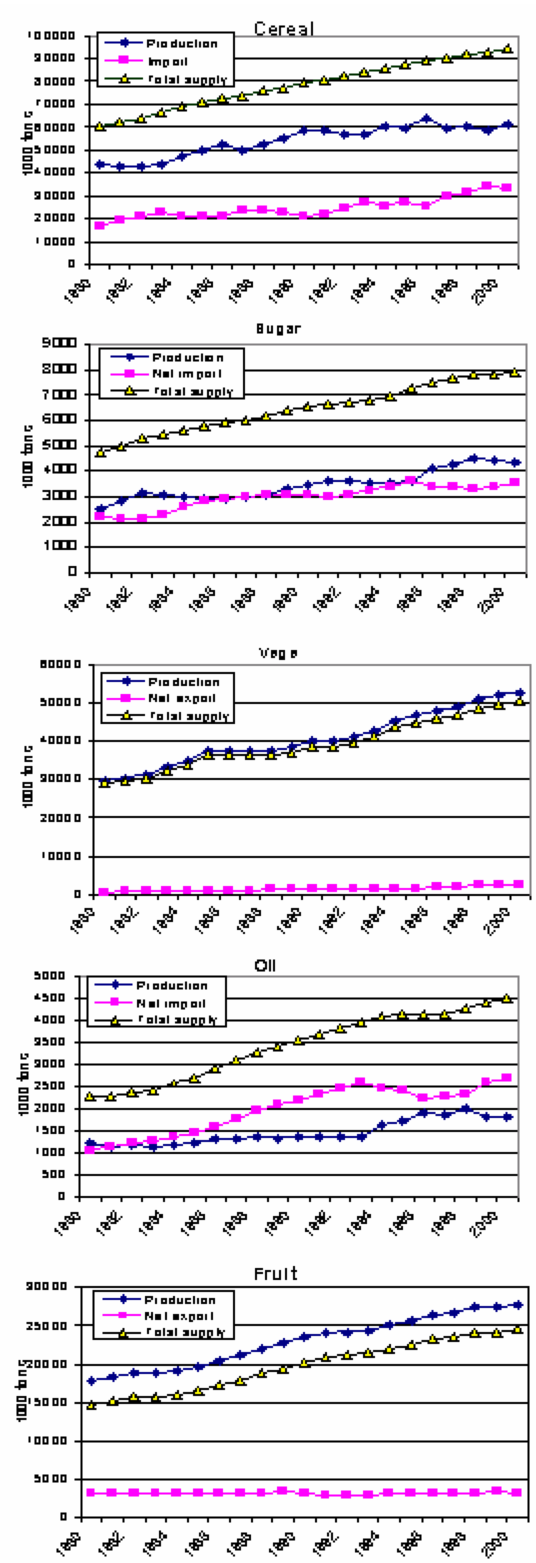

Figure 1. Trends in Domestic Food Production and Trade in the MENA Region (1980-2002)
(5-year running average)

Variations are significant across countries (Figure 2). For cereal, the import dependence in most countries is over 80%. The much lower regional average percentage (35%) is largely due to the very low trade dependence in Syria and Turkey, the two large countries with the highest per capita water resources availability in the region. The import patterns exhibited in vegetable oil are similar to cereal, but the changes in the import dependence were more manifest. As for sugar, except for Egypt and Morocco, the import dependence in other countries all exceeded 90%. Changes in the import dependence of sugar were marginal, plausibly because of the nearly full import dependence in most of the countries.

There are substantial variations in the export dependence of fruits and vegetables among the MENA countries. It is noticeable that the export dependence declined in major exporting countries, particularly in Israel and Cyprus. Only Turkey, Syria and Tunisia recorded a modest increase.

3. MODEL FORMULATION

Two model formulations are used for the analysis of water-food trade relations. Model I is a liner regression model that pools all the observations in the regression without considering country effects. Model II applies panel data following a fixed-effects formulation for country. In essence, Model I investigates the overall water-food trade relations in the region by assuming homogeneity across the countries. Model II takes into account the specific effects of individual countries on their food trade behaviour. Differences across the countries are captured in the constant terms (Greene, 2003).

Model I:

$$Crop\_trade = \alpha + \beta_1 \ln(Water) + \beta_2 \ln(GDP) + \beta_3 \ln(Irrigation) + \beta_4 T + \varepsilon \quad (1)$$

Model II:

$$Crop\_trade_{it} = \alpha_i + \beta_1 \ln(Water_{it}) + \beta_2 \ln(GDP_{it}) + \beta_3 \ln(Irrigation_{it}) + \varepsilon_{it} \quad (2)$$

where, *Crop_trade* is the net trade volume in kg/capita. For cereal, vegetable oil and sugar, it refers to net import. For fruits and vegetables, it refers to net export. *Water* is water resources availability in m^3/capita, *GDP* is in US$/capita converted to 1995 constant US dollars, *Irrigation* is the irrigated area in ha/capita, ε is the error term, and α is the constant term. *T* in Model I is a time dummy variable that picks up any specific effects that are common to all countries and change over time, examples including technological progress and the trend in international food market prices. Subscripts *i* and *t* in Model II denote, respectively, country *i* at year *t*. a_i is the individual effects of country *i* that are not explained by the independent

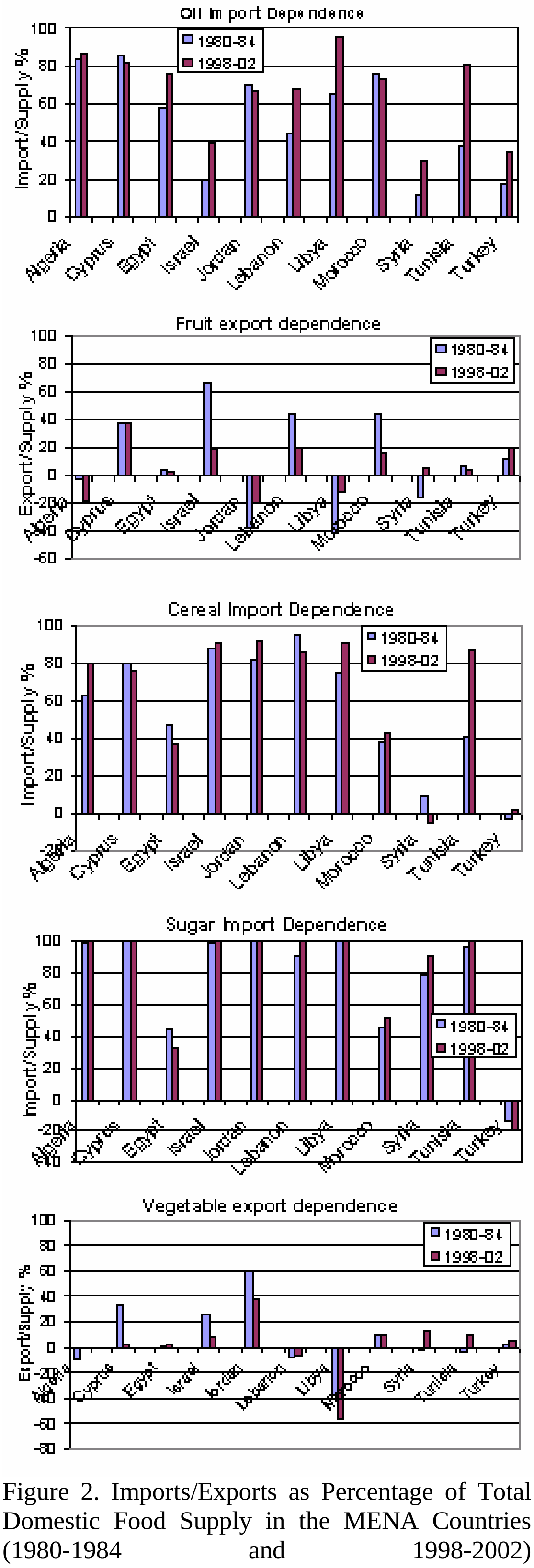

Figure 2. Imports/Exports as Percentage of Total Domestic Food Supply in the MENA Countries (1980-1984 and 1998-2002)

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variables included in Model II. β_1, β_2, β_3 and β_4 are the coefficients to be estimated. The total number of observations in the regression is 88 for each group of crops.

The selection of independent variables is based on the results of correlation analyses of a group of factors that are likely to influence the food trade. The results show that water, GDP, irrigation, arable land and fertilizer in general have high correlations with the trade of the food crops considered (or some of them). However, a high correlation is found between arable land and water resources availability, and between GDP and the level of fertilizer application. To avoid serious multicollinearity in the regression, only water, GDP and irrigation are selected.

In order to smooth the yearly fluctuations of trade caused by weather variations and international market price volatility (rather than a long term trend), three-year average is calculated for the period 1980 and 2002 (e.g., 1980-1982, 1983-1985, ..., 1998-2000, 2001-2002). This generates 8 observation points for each country (the last period is the average of two years) and 88 observation points for all the 11 countries for a given crop.

4. RESULTS AND DISCUSSION

Regressions are performed for each group of crops using Model I and Model II. The results are reported in Table 1.

The results from Model I, regression without considering country effects, show a statistically significant coefficient of ln*(Water)* for cereal, vegetable oil and sugar imports. The negative coefficient suggests that the increase in the import of water intensive crops in the MENA countries is related to the lack of water resources. The coefficient of ln*(Water)* for fruits is statistically insignificant. For vegetables, it is statistically significant at a low confidence level. A regression for vegetable export against water resources availability alone also results in a statistically insignificant t-value for the coefficient of ln(*Water*). The correlation between ln(*Water*) and other independent variables in the regression may have caused this inconsistence.

Table 1. Regression Results from Model I and Model II

Model I		
Cereal (importl)	coefficient	t-value
ln(Water)	-47.94***	-2.67
ln(GDP)	149.73***	9.17
ln(Irrigation)	-79.00***	-2.71
T	0.77	0.13
constant	-870.53***	-3.19
R^2	0.63 (0.61)	
F-statistic	47.06***	
Oil (import)	coefficient	t-value
ln(Water)	-2.67***	-3.46
ln(GDP)	2.27***	3.24
ln(Irrigation)	-0.39	-0.31
T	0.49**	2.04
constant	11.3	0.96
R^2	0.33 (0.31)	
F-statistic	10.23**	
Sugar (import)	coefficient	t-value
ln(Water)	-6.8***	-4.75
ln(GDP)	13.02***	10.05
ln(Irrigation)	-10.43***	-4.75
T	-0.03	-0.07
constant	-61.12***	-2.82
R^2	0.73 (0.70)	
F-statistic	75.92***	
Fruit (export)	coefficient	t-value
ln(Water)	-11.35	-1.03
ln(GDP)	66.72***	9.66
ln(Irrigation)	36.87**	2.11
T	-6.16**	-2.29
constant	-281.37***	-1.85**
R^2	0.45 (0.43)	
F-statistic	17.17**	
Vege (export)	coefficient	t-value
ln(Water)	9.59**	2.01
ln(GDP)	3.86	0.89
ln(Irrigation)	19.44**	2.16
T	-0.87	-0.5
constant	-154.24**	-1.91
R^2	0.25 (0.20)	
F-statistic	7.58*	
Model II		
Cereal (import)	coeffecient	t-value
ln(Water)	-136.39***	-5.11
ln(GDP)	-14.84	-0.45
ln(Irrigation)	-42.88	-1.01
R^2	0.96	(0.95)
F-statistic	141.46***	(68.08***)
Oil (import)	coefficient	t-value
ln(Water)	-10.29***	-5.31
ln(GDP)	-0.99	-0.62
ln(Irrigation)	2.86	0.94
R^2	0.76	(0.72)
F-statistic	22.69***	(17.48***)
Sugar (import)	coeffecient	t-value
ln(Water)	-5.16**	-1.87
ln(GDP)	18.73***	6.13
ln(Irrigation)	-16.18***	-4.74
R^2	0.95	(0.94)
F-statistic	111.67***	(36.27***)
Fruit (export)	coefficient	t-value
ln(Water)	8.47	0.35
ln(GDP)	-99.26***	-4.01
ln(Irrigation)	164.11***	5.35
R^2	0.87	(0.85)
F-statistic	20.22***	(15.16***)
Vege (export)	coefficient	t-value
ln(Water)	9.92	1.01
ln(GDP)	1.91	0.29
ln(Irrigation)	12.07	0.98
R^2	0.85	(0.83)
F-statistic	1.68	(31.08***)

For R^2, the values of adjusted R^2 are given in parentheses.
For F-statistics, the values in parentheses are the F-statistic tests for the significance of the fixed effects (with the null-hypothesis that all fixed effects are equal to zero).
***, ** and * denote statistical significance at 99%, 95% and 90% confidence levels, respectively. The coefficients of country effects in Model II are not reported as they are not of major interest to the analysis.

The coefficient of ln*(GDP)* is positive and statistically significant for the import of cereal, vegetable oil and sugar and the export of fruits. This explains partly the large variations in food trade dependence in the countries with similar water resources availability. The positive and highly significant coefficient of ln*(GDP)* for fruit export is noteworthy. It implies that high income in a country is conducive to fruit export. This is expected because high income is often linked with high inputs, better quality control, and more developed market networks, the conditions important for the export of fruits. These conditions are generally lacking in poor countries, leading to low ability of export. However, such a relationship is not clear for vegetable export, where the coefficient of ln*(GDP)* is statistically insignificant.

The coefficient of ln*(Irrigation)* is negative for the import of cereal and sugar, and positive for the export of fruits and vegetables, consistent with the expectation. For vegetable oil import, the coefficient of ln*(Irrigation)* is statistically insignificant.

The coefficient of *T*, the time dummy variable, is in general statistically insignificant, except for vegetable oil. This may be partly explained by the opposite effects of technological progress and changes in food prices in the international market on trade. During the period in consideration, market prices for cereal dropped by some 30-50% in constant US dollar terms. Similar situation was also seen for the prices of vegetable oil and sugar (FAO, 2004a). The decline in real food prices in the international market would have made food import more affordable and economically efficient for water scarce countries. On the other hand, technological progress during this period would have led to an improvement in total factor productivity, contributing to domestic food production and thus reducing the demand for import. The effects of these two factors on food trade are offset, resulting in a statistically insignificant coefficient of *T*.

Model II takes into consideration the country effects with a panel data approach. As the specific effects of a country are captured by the constant term for that country, the independent variables explain primarily the variations in food trade during the period observed.

The coefficient of ln*(Water)* is negative for the import of cereal, vegetable oil and sugar, consistent with the results from Model I. It is noticeable that the value of the coefficient of ln*(Water)* for cereal and vegetable oil is much higher than that in Model I and the t-test value is improved significantly. The effect of ln*(Water)* is dominant in explaining the variations in the trade of these crops. The result suggests that the increase in the import of water intensive crops during the period observed has been largely related to the decline in water resources availability. The coefficient of ln*(Water)* for fruit and vegetable export is statistically insignificant, consistent with the expectation.

The coefficient of ln*(GDP)* is statistically insignificant for the import of cereal and vegetable oil and for the export of vegetables. This is in contrast to the dominant role of ln*(GDP)* in Model I. One possible explanation to this result is that GDP per capita in many MENA countries increased only modestly during the period observed. Some even recorded a decrease (World Bank, 2002). For fruit export, the negative coefficient of ln*(GDP)* seems counter-intuitive. This may be partly caused by the decline in fruit export in major exporting countries during the period observed.

The coefficient of ln*(Irrigation)* is statistically significant for sugar import and fruit export. The results suggest that expanding irrigation had helped reduce sugar import and increase fruit export. However, for other crops, the coefficient of ln*(Irrigation)* is statistically insignificant.

The R^2 values in Model II are much higher than in Model I, indicating a better fit of the former. The F-test for the fixed effects for country is statistically significant at 99% confidence level for all the crops. This indicates that the level of trade in individual countries is strongly related to country specific conditions, which typically include policies concerning food, water and trade, political situation, international relations, etc. Overall, Model II is a more suitable formulation for explaining the variations in food trade in the MENA countries during the period observed. However, Model I can better reflect the important role of GDP per capita in shaping the level of food import in individual countries.

Three points can be summarized from the results of Model I and Model II: 1) GDP per capita has strong influence on the level of the import of water intensive crops in the MENA countries (the result of Model I). High income countries already had a high import level at the beginning of the period observed and the level remained high over the years. This situation coincides with Allan's claim that the MENA countries had run out of water since the 1970s (1997). High income countries were able to afford more food import to compensate for water scarcity, whereas low income countries had low import affordability, and thus low level of food import; 2) Water resources availability is a dominant factor in explaining changes in the import of water intensive crops during the period observed (the result of Model II). In other words, the increase in food import experienced in the MENA countries during this period is closely related to the intensification of water scarcity. No significant relationship is found between water resources availability and the trade of fruits and vegetables, implying that water scarcity does not impose a major constraint to a country's export of these crops; 3) Irrigated area per capita is negatively related to the level of import of water intensive crops and positively related to the level of export of fruits and vegetables (result of Model I). However, its effect on the changes in the trade of these crops is in general modest or insignificant (result of Model II).

5. MAJOR FOOD TRADE PARTNERS OF THE MENA COUNTRIES

The EU is the major food trade partner of the MENA countries. In contrast, the importance of North America is modest, except for cereal (Figure 3). The share of the rest of the world is relatively large. However, a considerable portion of the trade in this category is within the MENA region, especially for vegetable oil, fruits and vegetables. Excluding the intra-regional trade will make the shares of the EU more prominent.

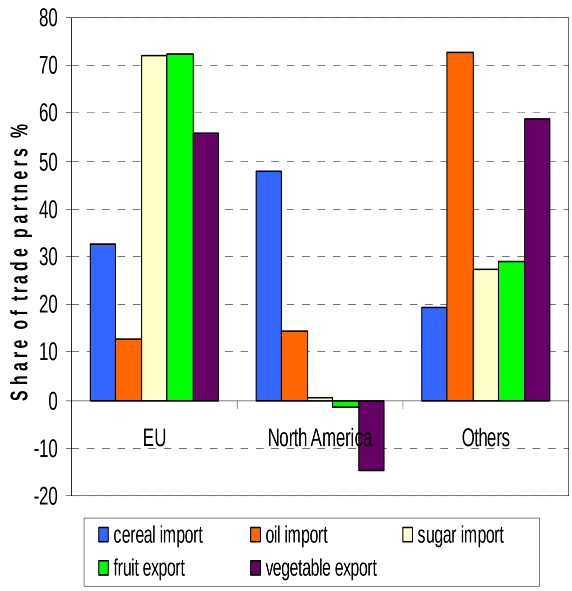

Figure 3. Shares of Food Trade Partners in Total Net Food Trade Value of the MENA Countries (average of 1997-2001)

The EU as a dominant exporting destination of fruits and vegetables of the MENA countries is noticeable. The shares are 71 percent and 56 percent, respectively, in value terms. In contrast, the MENA region is a net importer of vegetables from North America, while the export of fruits is negligible. It is worth noting that while the total quantity of fruit export of MENA was rather static during the period observed (Figure 1), the export to the EU declined: from 1.2 million tons to 0.97 million tons. For vegetables, the export to the EU increased relatively significantly from a rather low level of 0.36 million tons to 0.5 million tons during the same period (UNSD, 2004).

The close food trade partnership between MENA and the EU has natural, economic, and political backings. The natural endowments, especially water resources, in many EU countries are favourable for food production in comparison to most MENA countries. There is a rationale for the two sides to develop food trade in line with their comparative advantages in resource endowments. The geographical proximity between MENA and Europe helps the development of such trade. This is particularly so for the trade of fruits and vegetables, which are perishable and thus are important to reach the destination markets in a relatively short time. Meanwhile, the geographical proximity has also made the political relationship strategically important for both sides.

It has been widely recognized that the market protection, however, trade regulations targeted at agricultural products and high food safety requirements in the EU have impeded the MENA countries to expand the export of fruits and vegetables to the EU market. As the trade barriers in the EU market are unlikely to be lowered significantly any time soon, the expansion of the export of fruits and vegetables of the MENA countries is expected to be limited in the coming years.

6. CONCLUSION

This study examined the food trade patterns and changes in the MENA countries during the past two decades in relation to their water resources availability. Major findings are summarized below:

The multi-variation regression analyses show that the decline in water resources availability is an important factor in explaining the increase in the import of cereal, vegetable oil and sugar during the period observed. The relationship between water resources availability and the trade of fruits and vegetables is statistically insignificant. GDP per capita is an important factor in shaping the level of food trade of a country. However, its effect on changes in food import over the period observed is much less significant. The influence of irrigation on the changes in food trade is also modest.

The MENA countries are facing formidable challenges in safeguarding the food supply with diminishing per capita water resources in the coming years. Within the agricultural sector, exporting crops of high water use value, and importing part of cereal, vegetable oil and sugar are conducive to improving water use efficiency in the MENA countries. Such a trade pattern is particularly pertinent given the fact that agriculture remains a major provider of employment and a main source of income for rural people in most of these countries. For the MENA countries to pursue this trade pattern, however, a greater openness of the exporting markets and improved international political relations across countries are necessary.

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