REV. MIDDLE EAST ECON. FIN., DECEMBER 2003, VOL. 1, NO. 3, 215–230

# H–O for $H_2O$: can the Heckscher–Ohlin framework explain the role of free trade in distributing scarce water resources around the Middle East?

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This paper aims to test econometrically the validity of Heckscher–Ohlin (H–O) theory within the context of export patterns of 11 relatively water-abundant and relatively water-scarce countries located in the Eastern Mediterranean and Middle East and North Africa (MENA) regions. For this purpose, the paper calculates the revealed comparative advantage (RCA) and net trade indices (NTI) for 13 sectors in each country and estimates the relationship between RCA values and water requirements of production in each sector. The results are then used to test whether parameter values estimated from this exercise can be linked to water endowments of the countries considered. By helping determine whether the countries in the sample act according to their comparative advantages, econometric results from this innovative application of H–O theory yield interesting policy conclusions.

Keywords: international trade; water; Heckscher–Ohlin

JEL Classification: F11; F14; Q25; N55; C21; C67

## 1. Introduction

Despite the rapid growth of population, and common practices that lead to an excessive and inefficient use of fresh water resources in many countries, the world as a whole is not expected to face severe shortages of fresh water in the foreseeable future. However, given the uneven distribution of population and fresh water resource disparities among urban, agricultural and industrial areas, what is expected for the world as a whole is not necessarily true for individual regions. In fact, actual or potential water shortages in parts of the Middle East and North Africa (MENA) and South Asia have long been a serious concern in policy making and academic circles in these regions. This concern has also been shared in the rest of the world, as severe water shortages are feared to cause regional conflicts and even wars, thereby disturbing stability and peace in the world.

A former Vice President of the World Bank, Ismail Serageldin, summarized a sentiment shared by many, when he stated in 1995 his prediction that many

*Review of Middle East Economics and Finance* ISSN 1475-3685 print/ISSN 1475-3693 online

http://www.tandf.co.uk/journals
DOI: 10.1080/1475368032000158223

of the wars of the twenty-first century will be about water rather than oil—which was the cause of many wars in the twentieth century (World Bank, 2000).[1]

Opposing and, hence, more optimistic views have also been presented based on such arguments that tensions building up around water shortages can be released through technological and economic measures or diplomatic dialogue and international agreements. The debate has led to the rise of a copious, interdisciplinary literature with contributions from such seemingly diverse fields as hydrology and international relations, or hydraulic engineering and economics, analyzing various aspects of the 'water issue' and proposing solutions to the water shortage problem in MENA and other regions. The proposed solutions focus on increasing the fresh water supply through desalination; improving the efficiency in use of available resources through technical (such as improvement of water distribution networks and the infrastructure for irrigation) or economic measures (such as preventing excessive use of water by introducing pricing schemes to realistically reflect water scarcity), and on alternative ways of sharing water carried by rivers that run across countries through legal arrangements and international agreements.[2]

Although it is one of the best known and most efficient ways of allocating scarce resources from where they are relatively abundant to where they are needed, free trade is typically not considered as extensively in this literature. Even when it is considered as a means of allocating water across a region such as the Middle East, the discussion almost exclusively concentrates on direct trading of water through a pipeline (Wachtel, 1994). However, such a focus on direct water trade via a pipeline overlooks complete benefits of free trade, since trading of commodities other than the water itself also has the potential to help seriously relieve water shortages where they are faced. Since fresh water is an essential input in many production processes, particularly in agriculture, merchandise exports (imports) often act as a channel to transfer significant amounts of water (from) abroad, concealed in the form of an input embodied in the (im-)exported merchandise. J. A. (Tony) Allan who, in 1993, coined the term 'virtual water' for the water embodied in agricultural commodities argued that cereal imports allow more virtual water to flow into the Middle East each year than the water that is flowing down the Nile into Egypt and used for annual crop production in this country (Allan, 1997, 2003). Hoekstra and Hung (2002) have, in fact, estimated the net virtual water imports by Egypt at 15.3 billion cubic meters.

The trading of water in the form of virtual water is, of course, not limited to trade in food and covers other agricultural products as well. Given that cotton production requires extensive use of water, for example, the countries importing cotton are essentially importing the water that went into the production of imported cotton. Though less obvious, the same argument is equally valid for countries importing clothing and textiles—the production of which requires cotton and, hence, water indirectly used in the production of cotton (and other inputs) as well as any water directly consumed during the production of textiles and clothing. So, trade makes it possible to transfer water embodied in traded merchandise across borders, without requiring the rather high installation costs for infrastructure needed for transportation of water that is directly traded. Furthermore, while pipelines can only be built to transfer water directly between neighboring countries, merchandise trade makes it possible to transfer embodied water across oceans.

While explicitly recognizing the role of global trading system as a general channel to transfer water-intensive commodities from water-surplus to water-deficient regions, Allan (2003) focused his discussion on food imports which he views as important indicators of relative shortages of water. More concrete evidence to support the line of reasoning followed by Allan (1997, 2003) in his descriptive and general accounts of the role of global trading system as the solution for the water problem in the Middle East came in independent works by Sayan (2000), Hakimian (2003), and Sayan and Demir (2003). Like Sayan (2000), Hakimian (2003) noted that despite the availability for a long time of the analytical tools provided by the H–O theorem, and the existence of a voluminous literature empirically testing its validity for different countries, economists have failed to systematically analyse the relationship between the severe water scarcity problem facing the MENA region and the trade patterns of the regional countries and, particularly, their food imports. Hakimian (2003) found, based on a comparative cross-section regression analysis for 100 countries, that water-shortage areas tend to import large amounts of food and non-food agricultural produce. Sayan and Demir (2003), on the other hand, used input–output techniques to calculate total (direct and indirect) water requirements of agricultural and non-agricultural sectors in the Turkish economy, and found, among other things, that Turkish exports contain significant amounts of water that go into the production of exported merchandise, agricultural and non-agricultural alike.[4] A particularly interesting finding in the paper was that Turkey exported hundreds of millions of tons of water embodied in agricultural and industrial merchandise (such as textiles) demanded by its trade partners in the Middle East.

This implies that the arguments about agriculture in Allan (1997 and 2003) and Hakimian (2003) can easily be extended to production and trade in sectors other than the food production. Major export sectors whose outputs require heavy amounts of direct and indirect water consumption may be viewed essentially as water exporters in disguise. Moreover, given that Turkey is relatively better-endowed with fresh water resources than its Middle Eastern partners, the finding appears to be compatible with the H–O theory of international trade – which predicts that under free trade conditions, the countries that have a relatively abundant supply of a certain factor of production will export those commodities using that factor of production more intensively. Sayan and Demir (2003, p. 311) reflected a recognition of this compatibility, when they concluded their paper by stating that

> . . . in regions such as the Middle East where water is relatively scarce, and politically sensitive, free trade provides a means to peacefully share regional water resources. For relatively water-scarce countries in the region, imports of merchandise produced by sectors heavily using water could help alleviate some of the pressures created by water shortages, if these countries could identify and act according to their comparative advantages on the basis of water

> endowments. In that case, the welfare gains for all parties involved would be likely to follow.

Building on this idea, the present paper aims to investigate if trade is really an effective means of sharing regional water resources by testing the validity of H–O theory within the context of export patterns of a sample of relatively water-abundant and relatively water-scarce countries located across the Eastern Mediterranean and MENA regions. The sample of countries was chosen to include 10 MENA countries (Egypt, Iran, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, Tunisia and Turkey) for which data were available, and Greece, which was added to increase variation within the sample since most of the MENA countries are short in water resources.

Given the significance of the question addressed and the novelty of the approach employed, the paper is expected to provide a meaningful contribution to the existing trade literature, and add to the rather limited volume of empirical studies on the economics of water in the MENA region and elsewhere. Particularly notable among the few studies currently available in the related literature is a paper that is based on a similar idea by Hakimian (2003). The present paper differs from the Hakimian (2003) study in two major respects. First, unlike Hakimian's (2003) study where an attempt to explain the aggregate agricultural to non-agricultural import ratios in 1997 is made by using relative factor endowments for a cross-section of 100 countries, the analysis here considers 13 individual sectors producing agricultural and non-agricultural commodities, and total water requirements of production in each sector calculated through input–output techniques, as in Sayan and Demir (2003). Secondly, the present study relies on a different estimation methodology that is made up of two steps. In the first step, the revealed comparative advantage (RCA) indices are calculated across 13 sectors for each country and the relationship between RCA values and water requirements of production in each sector are estimated econometrically. The results are then used in the second step to test whether estimated parameter values from this regression exercise can be linked to water endowments of the countries in the sample. By helping identify comparative advantage-sectors for each country in the sample, econometric results from this innovative application of H–O theory yield interesting policy conclusions for the MENA region.

The next section describes the empirical testing of the H–O theory within the context of the water problem in the MENA area and reports findings. Section 3 discusses possible policy implications of these findings and repeats the same test by using an alternative indicator of comparative advantages to check their validity. Section 4 concludes the paper by summarizing the results and pointing out the policy lessons that can be derived.

## 2. Estimation methodology and results

The law of comparative advantage dictates that, in the absence of restrictions and market imperfections, trade will occur and create welfare gains for all nations involved, whenever relative costs of production differ across these nations. Heckscher–Ohlin theory of international trade considers differences in relative scarcity of factor endowments across nations and differing factor intensities across commodities as the primary determinants of comparative advantages of nations that trade with each other for mutual welfare gains. Thus, empirically testing the validity of H–O theory requires that simultaneous consideration be given to (1) trade flows, (2) factor intensities of commodities, and (3) factor endowments of countries (Leamer, 1984).

While international trade literature includes many studies attempting to test the theory empirically, most of these have failed to account for these three key elements together. The methods employed generally consist of regressing trade flow variables on factor intensities. Surely, inferences made about factor endowments based on these regression results may be incorrect. On the other hand, regressing trade flows on factor endowments alone does not add much to the solution of the problem, since factor intensities cannot be taken into consideration this time (Leamer, 1984).

Balassa (1979) proposed a solution methodology based on incorporation into the analysis of trade flows, factor intensities and factor endowments by means of a two-stage regression process (Kim, 1983; Balassa and Bauwens, 1988). As the idea revolves around the concept of comparative advantage, there needs to be a way to measure comparative advantages. Although several alternative measures have been suggested in the literature, one of the most elaborate and useful of these is the concept of 'revealed comparative advantage' (RCA) introduced by Balassa (1965). While Balassa and others have later proposed modified versions of the concept, the original definition was based on a comparison of the share of a particular commodity in a country's total exports to the share of that commodity in total world exports at a certain point in time. So, whether a country *j* has a RCA in commodity *i* can be decided using the ratio of a commodity's share in domestic exports to the share of that commodity in world exports:

$$RCA_i^j = \frac{X_i^j / \sum_k X_k^j}{\sum_j X_i^j / \sum_j \sum_k X_k^j} \equiv \frac{X_i^j / TX^j}{WX_i / TWX} \tag{1}$$

where $X_i^j$ denotes exports of commodity *i* by country *j*, $TX^j$ total merchandise exports by country *j*, $WX_i$ world exports of commodity *i* and *TWX* total merchandise exports in the world. Since all terms in this definition are non-negative, $RCA_i^j$ takes values between 0 and positive infinity. The critical value that this index takes is 1: if the RCA index for commodity *i* takes a value larger (smaller) than 1, then, the share of the commodity in domestic exports is larger (smaller) than the commodity's share in world exports, and the country *j* is said to have a revealed comparative (dis)advantage in that commodity.

Once equipped with this practical measure of comparative advantage, one can test the validity of H–O theory for various samples by using a two-stage regression procedure that takes all elements of the theory into consideration.[5] For this purpose, sectoral indices of RCA must be regressed on relative factor intensities, separately for each country first, and then, the estimated coefficient values obtained from this first step must be regressed on factor endowments of the countries cross-sectionally (Balassa, 1979; also see Kim, 1983; Balassa and Bauwens, 1988).

Within the context of the problem here, water is the specific factor of production to be considered. Hence, the application of the procedure proposed by Balassa requires the estimation of the following equation using data on sectoral $RCA_i$ and $WC_i$ values for each country $j$ ($j \in \{1, 2, \ldots, n\}$ where $n$ is the number of countries in the sample):

$$RCA_i^j = \alpha^j + \beta^j WC_i + u_i^j \tag{2}$$

and then, the estimation of

$$\hat{\beta}_j = a + bWE_j + v_j \tag{3}$$

thereby bringing the number of equations to be estimated to $n+1$.

In equation (2), $WC_i$ stands for relative water intensity (content) of production in sector $i$ that is assumed to be the same across countries, $\alpha^j$ and $\beta^j$ are parameters to be estimated for each country $j$, and $u_i^j$ is the random error term. In equation (3), on the other hand, parameters to be estimated are denoted by $a$ and $b$, and the random error term by $v_j$. The dependent variable, $\hat{\beta}_j$, in this equation represents a $j \times 1$ vector, each element of which corresponds to the estimated value of a $\beta^j$ from equation (2), and $WE_j$ represents the vector of relative water endowments for each country $j$ in the sample.[6]

In the regressions, the sample of countries was chosen to include Egypt, Greece, Iran, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, Tunisia and Turkey (that is, $n$ was set equal to 11). Since it is difficult to find internationally comparable data on a sectoral basis, the choice of sectors was imposed by the sectoral classification used by the International Trade Center (2000) which provided 1998 trade data for 14 sectors in 184 countries. The sectors distinguished by the International Trade Center (ITC) classification are Fresh food, Processed food, Wood products, Minerals, Textiles, Clothing, Leather products, Chemicals, Basic manufacturing, Non-electric machinery, Consumer electronics, Electronic components, Transport equipment and Miscellaneous manufacturing. In the regressions, the same sectors were used except that Textiles and Clothing sectors considered separately by the ITC were combined into one under the heading Textiles and clothing. While this reduced the number of sectors (and hence, the number of observations that can be used to estimate $\beta^j$ coefficients for each country $j$) by one, it became possible to find a compatible matching between sectors for which Sayan and Demir (2003) reported water intensity values (table 1).[7]

Table 1 lists the sectors for which RCA values were calculated for each country in a non-arbitrary fashion. That is, the listing in the first column of the table ranks sectors by direct and indirect water requirements (in cubic meters) per unit of output in a descending order (with the sectors that use significant amounts of water listed against a gray background). The same color coding is used also in ranking the RCA values calculated using equation

**Table 1. Matching of sectors.**

| Present study | Sayan and Demir (2003) |
|---|---|
| Fresh food | Crops, Livestock, Fishery |
| Textiles and clothing | Ginning, Textiles |
| Processed food | Cereal processing, Tobacco processing, Other food proc. |
| Leather products | Leather and furs, Shoes and apparel |
| Wood products | Forestry, Paper products, Furniture |
| Misc. manufacturing | Printing etc. |
| Chemicals | Chemicals, Fertilizers, Rubber and plastics |
| Basic manufacturing | Steel and metal, glass and cement |
| Minerals | Mining, Petroleum products |
| Non-electric machinery | Machinery and vehicles |
| Consumer electronics | Machinery and vehicles |
| Electronic components | Machinery and vehicles |
| Transport equipment | Machinery and vehicles |

(1) and the data supplied by the International Trade Center (2000) for each country, as shown in table 2.

The final piece of information needed to carry out the estimation procedure was relative water endowments by countries—$WE_j$ values in equation (2). Data on total water endowments for each country in the sample came from World Bank (2000). In order to adjust for differences in populations of the countries considered, per capita values for fresh water resources were used for $WE_j$. Table 3 shows water endowment data used in the study.

The expected values for $\beta^j$ coefficients estimated using equation (2) are negative (positive) for relatively water-short (water-abundant) countries.[8] This would imply that, in a relatively water-short (water-abundant) country, the magnitude of sectoral comparative advantage—as measured by the corresponding RCA value—decreases (increases) as water requirements (or water intensity) of production in the sector in question increases (decreases), as predicted by the H–O theory. The expected value for $b$ coefficient estimated from equation (3), on the other hand, is positive.

In order to address the heteroskedasticity problem commonly observed in estimations with cross-sectional data, the regressions were carried out using the technique developed by White (1980) to deal with this problem. Thus, the results reported in table 4 are corrected for heteroskedasticity.

The results indicate that the signs of coefficients estimated generally conform to expectations, with particularly water-scarce countries in the region (that is, the bottom four in table 3) all having negative $\beta^j$ coefficients—implying that their comparative advantages indeed decline, as water intensity of sectoral output increases. In the light of the data in table 3, when one looks at the signs of coefficients alone, the only striking observation would be the signs of $\beta^j$ coefficients for Iran (negative) and Tunisia (positive).

Even though the estimated coefficients for countries other than Egypt, Greece, Tunisia and Turkey in the first stage are not significantly different

**Table 2. Ranking of sectors by RCA values and countries.**

| | Top five RCA sectors by countries | | | | |
|---|---|---|---|---|---|
| Countries | Highest RCA | #2 | #3 | #4 | #5 |
| Egypt | Minerals | Textiles and clothing | Fresh food | Processed food | Basic manufacturing |
| Greece | Processed food | Textiles and clothing | Fresh food | Basic manufacturing | Minerals |
| Iran | Minerals | Fresh food | Textiles and clothing | Basic manufacturing | Processed food |
| Israel | Minerals | Consumer electronics | Miscellaneous manufacturing | Fresh food | Textiles and clothing |
| Jordan | Minerals | Fresh food | Miscellaneous manufacturing | Textiles and clothing | Non-electric machinery |
| Kuwait | Minerals | Transport equipment | – | – | – |
| Lebanon | Minerals | Fresh food | Processed food | Miscellaneous manufacturing | Leather products |
| S. Arabia | Minerals | Chemicals | Basic manufacturing | Consumer electronics | Non-electric machinery |
| Syria | Minerals | Fresh food | Textiles and clothing | Miscellaneous manufacturing | Processed food |
| Tunisia | Textiles and clothing | Leather products | Processed food | Chemicals | Minerals |
| Turkey | Textiles and clothing | Fresh food | Basic manufacturing | Processed food | Leather products |

**Table 3. Water endowments by countries.**

| Countries | Total fresh water resources (billions of $m^3$) (I) | Population in 1998 (millions) (II) | Per capita fresh water resources ($m^3$) (I)/(II) |
|---|---|---|---|
| Greece | 58.18 | 11 | 5289 |
| Turkey | 141.50 | 63 | 2246 |
| Iran | 83.02 | 62 | 1339 |
| Egypt | 58.93 | 61 | 966 |
| Lebanon | 3.76 | 4 | 941 |
| Syria | 12.89 | 15 | 859 |
| Tunisia | 4.02 | 9 | 447 |
| Israel | 2.26 | 6 | 377 |
| Jordan | 0.99 | 5 | 198 |
| Saudi Arabia | 2.52 | 21 | 120 |
| Kuwait | 0.02 | 2 | 11 |

Source: World Bank (2000).

**Table 4. White heteroskedasticity corrected estimation results.**

*Stage 1: Estimated values from equation (2)*

| Countries | $\alpha^j$ | $\beta^j$ | $R^2$ | Adj. $R^2$ |
|---|---|---|---|---|
| Egypt | $0.24956^{\Diamond}$ | $0.00951^{\ddagger}$ | 0.26 | 0.20 |
| Greece | $-0.13778^{\Diamond}$ | 0.01426* | 0.75 | 0.73 |
| Iran | $1.65040^{\Diamond}$ | $-0.00557^{\Diamond}$ | 0.02 | −0.07 |
| Israel | $1.27780^{\nabla}$ | $-0.00282^{\Diamond}$ | 0.06 | −0.03 |
| Jordan | $1.07430^{\Diamond}$ | $-0.00147^{\Diamond}$ | 0.01 | −0.08 |
| Kuwait | $1.98880^{\Diamond}$ | $-0.00857^{\Diamond}$ | 0.05 | −0.04 |
| Lebanon | $0.76453^{\Diamond}$ | $0.00430^{\Diamond}$ | 0.10 | 0.02 |
| Saudi Arabia | $1.89360^{\Diamond}$ | $-0.00879^{\Diamond}$ | 0.05 | −0.03 |
| Syria | $0.80233^{\Diamond}$ | $0.00402^{\Diamond}$ | 0.02 | −0.07 |
| Tunisia | $0.26118^{\Diamond}$ | $0.01350^{\ddagger}$ | 0.25 | 0.18 |
| Turkey | $-0.19585^{\Diamond}$ | 0.01515* | 0.56 | 0.51 |

*Stage 2: Estimated values from equation (3)*

| Constant, *a* | *b* | $R^2$ | Adj. $R^2$ |
|---|---|---|---|
| $-0.11808 \times 10^{-2\Diamond}$ | $0.36354 \times 10^{-5\nabla}$ | 0.37 | 0.29 |

$^{\Diamond}$Not significant; $^{\ddagger}$Significant at 90% or more; $^{\nabla}$Significant at 95% or more; *Significant at 99% or more.

from zero in the statistical sense, they all have values that are sufficiently close to zero (the farthest being –0.00879 estimated for Saudi Arabia). Balassa and Bauwens (1988, p. 29) note that:

> But coefficient values near to zero have an economic interpretation even if they are not significantly different from zero; they indicate that the country is at a dividing line as far as comparative advantage in capital- and in labor-intensive products is concerned.

Thus, $\beta^j$ estimates for all countries were included in the second stage of the regression procedure yielding an estimated value for *b* coefficient that is positive as expected, and is significantly different from zero at a confidence level higher than 95%. Nevertheless, the $R^2$ values from regressions are very low with the exception of four countries whose data produced $\beta^j$ estimates that are statistically significant. In fact, these countries (particularly Greece and Turkey) turned out to be the top four countries with respect to the $R^2$ values in the first stage regressions. A further discussion of these results from the first stage regressions is now left for the next section.

## 3. Further discussion of results

While their reliability depends directly on the quality of data available (and the associated problem of low degrees of freedom), the findings obtained in Section 2 indicated that the export patterns of the majority of the countries in the sample (Iran, Israel, Jordan, Kuwait, Lebanon, Saudi Arabia and Syria) are not significantly affected by amounts of water required to produce leading export commodities and/or intermediate inputs that go into the production of these commodities. Two alternative explanations seem to emerge for these findings. First, the export commodities in which these nations have a comparative advantage may not require significant amounts of water to produce. This would be a particularly plausible explanation in the case of Iran, Kuwait and Saudi Arabia whose major export commodity is oil. Secondly, it is possible that these countries specialize and export commodities that contain more water in an embedded form than is compatible with the relative scarcity of their fresh water resources, as other constraints are more binding than the water shortage problem they are facing.

The best way to formally test the validity of the first explanation would be to repeat the estimations here by using some sort of a RCA indicator in the first stage to focus on imports, rather than exports, by all countries in the sample.[9] This would clearly be an interesting exercise but it is left for future research to pay closer attention to the validity of the second explanation. This second possibility would be relevant in the case of export patterns distorted by domestic policies promoting exports of commodities that are heavy users of water (including primary and processed agricultural commodities—or fresh and processed foods in the terminology of ITC (2000)—and industrial merchandise like textiles and clothing), as well as differential protection regimes restricting, rather than encouraging, imports of such commodities. While there is a lot of evidence to the effect that many of the countries in the sample indeed distort trade patterns through such interventions and cause their scarce water resources to be transferred abroad, the lack of suitable data makes it rather difficult to incorporate detailed accounts of these domestic policies into the framework used here.[10] The best one can do to address this issue would be to use an alternative indicator of the sectoral export performance which is more or less sensitive to the effects of domestic policies. Such an indicator is provided by the so-called net trade index (NTI).

The NTI is even simpler to calculate than the RCA index in equation (1) and is defined as:

$$NTI_i = \frac{X_i - M_i}{X_i + M_i} \tag{4}$$

where $X_i$ shows sectoral exports and $M_i$ sectoral imports. NTI is simpler than RCA as it does not require data on anything beyond sectoral exports and imports. It is also easy to interpret as it only takes values between $-1$ and $+1$, with comparative advantages declining as NTI values fall. Furthermore, NTI is more sensitive to the effects of distortionary policies as a complete ban on imports of commodity *i*, for example, would yield $NTI_i = 1$ as long as exports are positive (no matter how small they might be) falsely pointing to a strong comparative advantage. Likewise, sectors excessively promoted through domestic subsidies and the like would seem to be good export performers (Brenton *et al.*, 1997). While these essentially are the limitations of NTI as a good indicator of a country's real strengths, NTI might be particularly useful within the present context. Based on this opinion, the foregoing analysis was repeated by replacing RCA values in equation (2) with the corresponding $NTI_i$ values for the same sectors.

The NTI calculations changed the comparative advantage ranking of sectors for all countries, except for Kuwait and Syria. Table 5 shows the new rankings along side the rankings in table 2 given in parentheses.

Despite the changes in sectoral rankings resulting from the switch from RCA to NTI as a comparative advantage indicator, the qualitative nature of the results from first stage regressions remained the same except for Egypt and Tunisia, whose $\beta_j$ parameters became insignificant. In other words, when NTI is used as a dependent variable, only the estimates of $\beta_j$ for Turkey and Greece continue to be positive and significantly different from zero (table 6).

The results in table 6 indicate that when consideration is given to sectoral imports alongside exports, the positive and statistically significant relation between water intensities and sectoral export performances in Tunisia (which has a particularly low ranking in table 3) and Egypt gets broken down. One can interpret this as a sign of inflated RCA values because of (over?) promotion of exports in Tunisia and Egypt. While further consideration needs to be given to this point, preferably after obtaining more evidence through additional work in the future, one can argue, on the basis of the first-stage regression results in tables 4 and 6, that, out of the countries in the sample, only Greece and Turkey specialize in the production of commodities whose water requirements are compatible with their respective water endowments. Yet, the results from second stage regressions indicate that relative water endowments matter for the whole set of countries considered here.

## 4. Conclusions

This paper aimed at empirically testing the validity of H–O theory within the context of export patterns of a sample of 11 countries that include relatively water-abundant and relatively water-scarce nations: Egypt, Greece, Iran,

**Table 5. Ranking of sectors by NTI values and countries.**

| | Top five NTI sectors by countries | | | | |
|---|---|---|---|---|---|
| Countries | Highest RCA | #2 | #3 | #4 | #5 |
| Egypt | Textiles and clothing<br>(Minerals) | Minerals<br>(Textiles and clothing) | Fresh food<br>(Fresh food) | Basic manufacturing<br>(Processed food) | Processed food<br>(Basic manufacturing) |
| Greece | Textiles and clothing<br>(Processed food) | Processed food<br>(Textiles and clothing) | Fresh food<br>(Fresh food) | Basic manufacturing<br>(Basic manufacturing) | Minerals<br>(Minerals) |
| Iran | Minerals<br>(Minerals) | Textiles and clothing<br>(Fresh food) | Fresh food<br>(Textiles and clothing) | Basic manufacturing<br>(Basic manufacturing) | Chemicals<br>(Processed food) |
| Israel | Miscellaneous manufacturing<br>(Minerals) | Consumer electronics<br>(Consumer electronics) | Minerals<br>(Minerals) | Textiles and clothing<br>(Fresh food) | Fresh food<br>(Textiles and clothing) |
| Jordan | Minerals<br>(Minerals) | Miscellaneous manufacturing<br>(Fresh food) | Textiles and clothing<br>(Miscellaneous manufacturing) | Fresh food<br>(Textiles and clothing) | Consumer electronics<br>(Non-electric machinery) |
| Kuwait | Minerals<br>(Minerals) | Transport equipment<br>(Transport equipment) | –<br>(–) | –<br>(–) | –<br>(–) |
| Lebanon | Minerals<br>(Minerals) | Fresh food<br>(Fresh food) | Miscellaneous manufacturing<br>(Processed food) | Textiles and clothing<br>(Miscellaneous manufacturing) | Wood products<br>(Leather products) |
| S. Arabia | Minerals<br>(Minerals) | Chemicals<br>(Chemicals) | Consumer electronics<br>(Basic manufacturing) | Basic manufacturing<br>(Consumer electronics) | Non-electric machinery<br>(Non-electric machinery) |
| Syria | Minerals<br>(Minerals) | Fresh food<br>(Fresh food) | Textiles and clothing<br>(Textiles and clothing) | Miscellaneous manufacturing<br>(Miscellaneous manufacturing) | Processed food<br>(Processed food) |
| Tunisia | Leather products<br>(Textiles and clothing) | Textiles and clothing<br>(Leather products) | Chemicals<br>(Processed food) | Electronic components<br>(Chemicals) | Processed food<br>(Minerals) |
| Turkey | Textiles and clothing<br>(Textiles and clothing) | Processed food<br>(Fresh food) | Leather products<br>(Basic manufacturing) | Fresh food<br>(Processed food) | Basic manufacturing<br>(Leather products) |

**Table 6. White heteroskedasticity corrected estimation results (with NTI as the dependent variable in the first stage).**

*Stage 1: Estimated values from equation (2)*

| Countries | $\alpha^j$ | $\beta^j$ | $R^2$ | Adj. $R^2$ |
|---|---|---|---|---|
| Egypt | $-0.93252^*$ | $0.002071^{\diamond}$ | 0.20 | 0.13 |
| Greece | $-0.81595^*$ | $0.002691^*$ | 0.50 | 0.46 |
| Iran | $-0.81106^*$ | $0.001910^{\diamond}$ | 0.08 | −0.01 |
| Israel | $-0.26698^{\diamond}$ | $0.000071^{\diamond}$ | 0.00 | −0.09 |
| Jordan | $-0.59179^{\nabla}$ | $-0.001066^{\diamond}$ | 0.03 | −0.06 |
| Kuwait | $-0.61454^{\ddagger}$ | $-0.001675^{\diamond}$ | 0.07 | −0.02 |
| Lebanon | $-0.86894^*$ | $0.000313^{\diamond}$ | 0.02 | −0.07 |
| Saudi Arabia | $-0.45531^{\ddagger}$ | $-0.002326^{\diamond}$ | 0.12 | 0.04 |
| Syria | $-0.86540^*$ | $0.002251^{\diamond}$ | 0.01 | 0.01 |
| Tunisia | $-0.46447^{\nabla}$ | $0.001672^{\diamond}$ | 0.11 | 0.03 |
| Turkey | $-0.72781^*$ | $0.004233^*$ | 0.67 | 0.64 |

*Stage 2: Estimated values from equation (3)*

| Constant, *a* | *b* | $R^2$ | Adj. $R^2$ |
|---|---|---|---|
| $-0.42951 \times 10^{-4\diamond}$ | $0.82994 \times 10^{-6\nabla}$ | 0.38 | 0.32 |

$^{\diamond}$Not significant; $^{\ddagger}$Significant at 90% or more; $^{\nabla}$Significant at 95% or more; *Significant at 99% or more.

Israel, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, Tunisia and Turkey. The revealed comparative advantage (RCA) and net trade (NTI) indices calculated for 13 tradeable sectors in each country in the sample were separately considered as indicators of comparative advantages underlying the sectoral export performance of individual nations. The relationship between RCA/NTI values and water requirements of production in each sector was then estimated econometrically. This regression exercise was repeated for each country in the sample so as to seek an answer to whether the water that goes into the production of each export sector's output (directly or indirectly through the other inputs used) is a critical factor of production in the sense of H–O theory. This is an important question, since an affirmative answer would mean that the total amount of water needed to produce tradable merchandise plays a significant role in determining the pattern and amount of exports. The estimation results from this first stage of the investigation are then used to test whether estimated parameter values can be linked to water endowments of the countries in the sample.

Even though the discussion so far remained inconclusive on certain questions, the basic lesson that can be derived at this stage is the following. If the H–O theory is applicable indeed within the context of trade flows of MENA countries and their neighbors, then the prevalence of free trade would direct the ones that are relatively better-endowed in water resources towards specialization in the production and exports of water-intensive commodities, and relatively water-scarce countries to specialize in commodities whose production requires less water. Within such a framework, free(r) trade might facilitate the resolution of water-related conflicts in the region by leading to a more efficient use of scarce resources on a regional scale, especially when it is complemented with direct exports/imports of water through a regional grid of water pipelines. Although it is distributed unevenly across the region, regional fresh water resources could be shared peacefully through merchandise trade as well as direct trading of water through pipelines.

## Acknowledgments

The author gratefully acknowledges comments by friends and colleagues who attended the session where a preliminary version of this paper was presented during the 7th Annual Meeting of the ERF in Amman, Jordan (October 26–29, 2000), and by Sebastian Dessus of the World Bank, Dr Mohamed el Hedi Lahouel of University of Tunisia III, and Dr Kivilcim Metin-Ozcan of Bilkent University on later versions. Also, an anonymous referee for this journal made additional comments and suggestions that were extremely helpful. The responsibility for any errors and omissions that might have remained, however, is solely the author's.

## Notes

1. Perhaps, there were water-related wars even in the twentieth century. It is often argued that the 1967 Arab–Israeli war broke out because Israel wanted, among other things, to increase its control over the high waters of Jordan River (Haddad, 1994).
2. See, for instance, Bagis (1994) for a collection of studies focusing on different means of solving the water shortage problem in the Middle East.
3. See UN (2003) for the amount of water required to produce selected food products, including livestock.
4. Total water requirements take into account both the water embodied in (i.e., the water that went into the production of) intermediate inputs required to produce a certain commodity and the water directly used in the production of that commodity itself.
5. For a discussion on other procedures that can be employed to test the Heckscher–Ohlin theory, and an alternative procedure proposed to test it within a multi-country, multi-factor context, see Bowen *et al.* (1987).
6. Econometrically, it is possible to estimate equations (2) and (3) jointly, after combining them into a single panel data equation as $RCA_i^j = \alpha^j + (a + bWE_j)WC_i + (WC_i v_j + u_i^j)$. But then, it would not be possible to test the H–O theory in the context considered here.
7. $WC_i$ values can be calculated by pre-multiplying the so-called Leontief inverse used in input–output modeling with the diagonal water requirement matrix. See Sayan and Demir (2003) for a more detailed discussion on this calculation.
8. As pointed out by an anonymous referee for this journal, relative water-shortage/abundance can also be defined with respect to fresh water resources per square kilometer of land mass for each country. Whether this would affect the results reported in this paper is an interesting and important question that will be a subject for future research.
9. This possibility has been suggested by an anonymous referee for this journal, who convincingly used Iran as an example by pointing out the status of this country as one of the top grain importers in the world. Being not particularly well-endowed in fresh water resources, importing large volumes of grains from countries that are relatively better-endowed appears to be the sensible thing for Iran to do.

   This, in turn, implies that the statistical significance of β coefficients estimated at the first stage may change, when revealed comparative disadvantage indicators are used instead of RCA indicators.

10. Admittedly, food security concerns of many nations, in the Middle East or elsewhere, significantly contribute to the maintenance of domestic support policies for agriculture or protection on food imports. Regardless of the rationale behind these policies, however, they lead to a rather inefficient use of water resources.

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