Drivers behind changing food dependency and associated water risk in the MENA-region between 1961 and 2011

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Abstract

Countries in the Middle East and North African (MENA-) region are acknowledged as having the largest water deficits in the world, which makes them dependent on food imports to provide in human food supply. MENA-countries are thereby dependent on natural resources abroad, carrying the risk of unreliable imports caused by limited resources elsewhere. In this study, food import dependency in the MENA-region and its drivers for change are investigated between 1961 and 2011, besides that, food imports are associated to water risks. At first, food import dependency ratios (IDR) over time for the countries are calculated. Secondly, IDR changes per country are related to predefined drivers. Finally, food imports are associated to the water risk. A rising food import dependency was found in all countries, except for Kuwait where the government decided to start food production to decrease the import dependency in the '80s. Globalization, population growth, human food supply and total renewable water resources were found to be the dominant drivers for change while effects of the GDP were weaker. Wars affect the IDR in case of high casualties per time unit. Trade treaties affected trade partner choice. Water risk is highest in Gulf Cooperation Countries (GCC) a high IDR and trade partners within the severely water scarce region and Australia. The North African countries imported mostly from the moderate to low water scarce European countries and has a lower water risk with an IDR lower than GCC countries. Trade partners of the Levant area (Lebanon, Iran, Iraq, Israel, Jordan and Syria) are found within the region itself and in Europe. IDR and water risk are in between those of the GCC and the North African countries. Water risk of food imports slightly increased over time in the whole region.

1. Introduction

Oil sources in abundance on the one hand and an enormous shortage in water resources at the other hand; two extremes coming together in the Middle East and North Africa (MENA-region) (Figure 1), and resulting in a complex region with many conflicts (Gleick, 1994). The region is acknowledged as having the largest water deficit worldwide, affecting the basic requirements of society, economy, environment and politics (Haddadin, 2001) with increasing severity

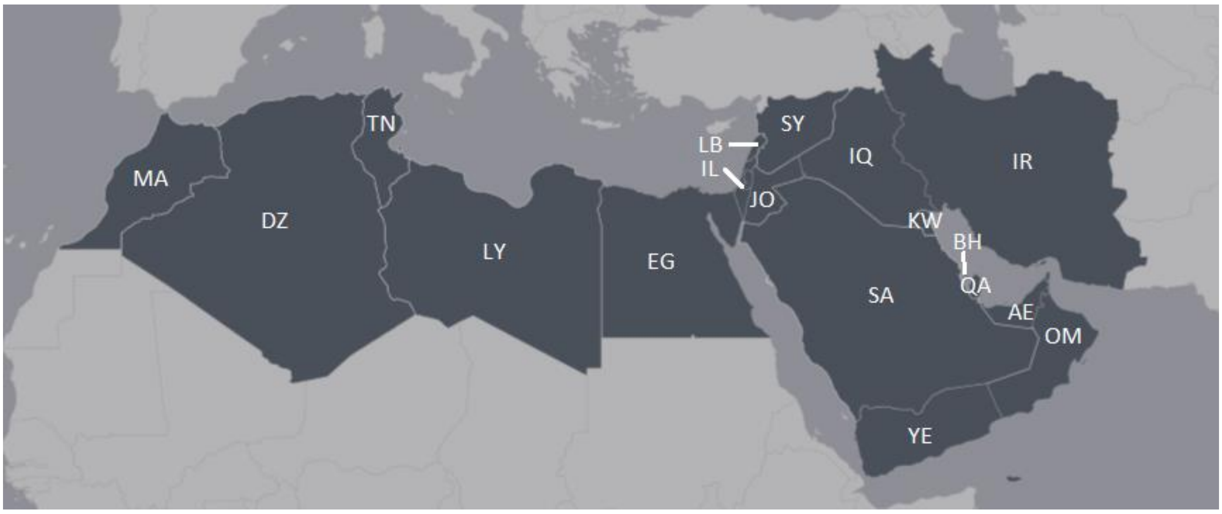

Figure 1: Overview of the countries in the MENA-region. MA=Morocco; DZ=Algeria; TN=Tunisia; LY=Libya; EG=Egypt; JO=Jordan; IL=Israel; LB=Lebanon; SY=Syria; IQ=Iraq; SA=Saudi Arabia; YE=Yemen; OM=Oman; AE=United Arab Emirates; BH=Bahrain; QA=Qatar; KW=Kuwait; IR=Iran.

foreseen for the future (Allan, 1996; Farzaneh Roudi-Fahimi et al., 2002). To provide in human food demand, the region is dependent on the imports of water-intensive commodities from trade partners (Antonelli & Tamea, 2015; Hoekstra & Mekonnen, 2012; Hsayan, 2008; Yang, Wang, & Zehnder, 2007). The import dependency affects food security (Allan, 2003), and sustainability of imports in future is not guaranteed since water resource limitations in the source countries is expected to grow as a result of climate change (Orlowsky et al., 2014; Suweis et al., 2013), growing food demand due to growing population, and changing consumption patterns (Ercin et al., 2013). Schyns et al., (2015) has studied the water risk of food imports and concluded that risks can be managed by importing water-intensive commodities from nations that are not under a high degree of water scarcity. However, this is a growing challenge, since water scarcity in many countries is growing. A second strategy to reduce water risk of food is by diversifying imports over various trade partner countries.

Several aspects are known to affect the food import dependency within a country (Acevedo, 2011; Godfray et al., 2010): food demand, food availability and politics, with each several drivers. At first, population growth increases food demand (Marienela et al., 2013; UN, 2012): the population in the MENA-region quadrupled during the second half of the twentieth century and with one-third of the region's population under the age of 15 a large number of young woman are reaching the reproductive age (Farzaneh Roudi-Fahimi & Mederios Kent, 2007). In Jordan, this number even reaches the 40% (Farzaneh Roudi-Fahimi et al., 2002). Secondly, economic development increases food demand: throughout the world, economic growth has led to an increased GDP, more diverse diets and an increasing food supply (Hawkes, 2006; Kearney, 2010; Luan, Cui, & Ferrat, 2013).

Food availability is, at first, affected by the internal food production, and secondly by the internal water availablity, influencing yield and production especially with droughts (Sheffield et al., 2012). Finally, access to food increased due to rising international trade in the last decades, leading to the globalization of food commodities (D'Odorico et al., 2014). Porkka et al., (2013) found that food supply has increased globally between 1965 and 2005, whereby insufficient food supply, has increasingly been compensated by rising food imports in recent years.

The WTO states that many factors may have contributed to the remarkable trade expansion in the last decades and that a significant reduction of trade barriers is one of the main reasons (WTO, 2013). The reduction of trade barriers has a political base, coming to the third aspect of food dependency: politics.

Politics is a driver of food dependency with at first trade treaties, secondly: conflicts, and at third the political decisions influencing the demand as well as the availability of food (Gleick, 1994; Haddadin, 2001; Raskin, Gleick, Kirshen, Pontius, & Strzepek, 1997).

Food dependency is already studied as a trend over time for several countries in the Middle East and North African region in various studies (Luan et al., 2013; Porkka et al., 2013), but the relation between drivers, food import dependency and associated water risks are not known yet. The objectives of this study are (1) to analyze the food import dependency for all countries in the MENA-region between 1961 and 2011 and (2) to indicate the effect of several drivers on the food import dependency. Subsequently (3), the risk of being dependent on water resources abroad is associated to the food import dependency. In the next section, method and data are discussed, where after results of the trends in food import dependency and the effect of drivers are analyzed. The food import dependency is associated with water risk afterwards, finally followed by a discussion and conclusion.

2. Method & Data

When talking about food and food dependency, *domestic food* supply is meant in general, see Figure 2. In some cases, *human food* is studied; this is indicated in those cases. At first, method and data to determine the *food import dependency ratio* (IDR) over time for all countries is mentioned. Secondly, the method to relate the IDR changes to predefined drivers is shown, whereby the method for the relation between the IDR of the whole region with the drivers is studied as well. Finally, the method of associating food imports to water risk are indicated.

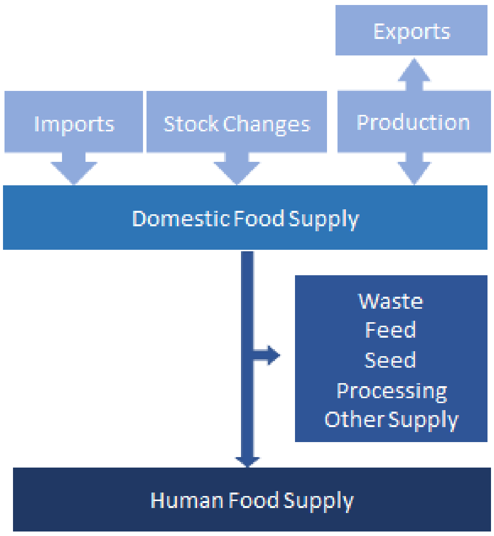

Figure 2: Relation between food production, domestic food supply and human food supply. Domestic food supply is dependent on food production, food import- and export from and to trade partners, and stock variation within the country and it includes feed, seed, food for processing, waste and food for other utilization. Arrows show the direction of the food flow.

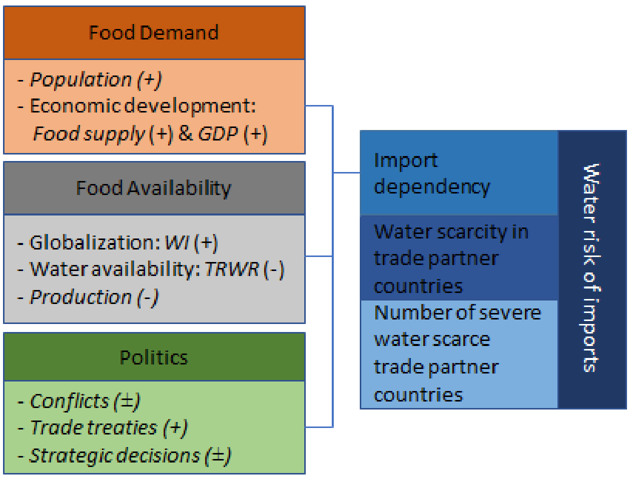

Figure 3: drivers and, in italic, their indicators for a changing IDR. TRWR= total renewable water resources. WI=Worldwide Imports. The signs represent a positive (+) or negative (-) expected correlation with the IDR.

2.1. Trends in import dependency

The import dependency ratio (*IDR*) of domestic food supply is calculated by (FAO, 2012):

$$IDR = \frac{IQ}{PQ+IQ-EQ} \qquad (1)$$

With food production quantity *PQ* (mass in kg), import quantity *IQ* (mass in kg), export quantity *EQ* (mass in kg) and changing stocks *dS* (mass in kg). Totals of *PQ, IQ, EQ* and *dS* are determined by summing the quantities of aggregated primary crops shown in Appendix I (FAO, 2017). Data were available for 14 countries: Algeria, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Morocco, Oman, Saudi Arabia, Tunisia, United Arab Emirates and Yemen. Data for Oman were available between 1990 and 2011. No data were present for Syria, Libya, Qatar and Bahrain; these countries are not considered. A 51x14 matrix is formed per quantity per year (51) per country (14), to calculate the IDR with.

The IDR only holds if imports are mainly used for domestic utilization and not for re-export. The latter is not taken into account due to a lack of data, it is therefore assumed that all imports are used for domestic utilization. The IDR trend is determined by a Hodrick-Prescott filter. Raw unfiltered values were used to analyze peaks. Changing stocks are not taken into account in the IDR, following the FAOSTAT pocketbook (FAO, 2012).

2.2. Drivers for changing import dependency

Predefined drivers for changes in the IDR are shown in Figure 3 and are set of the potential drivers based on the literature review. Drivers are represented by indicators. A Pearson's linear correlation coefficient between the indicators and the IDR per country is calculated and tested on significance. Following Evans (1996), a correlation of

0.00-0.19 = very weak
0.20-0.39 = weak
0.40-0.59 = moderate
0.60-0.79 = strong
0.80-1.00 = very strong

A p-value belonging to the correlation below 0.05 indicates a correlation significantly different from 0. The expected positive or negative correlations between the indicators and the IDR are shown in Figure 3.

Data about *population sizes* (# of people), *human food supply* (kcal/cap/day) and *worldwide imports* (kg/cap/year) came from FAOSTAT (FAO, 2017) for the crops mentioned in Appendix I. *GDP* (constant 2010 US$/cap) data are gained from the World Bank database (The World Bank, 2017). Hereby, GDP data of Iraq, Morocco, Oman, Saudi Arabia and Tunisia were available for the period 1969-2011, for Jordan and the UAE for 1975-2011 and for Kuwait, Lebanon and Yemen for 1995-2011. Others are from 1961-2011. *TRWR* (m^3/cap/year) is the sum of internal renewable water resources, external renewable water resources including average annual flow of rivers and recharge of aquifers generated from endogenous precipitation, inflows from upstream countries, and part of the water of border lakes and/or rivers (FAO, 2016). Data were gained from the AQUASTAT database as averages over periods of five years (no annual data were available) (FAO, 2016). Correlations are done with IDR data averaged over the same periods of 5 years.

Conflicts, *trade treaties* and *political decisions* are qualitative related to the IDR using the list of regional trade agreements and conflicts in Appendix III (Bilaterals, 2012; Encyclopaedia Britannica, 2015; WTO, 2017). For each event, it is analyzed if and in which way the IDR of the specific country has changed during the event and if it is likely that the change is caused by the event.

2.3. Water risk of imports

Water risk of imports is directly related to three aspects: (1) *the IDR*, (2) *the level of water scarcity in trade partner countries* and (3) *the number of trade partners experiencing severe water scarcity*, as seen in Figure 3. Water scarcity is measured by *the water resources vulnerability index* (WRVI): the ratio of annual freshwater withdrawals to the total renewable water resources (TRWR). A country can be low (WRVI <20%), moderate (20-40%), or severely (>40%) water scarce (Brown & Matlock, 2011; Raskin et al., 1997). Data are collected from the AQUASTAT database (FAO, 2016).

Annual imported food quantities are summed per trade partner country to calculate most important trade partners for each MENA-region country. The five most important trade partners are determined for three periods to reduce inter-annual variation and to overcome a lack of data in some years. Food quantity data including country of origin were available at the trade sheets of the FAOSTAT database (FAO, 2017) between 1986 and 2011 for 293 crops (see Appendix II). Data of Iraq were not available; all other countries in Figure 1 studied. For 90% of the total imports, the amounts of imports from trade partners were related to the degree of water scarcity (severe/moderate/low) in that trade partner country to analyze water risk (as shown in Figure 3). The higher the IDR and the higher the degree of food imports coming from severely water scarce trade partners, the higher the water risks of imports. Number of trade partners countries per degree of water scarcity of the imports are also calculated: the bigger the diversity, the lower the water risk of imports from a trade partner (Schyns et al., 2015).

3. Results

3.1. Trends in import dependency

Figure 4 shows the rising EQ, IQ, PQ over time for the 14 countries. The dS varies over time in all countries. The IDR is given in Figure 5 on top, in which three periods can be distinguished: an increasing trend till 1985, a stabilization until 1997, and finally a rising trend till 2011.

The five highest IDRs are found in countries in the Gulf Cooperation Council (GCC): Kuwait, Oman, Saudi Arabia, and the UAE, with values up to and over 1. The North African countries are showing IDRs between 0.1 and 0.45, much lower than those of the GCC countries and the third sub-region, the Levant region (Lebanon, Iran, Iraq, Israel, Jordan and Syria) has IDRs in between those of the GCC and North African countries, with Iran as an exception with the second lowest IDR of the whole region. IDRs of all countries are rising over time, except of Kuwait with an IDR >1 till 1984, caused by EQs being bigger than PQs and decreasing over the whole period due to growing PQs.

3.2. Drivers for changing import dependency

Correlations between the IDR and the predefined drivers are shown in Table 1. Strong to very strong correlations are found between the IDR and the population growth, globalization and human food supply for most countries. Production shows a weaker correlation, which is strikingly since the IDR is partly determined by the production (see Equation 1). The GDP is weakly correlated also. Kuwait is an exception with a negative correlation for all drivers, which is a result of the decreasing IDR over time.

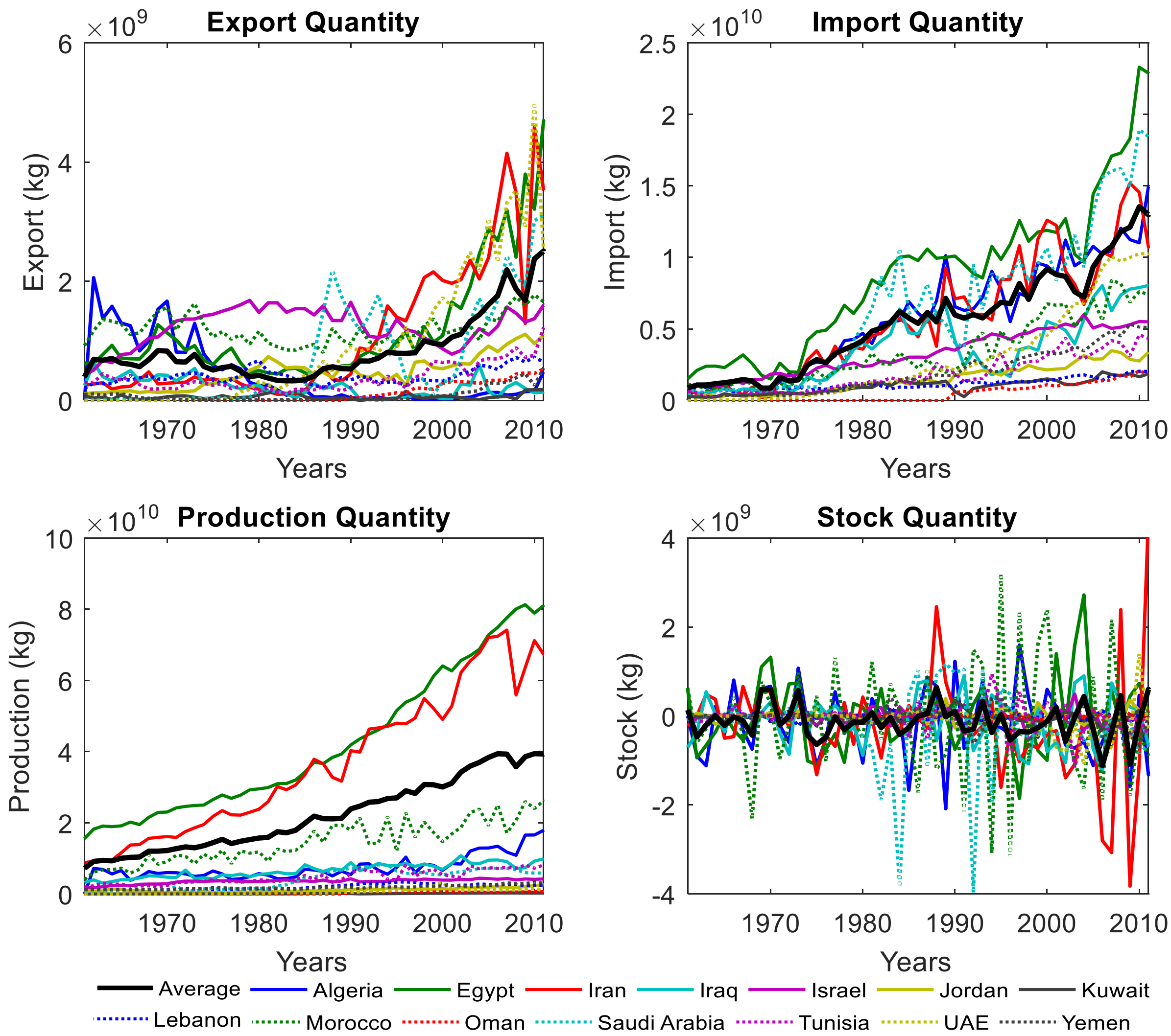

Figure 4: Export quantity, Import Quantity, Production Quantity and Stock Variation are all rising over time. Note differences in the vertical scale. Import quantities are much higher than export quantities. The bold black line shows the weighted (with the population as weight) average of all countries in the MENA-region.

3.2.1. Population

The population of the countries in the MENA-region increased enormously in the last decades, as is shown in Figure 5. (Very) strong correlations are seen with the IDR. Lebanon's correlation between the IDR and population is weak due to the decreasing IDR between 1975 and 1995, while the population still increased. Egypt, Jordan and Morocco show a moderate correlation, due to a gulfing IDR, while the population has a smooth increasing trend. Following the correlations, the population is not the strongest drivers of the IDR, but following the trends, population and IDR show a big similarity.

3.2.2. Economic development

The GDP (constant 2010 US$/cap/year) is a measure for economic growth and is shown in Figure 5, with the weighted average slightly increasing over time. Kuwait's GDP is strongly rising from 2000 onwards while the IDR decreases, resulting in a low correlation. The UAE shows the highest GDP per capita in the region around 1980, but it strongly decreased afterwards as a result of the rebounds in the oil market (Sadik, 2000), resulting in a decreasing IDR for a few years as well. In Jordan and Saudi Arabia, the effects of the decreasing GDP caused by the oil crisis are seen also, with the IDR showing a big decreased. This implies that the GDP directly affects the IDR at some moments in time, but correlations are weak to moderate in 7 of the 14 countries.

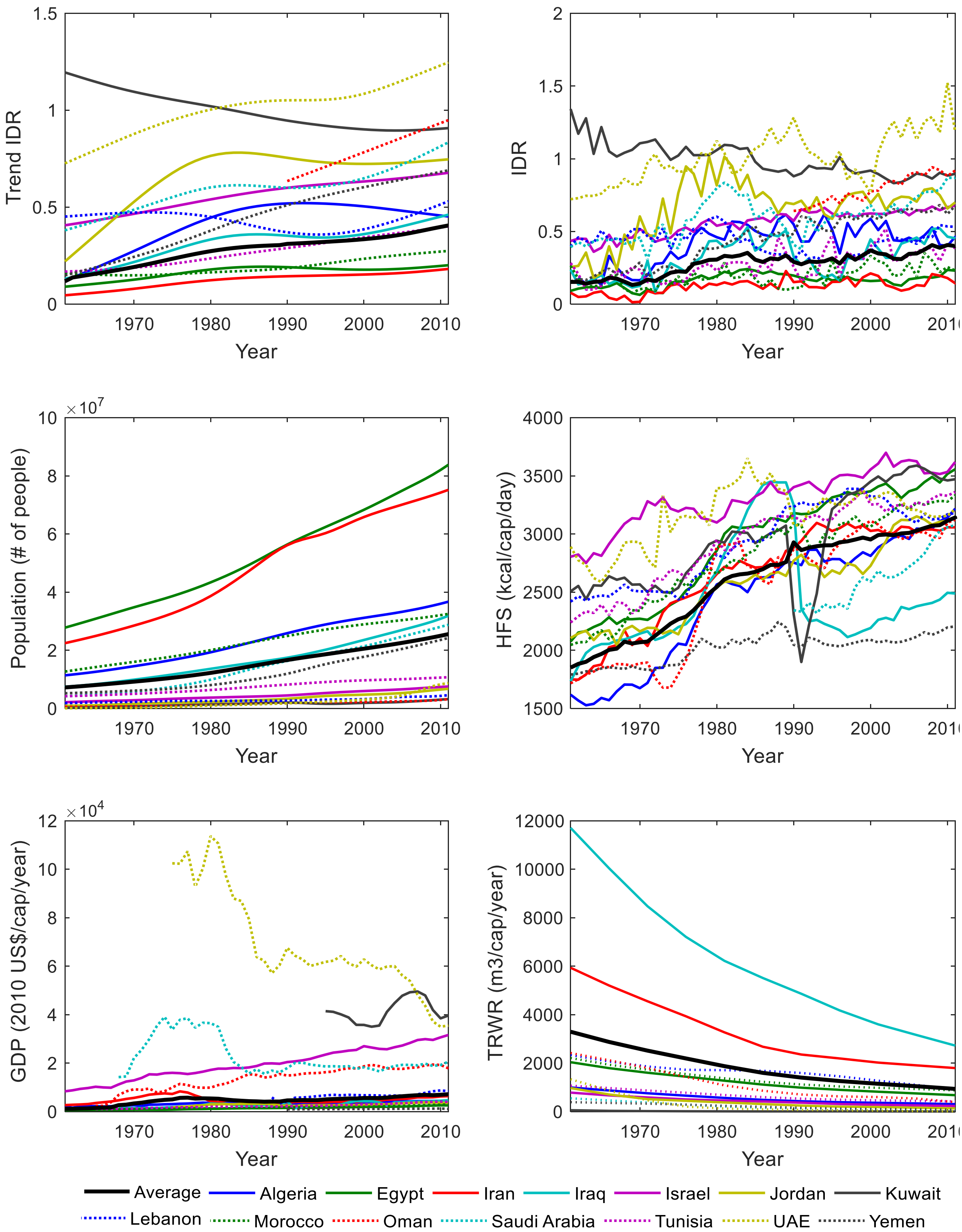

Figure 5: The trend of the import dependency ratio (trend calculated using a Hodrick-Prescott filter), the (non-trended) IDR, population, human food supply (HFS) in kcal/cap/day, GDP In 2010 US$/cap/year, total renewable water resources (TRWR) in m3/cap/year. Black lines are weighted averages (over the population per country) of the 14 countries.

Human food supply (kcal/capita/day), the second indicator of economic growth, increased enormously in the period studied, as shown in Figure 5. The correlation between human food supply and the IDR are very strong in 9 of the 14 countries. A big decrease in human food supply is seen Iraq and Kuwait 1991 and 1992 as a result of the wars at that time (see Appendix III), followed by a decreasing IDR in Iraq. Kuwait already had a decreasing trend at that time as result of the oil crisis. Human food supply and the IDR both increased strongly in Iraq, Algeria, Egypt, the UAE, Tunisia and Jordan in the period till 1990. These cases, together with the strong correlation implies that the human food supply is an important driver for IDR changes.

3.2.3. Globalization

Import quantities worldwide, the indicator of globalization (see Figure 6 and Table 1) is strongly correlated to the IDR of all countries, (except for Jordan and Lebanon), increasing at almost the same rate over time. The worldwide imports increasingly rose after 1980, where also a stronger increase in the IDR is seen, which suggests a strong relation between both.

3.2.4. Total renewable water resources

The TRWR is strongly descending, as seen in Figure 5. All countries besides Lebanon are, as expected, negatively correlated: the lower the TRWR, the higher the import since less can be

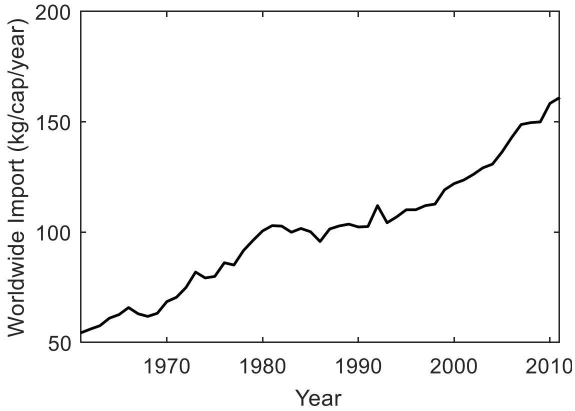

Figure 6: Worldwide imports per capita per year.

produced within the country. Correlations with the IDR are very strong. For Kuwait, Oman and the UAE hardly no food production is seen since water scarcity is the biggest limitation in increasing agricultural activity (Sadik, 2000; UAE Embassy, 2017). In Iran the strongly decreasing TRWR before 1985 and the stabilization afterwards, could have been the driver for the strongly rising IDR before 1985 and stabilization afterwards. TRWR is suggested to be one of the most important drivers in the region.

3.2.5. Politics

An overview of conflicts and international trade treaties is given in Appendix III. Indications for wars as driver for a changing IDR are found during several wars. Figure 7 shows conflicts influencing the IDR. In Appendix III, Figure III.1, IDR of other countries in combination with the conflicts are given.

Table 1: Overview of the correlation between the import dependency ratio and the various drivers. TRWR=total renewable water resources; WI=worldwide import; P.C. = per capita.

Country	Population	Human food supply (p.c.)	GDP (p.c.)	WI (p.c)	TRWR (p.c.)	Production
Algeria	0.66	0.80	0.71	0.63	-0.88	0.18*
Egypt	0.55	0.69	0.59	0.63	-0.65	0.44
Iran	0.78	0.73	0.07*	0.73	-0.86	0.55
Iraq	0.64	0.66	0.69	0.73	-0.75	0.47
Israel	0.89	0.84	0.90	0.89	-0.97	0.64
Jordan	0.45	0.53	-0.07*	0.58	-0.79	-0.04*
Kuwait	-0.69	-0.59	-0.27*	-0.70	-0.86	-0.73
Lebanon	0.27*	-0.49	0.68	0.14*	0.15*	-0.54
Morocco	0.58	0.44	0.61	0.62	-0.71	0.23*
Oman	0.89	0.73	0.86	0.84	-0.79	0.69
Saudi Arabia	0.69	0.88	-0.03*	0.81	-0.73	0.32
Tunisia	0.73	0.66	0.66	0.71	-0.90	0.35
UAE	0.71	0.46	-0.53	0.77	-0.78	0.31
Yemen	0.93	0.86	0.58	0.93	-0.99	0.79

* p-value > 0.05. A correlation which is not significantly different from 0

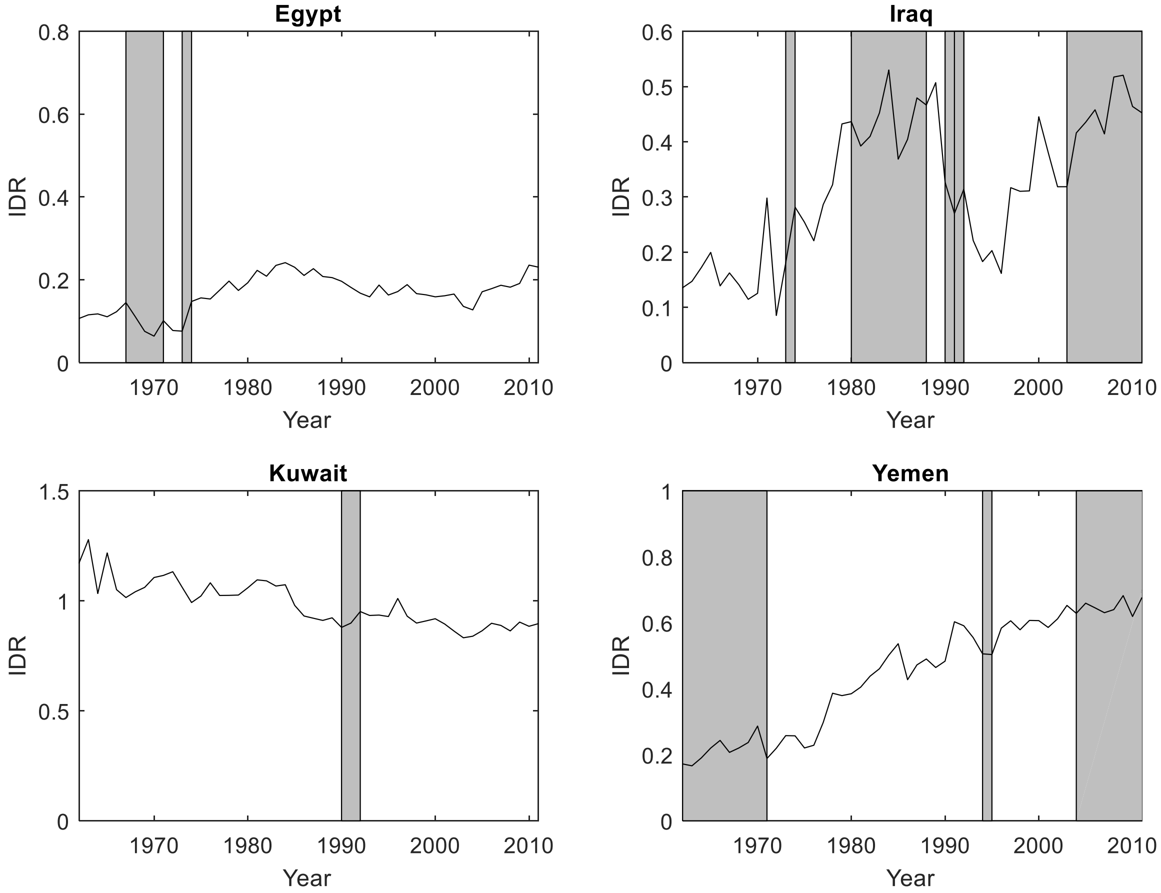

Figure 7: Conflicts in the MENA-region effecting the IDR. Gray areas are periods with conflicts. Vertical black lines represent conflicts of one year or less. Conflicts are given in Appendix III, Table 1.

In Yemen, the IDR stabilized during the North Yemen Civil War between 1962 and 1970 and started rising directly afterwards. Besides that, a dip in the IDR is seen in 1994, which is recovered in 1996: the moment of the civil war in Yemen (1994). In Egypt, the IDR decreased in the period of the Israeli-Egyptian war and the Six Day war, between 1967 and 1970. Import decreased in that time, while production further increased. After the war ended, the IDR started to rise. No effect of the Yorn Kippur war in 1973 is seen on the IDR.

During the Gulf War in Iraq in 1990-1991, descending IDRs were seen as a result of a big dip in human food consumption and imports. In Kuwait, the import decreased enormously, and export and production almost descended to 0. This combination leaded to only a small IDR change. For Iraq, the dip in the human food supply as well as in the IDR took longer than for Kuwait due to the uprisings in Iraq in 1991. No effect on the IDR is seen during the Iraq war between 2003 and 2011: the IDR kept increasing, just as in the decade before. A reason for the change in IDR in some conflicts, while other do not have an effect could be found in the difference in length and casualties per unit time: the more casualties in a shorter time, the bigger the effect on the country, economy and population, the lower the human food supply and the lower the IDR. The Iraq war is a longer war with relatively less casualties per year. Human food supply even increased in that period, indicating that food supply was not really affected by the war and the country was able to follow the region's increasing IDR trend, while the Gulf War for example, disrupted society, food production and food supply, affecting the IDR as a result.

Trade treaties are no obvious driver for the development of the IDR. No changes in the IDR are found after the agreements of trade treaties. However, the effect of trade treaties are partly assimilated in the globalization and the amount of imports worldwide, since taxes and levies has been expired by the trade treaties

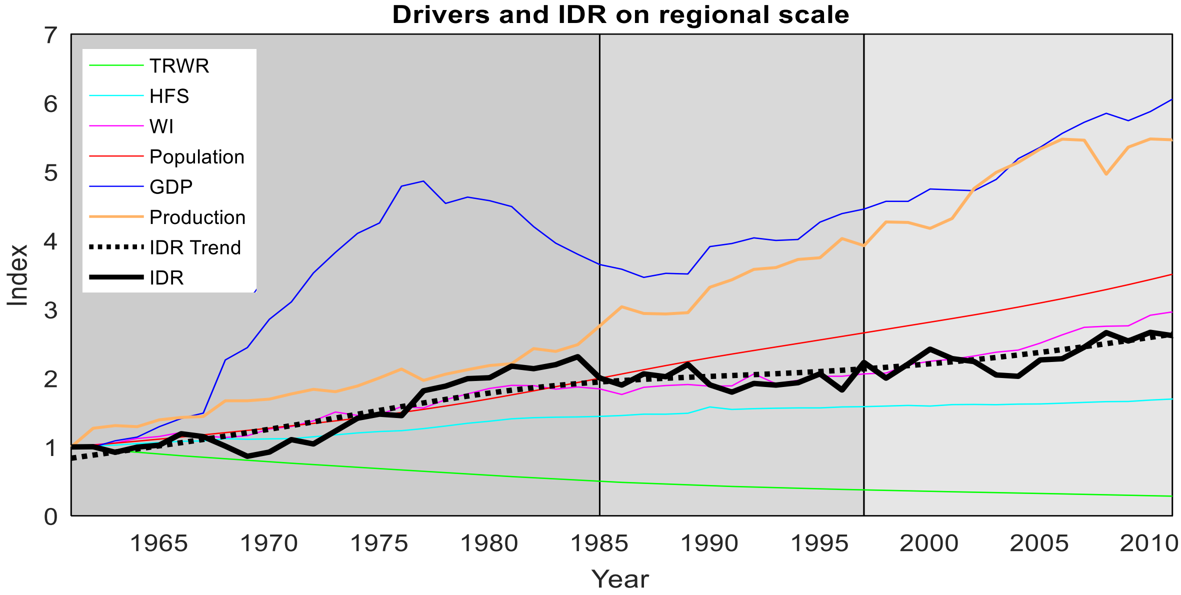

Figure 8: The weighted averages of the 14 countries in the region for the 6 drivers and the IDR. Data are indexed by their value in 1961. Three periods in the IDR can be distinguished: slightly increasing between 1961 and 1985, a stabilization between 1985 and 1997 and a small increase afterwards. Lines indicating these periods are shown in the graph.

and the thresholds for international trade became lower. Effect of trade treaties is seen in the case of Australia being an important trade partner for the GCC countries. Relations are confirmed by a free trade agreement (FTA) in 2007 (Australian Government, 2017). The role of Switzerland as an important trade partner for Israel is also political: already a long and good bilateral relationship exists (Schweizerische Eidgenossenschaft, 2017) and the EFTA-states Iceland, Liechtenstein, Norway and Switzerland signed a free trade agreement with Israel on 17 September 1992 (EFTA, 2017). This relation is also seen in North African countries: those MENA-region countries has treaties with European, moderate or low water scarce trade partners.

Political decisions influencing the IDR, are found in Kuwait in the 1980s, where the government decided to support large-scale food production: the goal was to decrease food dependency, increasing food security (Al-Qudsi Shawkat & Eid, 1986), which resulted in a decreasing IDR. The high IDR values in the rest of the GCC are also caused by political decisions: the government wanted to make the UAE a trade hub (UAE Embassy, 2017), resulting in high imports and re-exports and IDR values above 1.

3.3. Drivers on regional scale

In Figure 8 and Table 2 an overview of the effect of the drivers on the IDR for the whole MENA-region are given. Three periods in the IDR trend can be distinguished: a relatively strong increase between 1961-1985, a stabilization in the period 1986-1997 and a slight increase till the end. Over the whole period, worldwide imports has almost exactly the same trend as the IDR. Only in the third period, the worldwide imports showed a stronger increase.

In the first and third period, degree of population increase matches well with the IDR also, while in the second period the trend of the food supply shows almost the same increasing degree. The IDR decrease after 1984 is suggested to be affected by the decrease in the GDP as a result of the oil crises. The development of the production is not clearly seen on the IDR of the region, while it is directly related to the IDR (Equation 1). Its effect is probably diminished by the increasing imports due to the globalization and economic growth. Besides that, effect of production of the IDR can also be flattened by the effect of the population growth, mainly in the period after 1985: the total food supply within a country is mainly driven by the population and, despite the persistent population growth, the IDR did not grow strongly after 1985 for a period. This effect is most logically driven by the increase in production, partly providing the increasing food demand, due to which the IDR remained stable. The exact interaction between the various drivers and the IDR is difficult to say.

Table 2: Changes (in %) of IDR trend and the 6 drivers in three periods. Periods are based on the IDR and its rising trend from 1961-1985, the stabilization in the 2nd period between 1986-1997 and the slightly stronger change in the final period. Changes are calculated using the (non-indexed) weighted averages of the drivers and the IDR. WI=worldwide imports; TWRW=total renewable water resources. P.C. = per capita

	1961-1985	1986-1997	1998-2011
IDR	**100**	**11**	**20**
Population	100	35	35
Food supply	44	10	6
GDP (p.c.)	265	22	32
WI (p.c.)	84	12	41
TRWR (p.c.)	-43	-25	-33
Production	176	42	40

3.4. Water risk of imports

The IDR (Figure 5), the degree of food imported from trade partners experiencing severe water scarcity (Figure 9), and the number of trade partners (Figure 9), determine the water risk of food imports. A division of the region into three sub-regions is found. The first one is the GCC with Bahrain, Kuwait, Oman and Qatar, the UAE and Saudi Arabia. Those countries have a relatively high IDR, and with Australia and countries within their own severely water scarce region as trade partners, more than 50% (for the UAE and Saudi Arabia over 25%) of their food is imported from countries experiencing severe water scarcity. No striking changes in number of trade partners is found. Water risk of food imports in the GCC countries are high.

The second sub-region are the North African countries, which imported, with European countries, the USA and Canada as most important trade partners, less than 35% of their food from severely water scarce trade partners. IDRs are between 0.1 and 0.45, much lower those of the GCC countries. Number of trade partners did not vary much over time. Water risk of imports in the North African region are lower than those in the GCC countries.

The third sub-region is the Levant region (Lebanon, Iran, Iraq, Israel, Jordan and Syria) having trade partners within their own region, Argentina, Brazil, Russia and also European countries. The degree of imports coming from severely water scarce trade partners are comparable with the North African countries and also number of trade partners per degree of water scarcity are comparable with those in the North African region. IDRs are in between those of the GCC countries and the North African countries, with Iran as an exception with the second lowest IDR of the whole region. Water risk of food imports in the Levant region are in lower than those in the GCC countries, but, in general, higher than those in the North African region.

Looking at the changing water risk over time, the degree of food imports coming from water scarce trade partners play an important role. A change in the degree of food imports coming from water scarce trade partners over time can have two reasons: trade partner countries shifted from countries with low water scarcity to countries with higher water scarcity (or the other way around), or the trade partner countries became more/less water scarce over time. Morocco for example, has an increase in its part of imports from severely water scarce trade partners from 12% to 36% between 1986 and 2011, caused by the increasing amount of food imported from Argentina. This country shifted from moderately water scarce to severely water scarce. More important is the change in trade partners and changing quantity of food imports per trade partner: import quantities from the severely water scarce Brazil increased (see Appendix IV) and also the number of severely water scarce trade partners due to changing trade partners increased (Figure 9 and Appendix IV). For the whole MENA-region, an increasing number of severely water scarce trade partners responsible for 90% of the food imports is seen in 11 of the 16 MENA-region countries. This in combination with the rising IDR over time for most countries and the fact that the number of trade partners did not decrease substantially over time, has increased the water risk of imports in the last decades.

3. Discussion

Calculating the IDR is done using production, import and export data. However, in the latter, re-exports are not taken into account due to a lack of data. This resulted in the assumption that all imports are consumed within the country, while part of it is re-exported in reality. The assumption that all imports are consumed, without re-exports increases the IDR value wrongly. To study the IDR in more detail, data

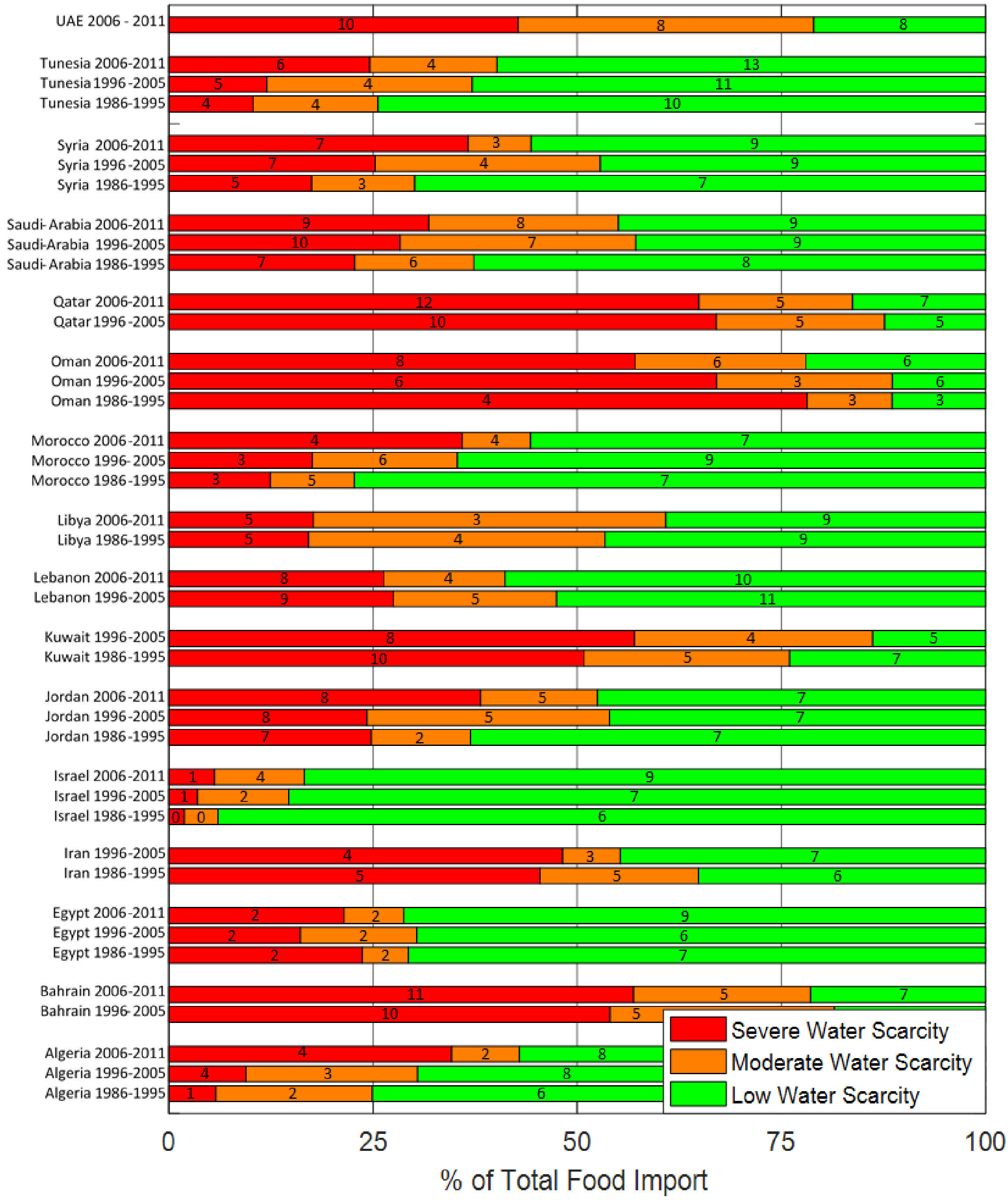

Figure 9: The total imported food quantity in the MENA-region countries is 100%. Every trade partner has his own share and is part of this 100%. Trade partners are categorized in 3 levels of water scarcity (severe, moderate, low), This is done for three periods between 1986 and 2011 (when data were available). Values within the bars shows the number of countries of 90% of the total imports (not 100% since small amounts of food are traded between almost all countries worldwide, which should blur the insight in the water risk, depending on the number of trade partner countries)

about re-exports are needed. If these become available, it can be recommended to use those data and to study the IDR more precise.

Secondly, the political driver 'conflicts' has different effects on the IDR: during short wars with a high number of casualties, the IDR decreased, while the IDR was not visibly affected by longer wars with less casualties per time unit. This suggests that the more casualties in a shorter time, the bigger the effect on the country, economy and population, the lower the human food supply, import and production and thus the lower the IDR. However, this conclusion is based on only a few events. The effect of wars on IDR should be studied more extensively to be able to conclude it properly.

Besides that, data for total renewable water resources were only available as averages of five-year periods. It was therefore not possible to analyze the effect of low TRWR or droughts occurring in one specific year or period. To gain further insight in this topic annual (or even smaller time scaled) data about TRWR are needed.

At fourth, drivers are correlated to the IDR and related by sight. By using a correlation alone, it is not possible to say something about causal relationships between the two variables. Besides that, the drivers mentioned in this report are thought to be the most important ones and were expected (substantiated by literature) to be the most important, but it has to be kept in mind that problems in the MENA-region are complex and other aspects than the drivers mentioned in this report will play a role in reality. Hereby can be thought of allies in former wars (before 1961), tensions between countries not represented by casualties etc.

Another aspect to discuss are that several indicators could be chosen to determine water scarcity. In this report, the water vulnerability index is used, which is simple and easy to use, but it has some limitations as well: (1) it does not take into account the variability in water availability within countries, (2) it does not take into account several sources of freshwater, such as dams storing water to flow in dry years, (3) it does not take into account the accessibility of water and (4) it does not account for differences in water demands within a country or region (Rijsberman, 2006). Besides that, water scarcity in this report does not take into account seasonal variations, since water scarcity is measured in periods of five years. measuring water scarcity annually, have underestimated experienced water scarcity by failing to capture the seasonal fluctuations in water consumption and availability (Mekonnen & Hoekstra, 2016).

The water vulnerability index is chosen on the basis of data availability: data to calculate this index were available for the MENA-region countries between 1961 and 2011. And although it is not really detailed, it gives insight in the water scarcity in the region is that period.

Finally, it has to be realized that data can be different from reality, due to the fact that countries in this region are not always able to document trade and food data with high accuracy. A second reason therefore is also that time series are relatively long (from 1961 onwards). In the beginning of those periods, measurements were less accurate than measurements nowadays (FAO, 2017).

4. Conclusion

A rising IDR trend was found in the MENA-region countries between 1961 and 2011, except for Kuwait. Important drivers for changes were suggested to be globalization (indicated by worldwide imports), population growth, total renewable water resources and the human food supply, which was an indicator of economic growth. The exact interaction between the various drivers and the changing IDR is difficult to say: a combination of all drivers determines the final IDR change. It is implied that population growth, decreasing TRWR, globalization and economic growth led to an increasing IDR, while the effect is partly diminished by the effect of production and conflicts.

Trade treaties were an important factor in the choice of trade partners and is seen as a driver for water risk. Water risk of imports differed within the MENA-region: GCC countries imported food mostly from trade partners within the severely water scarce MENA-region and Australia, while the North African countries imported much more from the moderate to low water scarce European countries. In the Levant region, both are seen. This together with the highest IDR in the GCC region, water risk highest there, followed by the Levant region and the lowest water risk in the North-African countries. No striking differences of number of trade partner countries are seen within the region and over time.

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Appendix I: list of commodities classified by major food groups

Below, a table with an overview of the commodities taken into account in the food trade.

I. Cereals and products	Pistachios	VIII. Oilcrops	Other vegetables
Wheat	Hazelnuts	Soybeans	**X. Fruit and products**
Rye	Walnuts	Coconuts (incl. copra)	Plantains
Barley	Brazil nuts	Oil palm fruit	Bananas
Oats	Kola nuts	Groundnuts	Oranges
Maize	Cashew nuts	Olives	Lemons and limes
Rice	Other tree nuts	Rape and mustard seed	Grapefruit and pomelos
Mixed grains	**VI. Fruits and products**	Sunflower seed	Tangerines, mandarins
Buckwheat	Melons	Cottonseed	Other citrus fruit
Sorghum	Watermelons	Linseed	**XI. Stimulants**
Millet	Apples	Hempseed	Coffee
Quinoa	Apricots	Sesame seed	Cocoa beans
Other cereals	Avocados	Other oil crops	Tea
II. Starchy roots	Cherries	**IX. Vegetables**	Mate
Potatoes	Figs	Beets	**XII. Spices**
Sweet potatoes	Grapes	Carrots	Pepper
Cassava	Mangoes	Turnips	Pimento
Taro	Papaya	Rutabagas or swedes	Vanilla
Yams	Peaches	Onions, green	Cloves
Other roots and tubers	Pears	Onions, dry	Other spices
III. Sugar, sweeteners & sugar crops	Persimmons	Artichokes	**XIII. Alcoholic beverages**
Sugar cane	Pineapples	Tomatoes	Wine
Sugar beet	Plums	Asparagus	Beer
Sugar, refined	Quinces	Cabbage	Beverages, fermented
Sugar, non-centrifugal	Blueberries	Cauliflower	Beverages, alcoholic
Molasses	Cranberries	Celery	**XIV. Vegetable oils**
Honey	Gooseberries	Kale	Rape and mustard seed oil
Other sugars and syrups	Raspberries	Lettuce	Sunflower seed oil
IV. Pulses	Strawberries	Spinach	Cottonseed oil
Beans, dry	Kiwi	Beans, green	Linseed oil
Broad beans, dry	Other fruits, fresh	Broad beans, green	Hempseed oil
Peas, dry	Dates	Chilli peppers	Sesame seed oil
Chick peas	Figs, dried	Garlic	Copra and coconut oil
Cow peas	Prunes	Cucumbers	Palm kernel oil
Pigeon peas	Currants	Mushrooms	Palm oil
Lentils	Raisins	Eggplant	Soybean oil
Vetches	Other dried fruits	Peas, green	Olive oil
Lupins	**VII. Miscellaneous**	Pumpkins	Maize oil
Other pulses	Infant food	Squash	**XV. Tobacco and Rubber**
V. Treenuts	Beverages, non-alcoholic	Gourds	
Almonds	Ice cream	Okra	
Chestnuts	Other food preparations	Radishes	
Areca nuts			

Appendix II

Overview of the 293 crops and products used out of the detailed trade matrix to determine the trade partners of the countries in the MENA-region.

Alfalfa meal and pellets	Flour, roots and tubers nes	Olives
Almonds shelled	Flour, wheat	Olives preserved
Anise, badian, fennel, coriander	Fonio	Onions, dry
Apples	Food prep nes	Onions, shallots, green
Apricots	Food preparations, flour, malt extract	Oranges
Apricots, dry	Food wastes	Papayas
Artichokes	Forage and silage, clover	Pastry
Asparagus	Forage and silage, grasses nes	Peaches and nectarines
Asses	Forage and silage, legumes	Peanut butter
Avocados	Forage products	Pears
Bambara beans	Fructose and syrup, other	Peas, dry
Bananas	Fruit, cooked	Peas, green
Barley	Fruit, dried nes	Pepper (piper spp.)
Barley, pearled	Fruit, fresh nes	Peppermint
Beans, dry	Fruit, prepared nes	Persimmons
Beans, green	Fruit, tropical fresh nes	Pineapples
Beer of barley	Garlic	Pineapples canned
Beer of sorghum	Germ, maize	Pistachios
Beet pulp	Ginger	Plantains
Beverages, distilled alcoholic	Glucose and dextrose	Plums and sloes
Beverages, fermented rice	Gooseberries	Plums dried (prunes)
Beverages, non alcoholic	Grain, mixed	Popcorn
Blueberries	Grapefruit (inc. pomelos)	Poppy seed
Bran, buckwheat	Grapes	Potato offals
Bran, fonio	Grease incl. lanolin wool	Potatoes
Bran, maize	Groundnuts, shelled	Potatoes, frozen
Bran, millet	Hazelnuts, shelled	Pumpkins, squash and gourds
Bran, sorghum	Hops	Pyrethrum, dried
Bran, wheat	Ice cream and edible ice	Pyrethrum, extraction
Brazil nuts, shelled	Infant food	Quinces
Bread	Juice, citrus, concentrated	Raisins
Buckwheat	Juice, citrus, single strength	Rapeseed
Bulgur	Juice, fruit nes	Rice - total (Rice milled equivalent)
Butter of karite nuts	Juice, grape	Roots and tubers, nes
Cabbages and other brassicas	Juice, grapefruit	Rye
Cake, copra	Juice, grapefruit, concentrated	Sesame seed
Cake, cottonseed	Juice, lemon, concentrated	Sorghum
Cake, groundnuts	Juice, orange, concentrated	Soya curd
Cake, hempseed	Juice, orange, single strength	Soya paste
Cake, kapok	Juice, pineapple	Soya sauce
Cake, linseed	Juice, pineapple, concentrated	Soybeans
Cake, maize	Juice, plum, concentrated	Spices, nes
Cake, mustard	Juice, plum, single strength	Spinach

Cake, palm kernel	Juice, tomato	Starch, cassava
Cake, rapeseed	Jute	Straw husks
Cake, rice bran	Kapok fibre	Strawberries
Cake, safflower	Kapokseed in shell	Sugar beet
Cake, sesame seed	Kapokseed shelled	Sugar confectionery
Cake, soybeans	Kiwi fruit	Sugar crops, nes
Cake, sunflower	Kola nuts	Sugar flavoured
Cane tops	Leeks, other alliaceous vegetables	Sugar non-centrifugal
Carrots and turnips	Lemons and limes	Sugar Raw Centrifugal
Cashew nuts, shelled	Lentils	Sugar refined
Cashew nuts, with shell	Lettuce and chicory	Sugar, nes
Cashewapple	Linseed	Sunflower seed
Cassava	Macaroni	Sweet corn frozen
Cassava dried	Maize	Sweet corn prep or preserved
Cauliflowers and broccoli	Maize, green	Sweet potatoes
Cereal preparations, nes	Malt	Tangerines, mandarins, clementines, satsumas
Cereals, breakfast	Mangoes, mangosteens, guavas	Tea
Cherries	Manila fibre (abaca)	Tea, mate extracts
Cherries, sour	Maple sugar and syrups	Tomatoes
Chestnut	Margarine, liquid	Tomatoes, paste
Chick peas	Margarine, short	Tomatoes, peeled
Chillies and peppers, dry	Melons, other (inc.cantaloupes)	Triticale
Chillies and peppers, green	Millet	Turnips for fodder
Chocolate products nes	Mixes and doughs	Vanilla
Cider etc	Molasses	Vegetable tallow
Cinnamon (canella)	Mushrooms and truffles	Vegetables in vinegar
Cloves	Mushrooms, canned	Vegetables, canned nes
Cocoa, beans	Mustard seed	Vegetables, dehydrated
Cocoa, butter	Nutmeg, mace and cardamoms	Vegetables, dried nes
Cocoa, paste	Nuts, nes	Vegetables, fresh nes
Cocoa, powder & cake	Nuts, prepared (exc. groundnuts)	Vegetables, fresh or dried products nes
Coconuts	Oats	Vegetables, frozen
Coconuts, desiccated	Oats rolled	Vegetables, homogenized preparations
Cocoons, unreelable & waste	Oil, boiled etc	Vegetables, preserved nes
Coffee, extracts	Oil, castor beans	Vegetables, preserved, frozen
Coffee, green	Oil, citronella	Vegetables, temporarily preserved
Coffee, husks and skins	Oil, coconut (copra)	Vermouths & similar
Coffee, roasted	Oil, cottonseed	Vetches
Coffee, substitutes	Oil, essential nes	Vitamins
Copra	Oil, groundnut	Wafers
Cranberries	Oil, kapok	Walnuts, shelled
Cream fresh	Oil, linseed	Walnuts, with shell
Crude materials	Oil, maize	Watermelons
Cucumbers and gherkins	Oil, olive residues	Waters,ice etc
Currants	Oil, olive, virgin	Waxes vegetable

Dates	Oil, palm	Wheat
Dregs from brewing, distillation	Oil, palm kernel	Whey, condensed
Eggplants (aubergines)	Oil, poppy	Whey, dry
Figs	Oil, rapeseed	Wine
Figs dried	Oil, rice bran	
Flour, cereals	Oil, safflower	
Flour, fonio	Oil, sesame	
Flour, maize	Oil, soybean	
Flour, mixed grain	Oil, sunflower	
Flour, mustard	Oil, vegetable origin nes	
Flour, potatoes	Oilseeds nes	
Flour, pulses		

Appendix III: Political issues as driver

Table 1: Conflicts in the MENA-region with casualties above 5000 between 1961 and 2015 (White, 2010).

Year	Conflict	Location conflict	Casualties
1962-1970	North Yemen Civil War	Yemen	100.000 – 200.000
1967-1970	Israeli – Egyptian War	Israel, Egypt	5.370 (Small, 1982)
1967	Six day war	Egypt, Syria, Jordan, Israel	20.000
1973	Yorn Kippur War	Egypt, Syria, Israel, Iraq	15.000 (Sivard, 1996)
1975-1990	Lebanese Civil War	Lebanon	150.000
1980-1988	Iran-Iraq war	Iran, Iraq	700.000
1990-1991	Gulf War	Iraq, Kuwait	40.000-57.000
1991	Uprisings in Iraq; civil war	Iraq	50.000-100.000
1992-2002	Algeria; fundamentalist Moslem Insurrection	Algeria	100.000
1994	Civil war in Yemen	Yemen	7000-10.000
2003-2011	Iraq War	Iraq	100.000-650.000
2004-2014	Shia insurgency in Yemen	Saudi Arabia, Yemen	8.500-25.000
2011-	Syrian Civil War	Syria	250.000-500.000

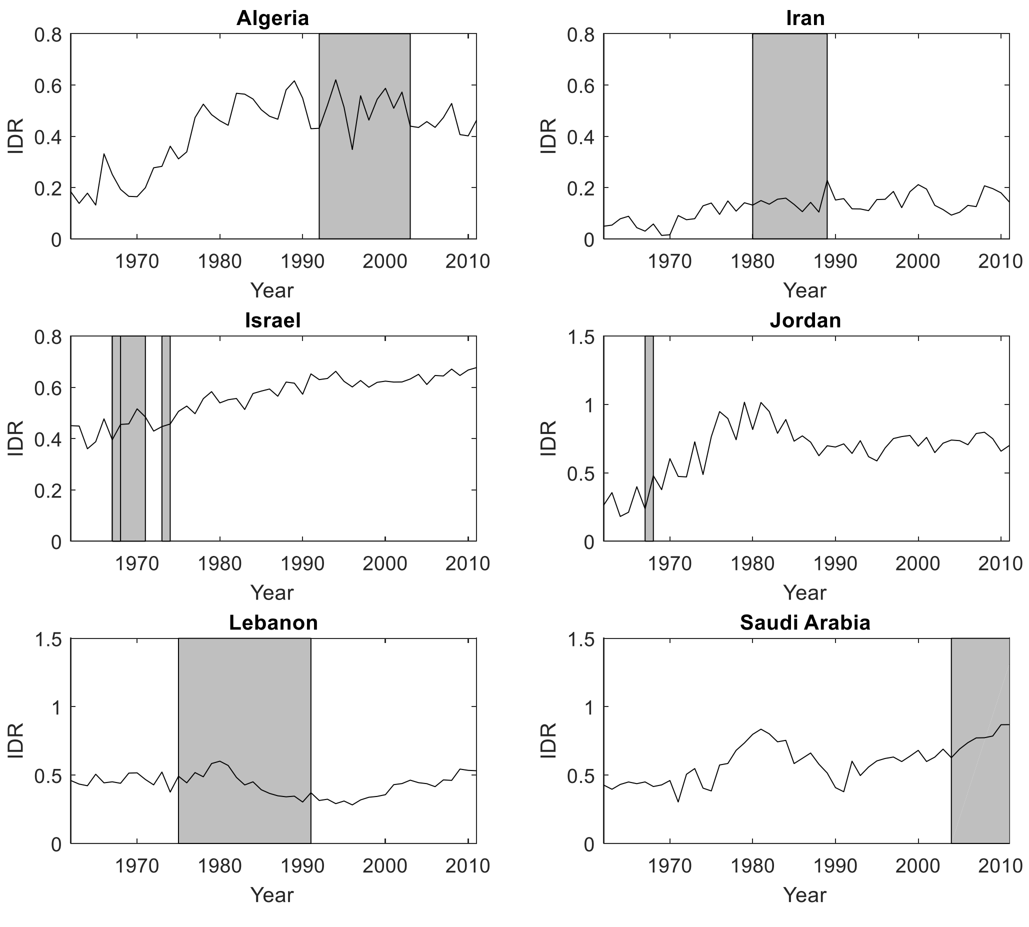


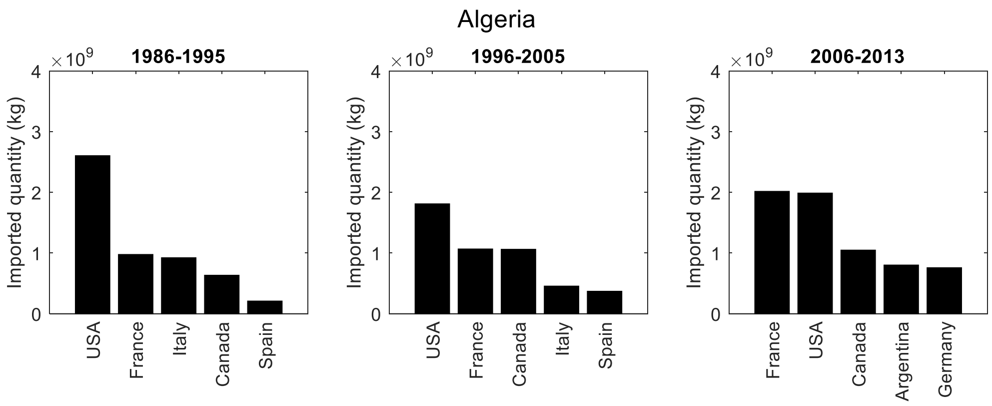
Figure III.1: Conflicts (indicated by the gray areas) and the IDR of 6 countries, in which the conflicts do not have a distinct effect on the IDR.

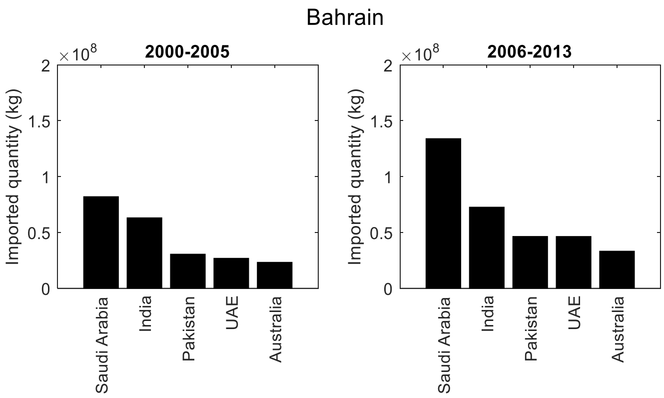
Table 2: Trade treaties

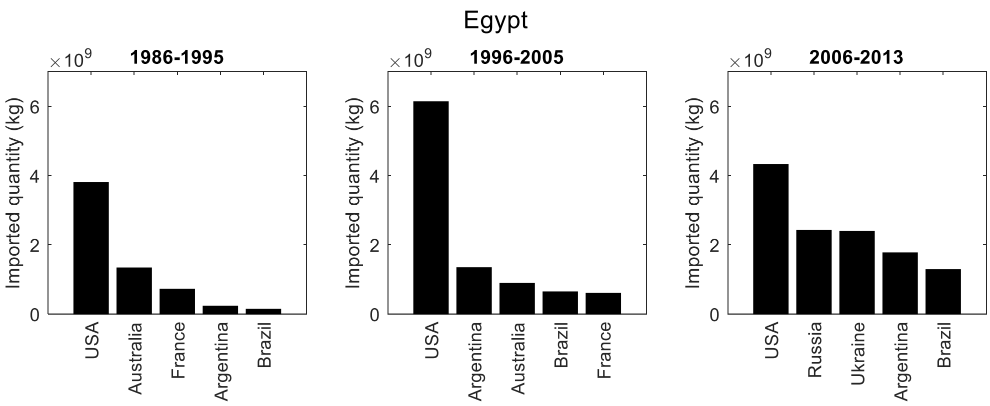
Year	Treaty	Countries involved
1981	Riyadh-based Gulf Cooperation Council (GCC) (Encyclopaedia Britannica, 2015)	Saudi Arabia, United Arab Emirates, Bahrain, Oman, Qatar and Kuwait, Singapore and the European Free Trade Association (with Iceland, Liechtenstein, Norway and Switzerland)
1992	Free Trade Agreement EFTA-Israel	Iceland, Liechtenstein, Norway, Switzerland with Israel, Egypt, Jordan, Lebanon, Morocco, GCC countries and Tunisia (EFTA, 2017).
1997	Creation of the Arab Free Trade Area (GAFTA)	Algeria, Bahrain, Egypt, Iraq, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen
2000-2006	Associaton Agreements with EU members	EU-countries, Algeria (2005), Egypt (2004), Israel (2000), Jordan (2002), Lebanon (2006), Morocco (2000), Syria (1978&2011), Tunisia (1998)
2005	GAFTA: import tariffs dissolved	Algeria, Bahrain, Egpyt, Iraq, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen
2007	Free Trade Agreement Australia-GCC	Australia, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates

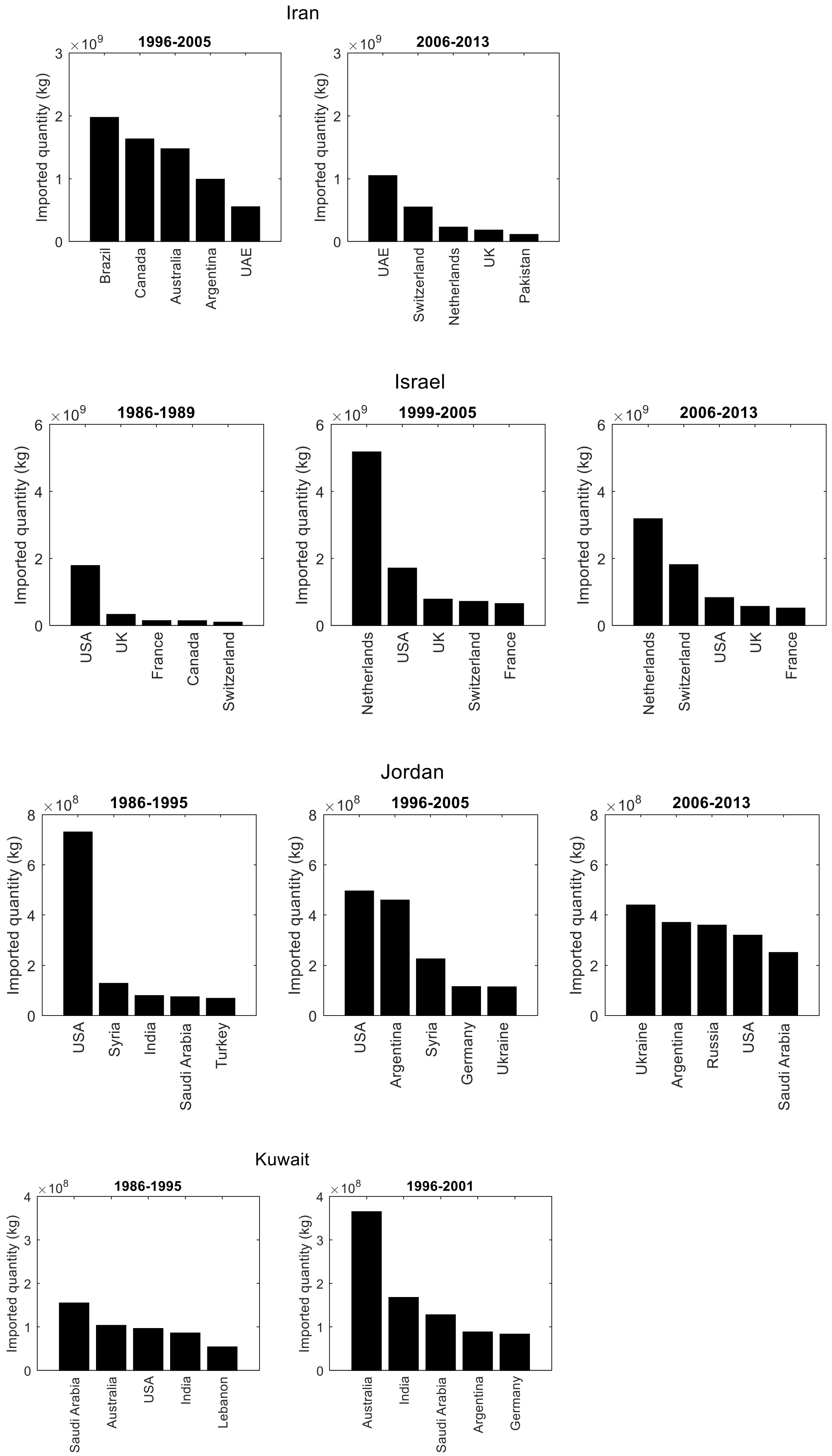
Appendix IV.

Top 5 trade partner countries per decade for each MENA-region country.

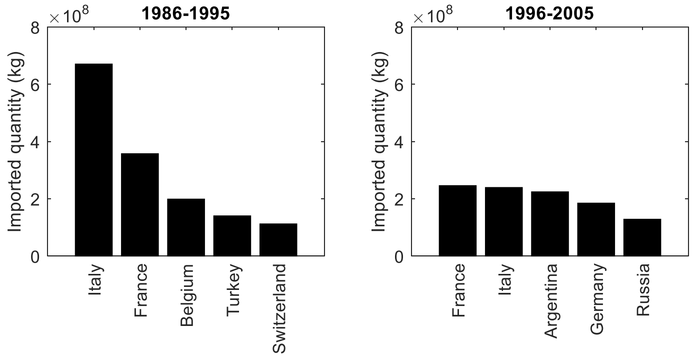




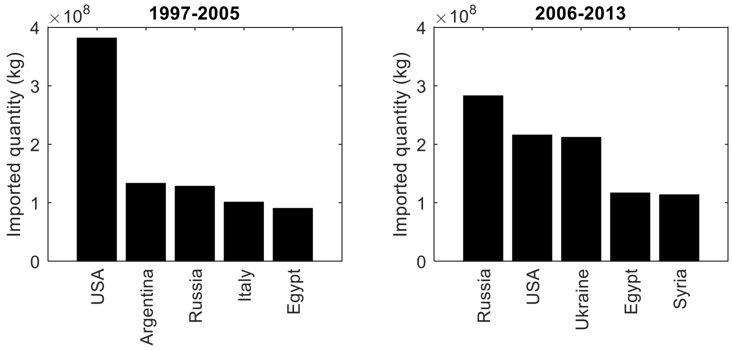



Iran
1996-2005
2006-2013
×10^9
Imported quantity (kg)
Brazil
Canada
Australia
Argentina
UAE
UAE
Switzerland
Netherlands
UK
Pakistan
Israel
1986-1989
1999-2005
2006-2013
×10^9
Imported quantity (kg)
USA
UK
France
Canada
Switzerland
Netherlands
USA
UK
Switzerland
France
Netherlands
Switzerland
USA
UK
France
Jordan
1986-1995
1996-2005
2006-2013
×10^8
Imported quantity (kg)
USA
Syria
India
Saudi Arabia
Turkey
USA
Argentina
Syria
Germany
Ukraine
Ukraine
Argentina
Russia
USA
Saudi Arabia
Kuwait
1986-1995
1996-2001
×10^8
Imported quantity (kg)
Saudi Arabia
Australia
USA
India
Lebanon
Australia
India
Saudi Arabia
Argentina
Germany

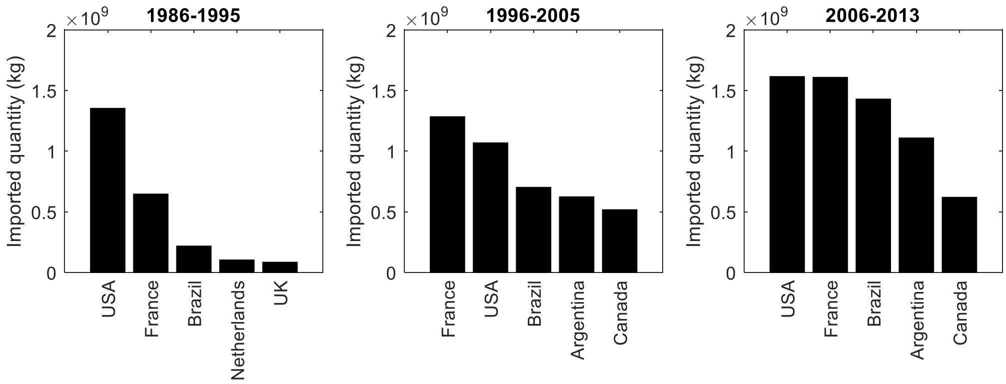
Libya



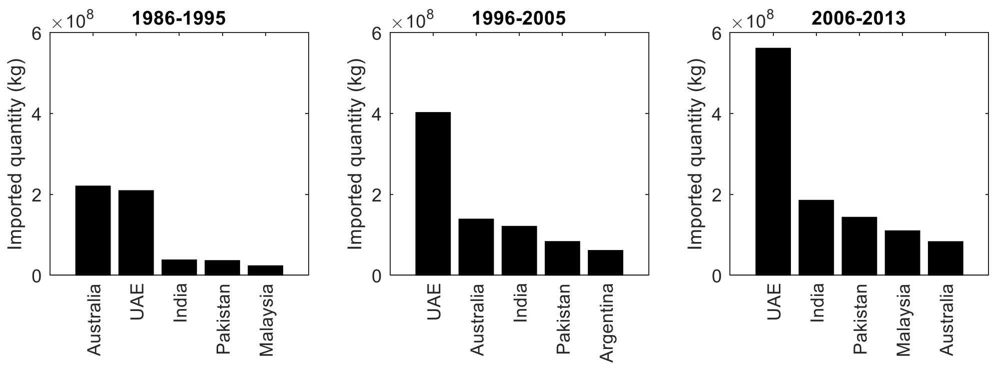
Lebanon

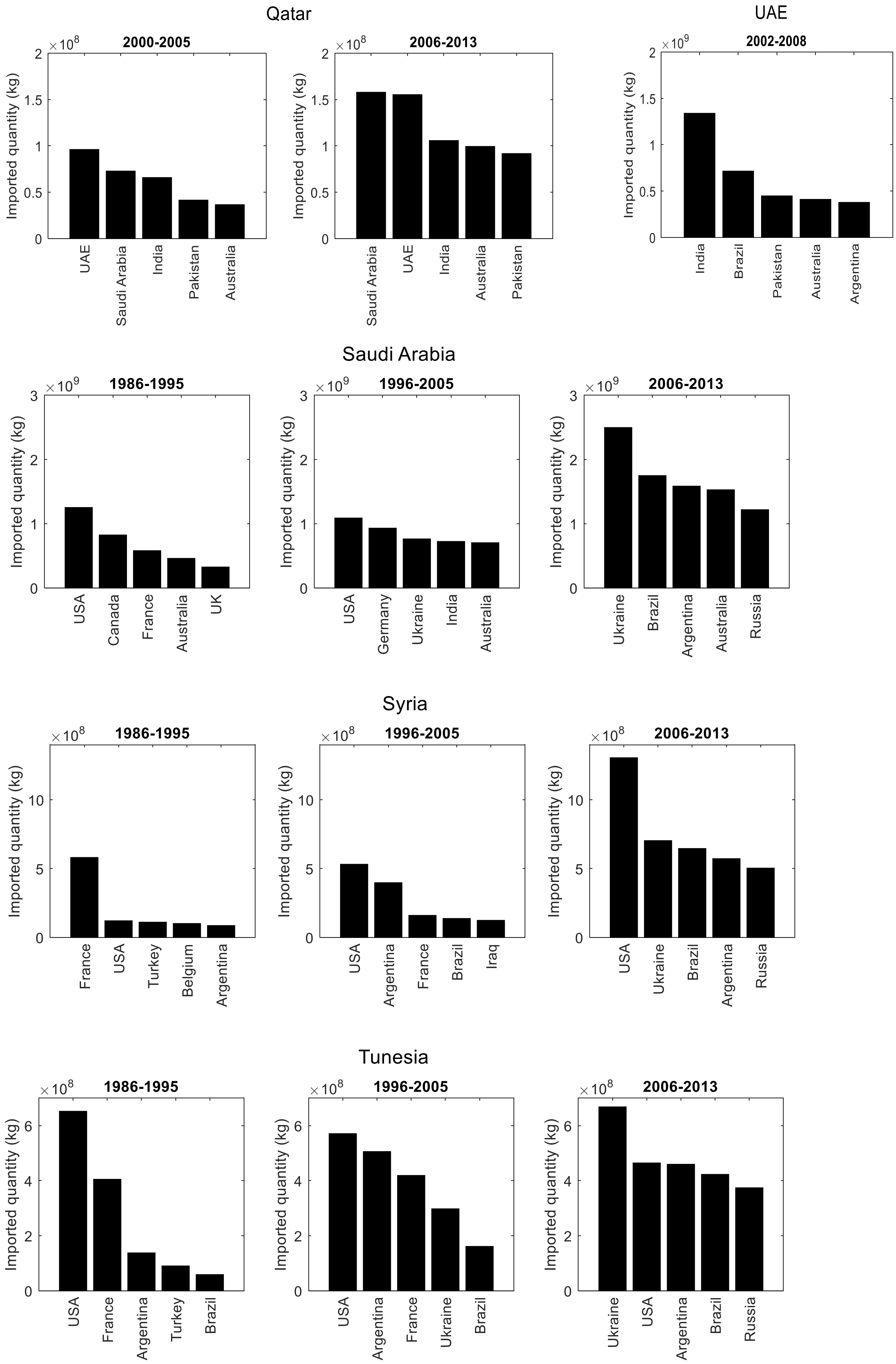


Morocco



Oman




Qatar
2000-2005
UAE
Saudi Arabia
India
Pakistan
Australia
2006-2013
Saudi Arabia
UAE
India
Australia
Pakistan
UAE
2002-2008
India
Brazil
Pakistan
Australia
Argentina
Saudi Arabia
1986-1995
USA
Canada
France
Australia
UK
1996-2005
USA
Germany
Ukraine
India
Australia
2006-2013
Ukraine
Brazil
Argentina
Australia
Russia
Syria
1986-1995
France
USA
Turkey
Belgium
Argentina
1996-2005
USA
Argentina
France
Brazil
Iraq
2006-2013
USA
Ukraine
Brazil
Argentina
Russia
Tunesia
1986-1995
USA
France
Argentina
Turkey
Brazil
1996-2005
USA
Argentina
France
Ukraine
Brazil
2006-2013
Ukraine
USA
Argentina
Brazil
Russia
Imported quantity (kg)

Appendix V: countries into more detail

Production, import and export into more detail, per country.