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## Article

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## GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

# Food security in the United Arab Emirates: External cereal supply risks

Beshir M. Ali<sup>1\*</sup>, Ioannis Manikas<sup>1</sup> and Balan Sundarakani<sup>1</sup>

**Abstract:** The coronavirus pandemic and the Russian invasion of Ukraine have exposed the vulnerability of the food systems of import-dependent countries to supply chain disruptions. This study measured the short-term external cereal supply risks for the United Arab Emirates (UAE) by applying the Herfindahl–Hirschman Concentration Index (HHI) and the Shannon–Wiener Diversity Index (SWI) during 2012–2020. We measured the security of UAE’s external cereal supplies by taking the degree of UAE’s cereal import dependency, the level of political- and business-related risks of UAE’s cereal supplying countries, and the distance between UAE and its supplying countries into account. The results of the index values generally imply that UAE’s cereal external supply risk has been low during the sample period. However, the external wheat supply risk has increased since 2017. This was mainly attributable to UAE’s increasing dependence on less secured countries, i.e. countries with higher levels of risk assessment values such as Russia. UAE has heavily been dependent on one or two, mostly price competitive, sources for its cereal imports, which also raises the external cereal supply risk. The UAE’s increasing dependence

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on Russia as the main source of cereals and the increasing consolidation of sources pose a serious threat to sustaining food security.

**Subjects:** Agriculture and Food; Microeconomics; International Economics; International Trade; incl; trade agreements & tariffs

**Keywords:** Cereals; COVID-19; food security; import dependency; risk; United Arab Emirates

## 1. Introduction

The coronavirus (COVID-19) pandemic and the Russian invasion of Ukraine have once again tested the resilience of food security of import-dependent economies, and exposed the vulnerability of their food systems to disruptions of food supply chains. Several countries have imposed export restrictions for agri-food products since the outbreak of the COVID-19 pandemic (Koppenberg et al., 2021), which might raise food insecurity in import-dependent economies. Besides the disruptions of the flow of food supplies through the Black Sea region (e.g., due the blockade of Odessa—Ukraine’s main port), the Russia-Ukraine war and the subsequent sanctions have led to a surge in global food and fertilizer prices, posing a major risk to food security in the short term (Berkhout, Bergevoet and van Berkum 2022; Abay et al., 2022). Food security is said to be achieved, according to the 1996 World Food Summit, “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 2009). According to this definition, achieving food security may be threatened due to two factors (Hubbard & Hubbard, 2013): (i) increase in food prices that make food unaffordable for citizens (e.g., the 2007/2008 and 2010/2011 food prices crises) or (ii) unavailability of food at any price, for example, due to export bans as experienced during the onset of the COVID-19 crisis.

The United Arab Emirates (UAE) and the other Gulf Cooperation Council (GCC) countries (Bahrain, Kuwait, Oman, Qatar and Saudi Arabia) are among the richest region in the world in terms of per capita wealth owing to their oil and gas reserves. The region is, unfortunately, one of world’s most food deficient and water insecure, where imports cover up to 90% of the domestic food requirements (EIU, 2018, 2021; Hamza, 2019).<sup>1</sup> In these countries, domestic food production is not a viable option as a result of the harsh environment and lack of resources for agriculture (e.g., water and arable land; Pirani & Arafat, 2016; Shah, 2010). Subsequently, food security in the GCC heavily relies and will continue to rely on import of agri-food products (Pirani & Arafat, 2016; Sadler & Magnan, 2011). Although the GCC countries are food secure through imports owing to their wealth and affluence (Hassen & El Bilali, 2019), they lack food sovereignty and food self-sufficiency since food security “does not equal to food self-sufficiency” (Breisinger et al., 2010; EIU, 2018). The degree of a nation’s food self-sufficiency reflects the extent to which its food requirements are covered by domestically produced food (Luan et al., 2013). As a result, food security in these countries is prone to food supply chain disruptions, and social, economic and/or political instabilities in supplying (exporting) countries such as the current Russia-Ukraine war.

The UAE government in 2018, prepared and presented a National Food Security Strategy 2051 in order to enhance the national food security by diversifying food import sources, identifying alternative supply schemes such that three to five sources can be identified for each major food category, raising domestic production, and facilitating the global food trade. The government is supporting the development of the country’s agri-food production, at levels that will contribute to food self-sufficiency and sustainability. The strategy aimed at raising the UAE’s rank among the top 10 countries by 2021, and among the best by 2051 as per the Global Food Security Index (GFSI). Yet the UAE was ranked 35<sup>th</sup> based on the 2021 GFSI score among the indexed countries (EIU 2021). This shows that the country still has to enhance the resilience of its food security, by managing and mitigating the vulnerability of the agri-food supply chains to unforeseen disruptions such as the COVID-19 pandemic and the Russia-Ukraine crisis.

Previous studies applied the concepts of food self-sufficiency and import dependency in analyzing the risks associated with external food supplies for achieving food security (Clapp, 2017; Hubbard & Hubbard, 2013; Luan et al., 2013; Puma et al., 2015). Food self-sufficiency can be measured as the proportion of domestically produced food in a country's total supply of food for consumption; where total food supply (domestic supply quantity) is equal to domestic production plus imports minus exports minus changes in stock (FAOSTAT, 2022). On the other hand, import dependency is measured as the proportion of the total domestic supply quantity of a country that is imported from external suppliers. A high food self-sufficiency is normally thought to be associated with better food security (availability). However, a higher self-sufficiency may heavily depend on imported (intermediate) inputs, which may undermine domestic food supply and food security. On the other hand, a less self-sufficient country may achieve a better food security through imports, which allows diversification of food suppliers and supplies (Hubbard & Hubbard, 2013). Besides food products, it is therefore critical to account for the dependency of domestic food production on imported (intermediate) inputs when assessing external food supply risk. The measures of self-sufficiency and import dependency can be derived at product level (e.g., wheat), or for an aggregate measure of food based on each product's caloric contribution (e.g., cereals). The calorie-based measure is better as it provides more information for food security analysis.

Managing external food supply risks (e.g., instability in supplying countries like the current situation in Ukraine and Russia, export bans as experienced during the onset of the COVID-19 crisis) is therefore critical to reduce import-related adverse impacts on food security (e.g., rising prices, exporters' failure to supply contracted quantity and quality of food). For example, the current Russia-Ukraine crisis will adversely affect food security in UAE and other GCC countries since Russia and Ukraine are important suppliers of cereals to these countries. The crisis is affecting the global food prices as IFPRI (2022a) noted that "repercussions from the invasion of Ukraine are creating significant additional pressures on price, [and] agricultural commodity prices are reaching levels close to those witnessed in 2007/08 and 2010/11". Although achieving sustainable food security in the UAE (and the GCC in general) has remained a top priority for the governments and other food security stakeholders, there are no comprehensive studies that measured risks associated with their dependence on external food supply (imports). Moreover, existing studies did not analyze the factors influencing the risk levels related to external food supply such as the degree of import dependency, the reliability of supplier countries (i.e. the level of political and social risks of supplying countries) and distance to supplier countries (transportation risk). A few studies assessed external food supply risks in the literature, notably Hubbard and Hubbard (Hubbard & Hubbard, 2013) for the United Kingdom. A study by Sadler and Magnan (2011) identified and analyzed risk management options associated with grain import dependency in the MENA region, without measuring and assessing the actual risk levels associated with the import dependency.

In the light of the foregoing discussion, the objective of this study was to measure and analyze the short-term external cereal supply risks for the UAE by applying the Herfindahl-Hirschman Concentration Index (HHI) and the Shannon-Wiener Diversity Index (SWI). These indices have commonly been applied in the literature for analyzing energy security (Fronzel & Schmidt, 2008). Specifically, we assessed the short-term security of cereal imports in the UAE during 2012–2020, by taking the degree of UAE's cereal import dependency, the level of political- and business-related risks of UAE's cereal supplying countries, the distance between UAE and the supplying countries (capturing supply chain disruption risk), and the degree of consolidation of sources into account. The study contributes to the on-going discussion regarding the resilience of food security in the GCC to supply chain disruptions and food price spikes.

## 2. Materials and methods

### 2.1. Measuring the security and diversity of food imports

The security of external supply of a product refers to the availability of the demanded product at a reasonable price (Le Coq & Paltseva, 2009). As illustrated in the energy security literature (Le Coq

& Paltseva, 2009; Frondel & Schmidt, 2008), the Herfindahl–Hirschman concentration index (HHI) and the Shannon–Wiener diversity index (SWI) can be adapted to assess the food supply risks associated with relying on foreign supplies (Hubbard & Hubbard, 2013). These indices can also allow to account for additional factors influencing risks associated with external food supplies, such as level of import dependency, the risk status of supplying countries, and transportation/transit risk. Although both indices are measures of concentration of supplies, the SWI emphasis on diversification, by assigning higher weights to the less important trading partners. Although external suppliers with low import shares contribute less to the total cereal supply of an importing country, the established trade relation with these sources enables the importing country to smoothly switch to these sources in case of supply issues from other key partners.

The Herfindahl–Hirschman index (HHI), commonly used to measure concentration level of firms within an industry, can be derived as:

$$HHI = \sum_{i=1}^n x_i^2 \quad (1)$$

where  $x$  is the market share of firm  $i$ . In food supply risk analysis, this index can be derived by replacing market share ( $x$ ) with import shares of suppliers.

Le Coq and Paltseva (2009) applied a modified HHI to assess the energy security of countries by incorporating several factors influencing the energy supply risk including the degree of import dependency, political stability in the supplying country, the distance between the importing and supplying countries and a crude fungibility indicator to account for substitutability between different types of energy. Rather than using import shares ( $x$ ) when deriving the modified HHI, Le Coq and Paltseva (2009) used Net Positive Imports (NPI):

$$NPI_i = \text{Maximum}\{0, (M_i - X_i)\} \quad (2)$$

where  $M_i$  is import from country  $i$  and  $X_i$  is the country's exports to country  $i$ . The use of net imports ( $NPI_i$ ) instead of import shares ( $x$ ) in the computation of HHI is more realistic as food security (i.e. food availability) depends more on net imports than import shares. Equation 2 suggests that large amounts of re-exports of a cereal type to a supplier country (e.g., UAE's export of rice to India) implies that the external supply risk of that cereal type from that particular supplier is very low (i.e. UAE's risk of external rice import from India would be very low if the UAE re-exported rice to India since the UAE can cut its re-export if the supply of rice from India falls below a contracted level). It is true that large amounts of re-exports adversely impact domestic food security. However, it is unlikely that import dependent countries like the UAE would re-export large amounts of cereals to the extent affecting their domestic food security. Following Le Coq and Paltseva (2009), in this study, we derived the external food supply risk index ( $F_j$ ) for cereal type  $j$  as:

$$F_j = \left[ \sum_i \left( \frac{NPI_i}{\sum_i NPI_i} \right)^2 r_i d_i \right] ID_j \quad (3)$$

where  $NPI_i$  is the net positive cereal  $j$  imports from supplier country  $i$ ,  $r_i$  is a risk assessment relating to supplier country  $i$ ,  $d_i$  is the distance between the external supplying country and the importing country (UAE), and  $ID_j$  is the UAE's import dependency of cereal  $j$ . The risk assessment variable ( $r_i$ ) measures the level of political- and business-related risks that firms operating in the supplying country face (PRS, 2022). The cereal import dependency ( $ID_j$ ) is computed as  $\sum_i M_{ij}/C_j$ , where  $C_j$  is the domestic total supply quantity of cereal  $j$ . The domestic supply quantity refers to the amount of cereal type  $j$  that is available for domestic consumption, and is equal to domestic production plus imports less exports, and less the change in stocks (FAOSTAT, 2022). The distance between UAE and the external supplying countries is included to account for transportation or transit risks



(Le Coq & Paltseva, 2009). The inclusion of distance enables to capture supply risks associated with supply chain disruptions that may happen during the cereal's shipment for infrastructural or political reasons (Le Coq & Paltseva, 2009). The  $F$  value would be equal to 3 if the UAE is totally dependent on cereal imports and these imports are supplied by a single country with highest level of risk ( $r_i$ ). On the other hand,  $F$  would be close to 0 if the suppliers are diversified countries with lower levels of risk assessment scores, nearby countries and the UAE's import dependency is close to zero.

The SWI can be used to measure the diversity of external supplies as:

$$SWI = \sum_{i=1}^n x_i \ln x_i \quad (4)$$

As it can be seen in Equation 4, the SWI attaches greater weights to smaller supplies (i.e. more weights ( $\ln x_i$ ) are given to suppliers with smaller import shares to emphasis the importance of diversification of sources). Equation 4 can be rewritten to account for risk assessment of the supplying country  $i$  and level of domestic production ( $p$ ; Neumann, 2004) as:

$$SWNI = \sum_{i=1}^n (x_i \ln x_i r_i) (1 + p_j) \quad (5)$$

In this study, the SWI accounting for the factors influencing external food supply risks with higher weights assigned to the less important trading partners [ $\ln(\frac{NPI_i}{\sum_i NPI_i})$ ], is defined as:

$$F'_j = - \left[ \sum_i \left( \frac{NPI_i}{\sum_i NPI_i} \right) \ln \left( \frac{NPI_i}{\sum_i NPI_i} \right) (1 - r_i) \right] \frac{1}{ID_j} \quad (6)$$

In Equation 6, the reverse of the risk assessment value and the reciprocal of import dependency are used. Since the SWI index is unbounded and non-positive, we have multiplied the value by  $-1$  (Equation 6). An  $F'$  value closer to zero implies higher level of cereal supply risk (i.e. external supplies are highly insecure). On the other hand, larger values of  $F'$  indicate a more secured external cereal supply (lower level of import-related risk). Therefore, Equation 6 shows that diversifying external supplies (i.e. by having more suppliers, even with lower import shares) would reduce external supply risk.

To sum up, four factors determine the level of the external cereal supply risk ( $F_j$  and  $F'_j$ ): (i) the degree of UAE's import dependency, (ii) the risk status of the source countries, (iii) distance between the UAE and the source countries, and (iv) the degree of source consolidation (diversification of sources). The level of risk would be higher (i.e. HHI closer to 3 and SWI closer to 0) if (i) UAE's import dependency for a given cereal type is very high, or (ii) UAE imports all of its cereals from countries with highest risk assessment values, or (iii) UAE sources all of its cereals from very distant countries, or (iv) UAE imports all of its particular cereal type from very few sources (e.g., Canada and Australia versus Russia and Ukraine), irrespective of the levels of riskiness of the suppliers and distances since the degree of consolidation of sources, instead of diversification of sources, is a risk onto itself.

## 2.2. Data

This study employed secondary data over the period 2012–2020 to assess the risks associated with cereal import dependency (wheat, barley, rice, maize, oats, sorghum, and other cereals). The sample period covers seven years prior to the outbreak of the COVID-19 crisis (2012–2018) and two years during the pandemic (2019–2020). We did not include 2021 in the sample period since data were not available for most of the variables of interest. The UAE's import and export data for each cereal type per trade partner were obtained from the International Trade Centre (ITC; ITC, 2022). Data on total domestic cereal supply quantity were retrieved from FAOSTAT (2022). The domestic supply quantity of each

cereal type is used for deriving the import dependency for each cereal type; as the ratio between volume of import (Table 1) and the domestic supply quantity available for consumption. Figure 1 depicts UAE's import dependency over the sample period for each cereal type. Due to lack of data on domestic supply quantity for 2020, we assumed that the import dependency rate for 2020 is equal to the rate for 2019. In most cases, the import dependency rates are greater than 100%, implying that the UAE has been importing large amount of cereals than needed for satisfying domestic consumption requirement (i.e. parts of the imports were for cereal stock or reserve management). The import dependency rate for wheat has been fluctuating during the sample period, where it reached a peak in 2016 (211%), and declined to 107% in 2018 before reaching to 160% in 2019. The import dependency rates for maize and sorghum have been stable during the sample period, whereas risk has increased for oats.

Data on the risk assessment scores of external suppliers ( $r_i$ ) were obtained from the International Country Risk Guide, which is published by the Political Risk Services (PRS) Group (PRS, 2022). The International Country Risk Guide publishes a Political Risk Index annually for over 140 countries worldwide. The index is constructed using six dimensions measuring the political and business environment facing firms operating in that external country. The dimensions used for constructing the index are *Political stability and absence of violence*; *Voice and accountability*; *Government effectiveness*; *Regulatory quality*; *Rule of law*; and *Control of corruption*. The dimensions are in turn constructed from various indicators. In this study, we used the average of the six dimensions for the risk assessment variable. The level of risk faced by the UAE, as a result of trading with external suppliers is displayed in Figure 2. The risk levels are weighted by the net positive imports to account for the import volume from each external supplier. With a few exceptions (e.g., Barley in 2016 and sorghum in 2017), the risk assessment values have somehow remained stable during the sample period. Relatively, UAE's imports of maize, rice and sorghum are from medium risk countries ( $r_i > 0.35$ ) whereas oats, barley and wheat are imported from low risk countries ( $r_i < 0.35$ ).

Data on distances between the UAE and its cereal supplying partners, using distances between capital cities as a proxy, were obtained from the CEPII (Centre d'Études Prospectives et d'Informations Internationales; Mayer & Zignago, 2011). Le Coq and Paltseva (2009) argued that the effect of distance on transportation risk is not linear—"above a certain threshold the effect of any additional distance should level off, as long as any related political risks are accounted for" (Le Coq & Paltseva, 2009), p. 4478), which is the case in the present study through the risk assessment variable capturing political and other supplier-related internal sources of risks ( $r_i$ ). Therefore, we included distance as a categorical variable in the present study to account for transportation risk following Le Coq and Paltseva (2009) as (Le Coq & Paltseva, 2009):

$$d_i = \begin{cases} 1, & \text{if distance is less than 1500KM} \\ 2, & \text{if distance is between 1500 and 4000KM} \\ 3, & \text{if distance is greater than 4000KM} \end{cases} \quad (7)$$

Figure 3 presents the values of the categorical distance variable, representing the distance between UAE and its external suppliers per cereal type over 2012–2020. The values indicate that all of UAE's external suppliers are distant countries ( $>1,500$  KM). Relatively, sorghum and wheat are imported from nearby countries (e.g., Sudan and Russia, respectively) whereas maize is imported from very distant countries (e.g., Argentina).

### 3. Results

#### 3.1. UAE's cereal supplying countries

Table 2 summarizes the main sources of UAE's cereal imports over 2012–2020. The number of UAE's external suppliers of cereals has somewhat remained constant, but consolidated, during the sample period, with the exception for barley. The main cereal suppliers to the UAE since 2018 are Russia (wheat), India (rice), Argentina (maize), and Australia (barley). India were the main supplier

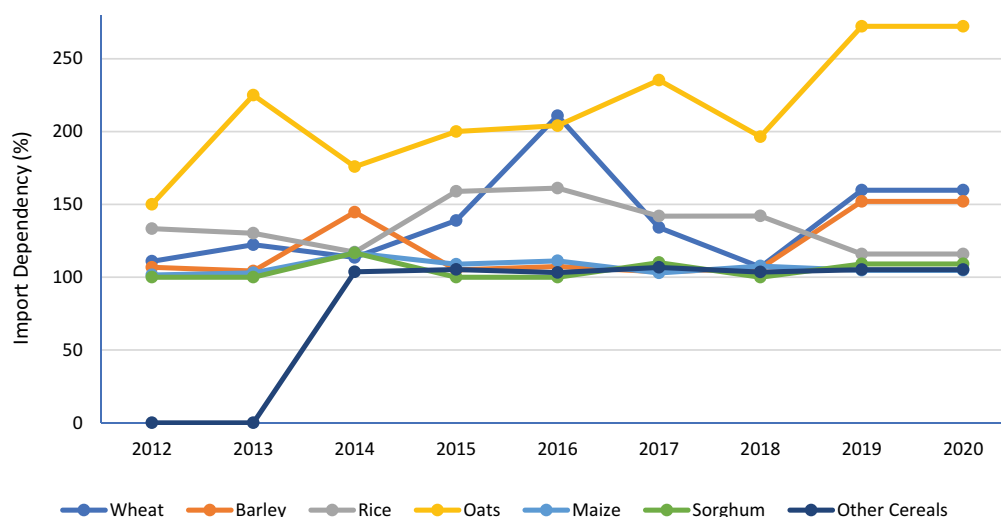


**Table 1. UAE's cereal import volumes (tons) over 2012–2020**

Cereal type	2012	2013	2014	2015	2016	2017	2018	2019	2020
Wheat	93,314	1,099,903	1,337,733	895,367	809,962	975,427	1,237,624	1,263,013	1,400,697
Barley	122,920	435,692	323,824	505,167	466,825	424,789	365,794	301,250	414,127
Rice	945,832	690,807	805,361	1,220,623	1,208,830	975,758	848,984	677,631	748,510
Maize	430,272	386,736	391,802	546,117	535,836	635,292	414,666	452,081	556,538
Oats	1,703	10,727	39,148	30,806	33,645	23,861	42,139	34,960	42,758
Sorghum	1,718	4,219	5,646	6,818	6,039	10,865	10,124	11,629	13,952
Other cereals	4,840	17,139	20,124	18,028	20,702	21,372	19,141	23,566	20,109

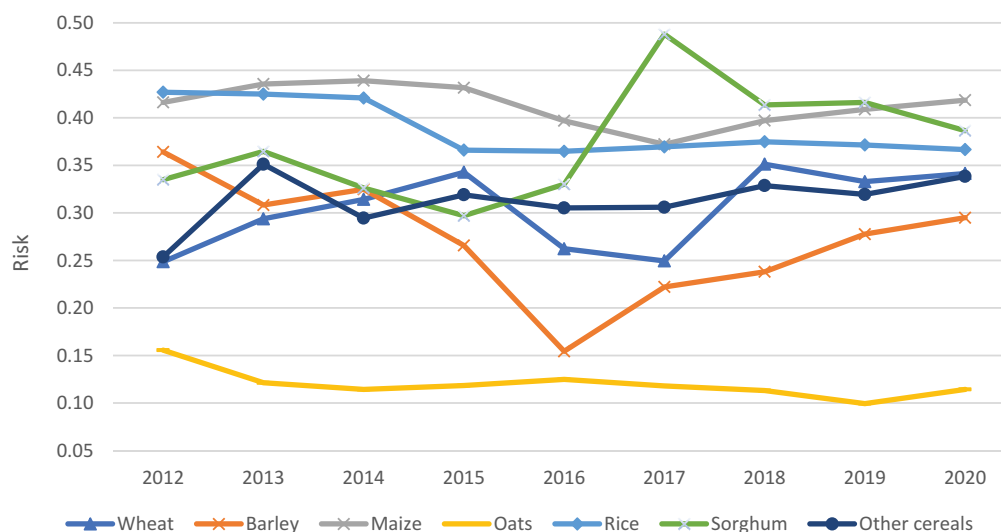
Source: ITC (2022)

**Figure 1. Cereal import dependency of the UAE over 2012–2020.**



**Figure 2. Weighted average of risk assessment scores of UAE's cereals supplying countries.**

Note: The UAE's net positive import is used for weighting the actual risk assessment scores of supplying countries.



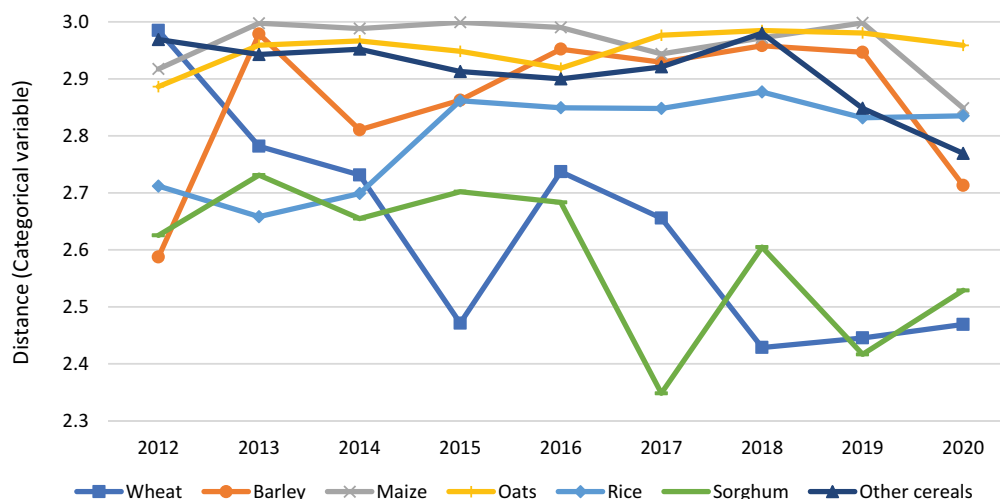
of UAE's wheat imports between 2012 and 2014 (Table 2). However, Russia has been the key supplier of wheat to the UAE since 2015. Canada was the second important wheat supplying country to the UAE, covering about 25–30% of the UAE's imports during the sample period. Whereas Canada's share in UAE's wheat import has remained stable during the sample period around 27%, the import share of Russia has been fluctuating very much (Figure 4). For example, Russia's share in UAE's wheat import dropped from 55% in 2015 to 13% in 2016, and again increased to 43% in 2018; which might raise UAE's external cereal supply risk. Australia has been the main supplier of barley to the UAE during the sample period, followed by Argentina.

### 3.2. External cereal supply risks

The values of the two measures of UAE's security of external cereal supply (HHI and SWI) are presented below in Figures 5 to 11 by cereal type. An HHI value closer to 0 implies secured external supply (less risk) whereas a value closer to 3 implies less secured external supply (higher risk). On the other hand, an SWI value closer to zero implies less secured supplies (higher risk) whereas larger values imply secured external supplies (i.e. less risk). The level of external cereal supply risk

**Figure 3. Weighted average of distances between the UAE and its cereal supplying countries.**

Note: The net positive import values were used for weighting the actual values of the categorical distance variable.



would be higher (i.e. HHI closer to 3 and SWI closer to 0) if (i) UAE's import dependency for a given cereal type is very high, or (ii) UAE imports all of its cereals from countries with the highest risk assessment values, or (iii) UAE sources all of its cereals from very distant countries, or (iv) UAE imports all of its particular cereal type from very few sources (e.g., Canada and Australia versus Russia and Ukraine), irrespective of the levels of riskiness of the suppliers and distances since the degree of consolidation of sources, instead of diversification of sources, is a risk onto itself.

The HHI and SWI values over 2012–2020 for wheat are given in Figure 5. The average HHI value during 2012–2020 was 0.32, which implies that, on average, the external wheat supply risk has been low during the sample period. The HHI values have been fluctuating during the sample period, where the highest risk was recorded in 2015 and 2019 (HHI = 0.43), and the lowest in 2017 (HHI = 0.16). The main driver of this fluctuation in the level of the external supply risk was the switch of UAE's import sources from distant (e.g., India) to nearby countries (e.g., Russia and Romania), and from relatively more secured countries (i.e. countries with lower level of risk assessment value, e.g., Australia) to risky countries (i.e. countries with relatively higher level of risk assessment values, e.g., Russia). Specifically, the import share of Russia has increased from 25% in 2017 to 52% in 2019, by replacing imports from Australia, Romania and India (Table 2), which raised UAE's external supply risk. This implies that the strong dependence on Russia as the main source of wheat imports is associated with a relatively higher external supply risk (due to the consolidation of sources, and the higher risk status of Russia).

Like the HHI values, the SWI values for wheat have also been fluctuating during the sample period, where the average annual SWI was 0.74. The lowest SWI value was recorded in 2015 (SWI = 0.61, implying a relatively less secured supply), and the highest SWI was recorded in 2014 (SWI = 0.89, implying a relatively more secured supply). The main source of this variation in the level of external supply risk was the fluctuation in import dependency rate (where the import dependency rate increased from 111% in 2012 to 211% in 2016). Moreover, the increase in the import share of Russia since in 2018 (which has relatively a higher risk assessment value) in place of other suppliers with relatively lower risk assessment values such as Australia, Romania and India contributed to the rise in the external supply risk. The less diversification of import sources due to the reliance on one/two main sources (with the other suppliers with negligible import shares) also contributed to the rise in the external supply risk.

The values of the two indices measuring the security of the external supply of barley over 2012–2020 are presented in Figure 6. The average HHI value between 2012 and 2020 was 0.28, which implies that the external barley supply risk has relatively been low during the sample period. The

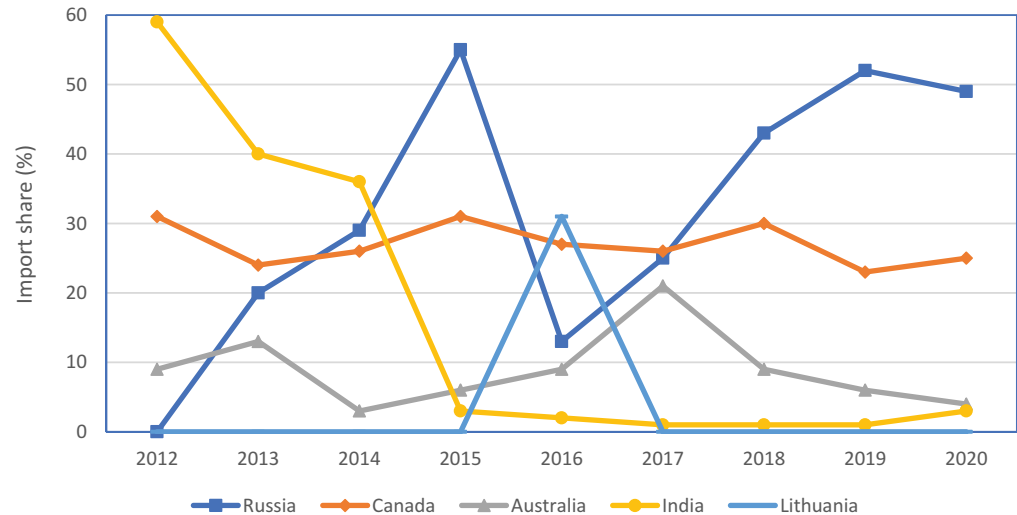
Table 2. Import shares of UAE's cereal supplying countries (%)										
Suppliers	2012	2013	2014	2015	2016	2017	2018	2019	2020	
<i>Wheat</i>										
Russian Federation	0	20	29	55	13	25	43	52	49	
Canada	31	24	26	31	27	26	30	23	25	
Australia	9	13	3	6	9	21	9	6	4	
India	59	40	36	3	2	1	1	1	3	
Romania	0	0	0	4	15	18	2	0	8	
Lithuania	0	0	0	0	31	0	0	0	0	
Pakistan	1	0	0	0	0	0	13	6	0	
Other countries	0	4	5	1	3	10	1	12	11	
Total number of supplying countries	4	6	7	6	8	8	7	9	8	
<i>Barley</i>										
Australia	32	29	29	40	84	67	52	43	39	
Argentina	12	29	31	27	10	26	31	42	25	
Russian Federation	38	0	11	10	0	3	2	0	18	
India	13	35	11	1	0	0	0	0	0	
Ukraine	5	1	1	5	5	5	1	4	9	
Other countries	0	5	18	17	1	0	13	10	10	
Total number of supplying countries	5	6	8	9	3	4	7	6	7	
<i>Rice</i>										
India	65	57	61	80	77	74	75	70	73	
Pakistan	26	30	25	13	14	14	12	15	14	

(Continued)

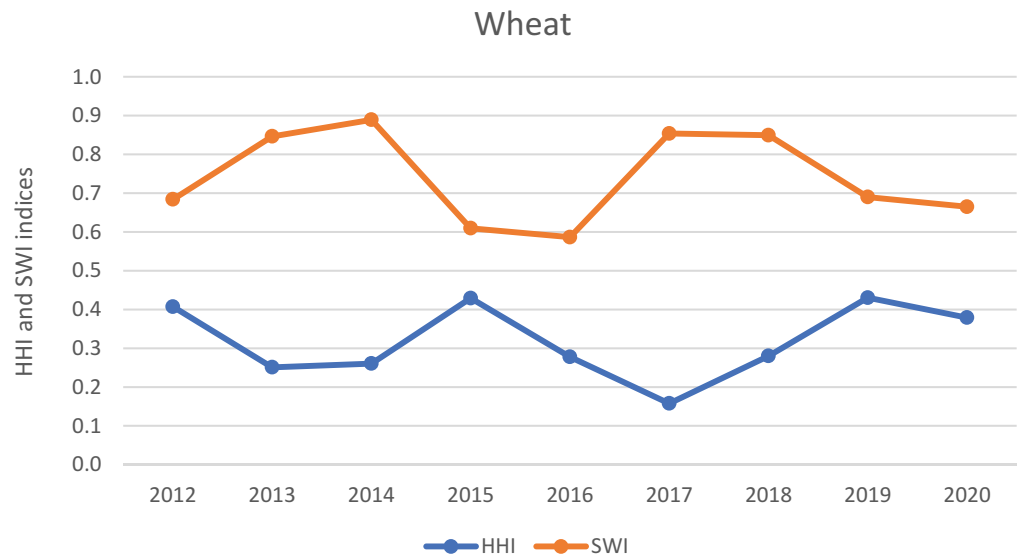
Table 2. (Continued)

Suppliers	2012	2013	2014	2015	2016	2017	2018	2019	2020
Viet Nam	1	3	3	3	3	4	6	8	7
Thailand	6	7	9	3	4	5	4	4	3
Other countries	2	4	3	0	2	1	3	2	2
Total number of supplying countries	6	8	7	4	6	5	7	6	6
Maize									
Argentina	36	64	42	45	32	30	51	58	48
Brazil	21	18	41	32	26	29	11	20	20
Australia	4	0	0	13	25	16	22	17	14
India	25	16	13	3	2	1	2	1	0
United States of America	5	0	1	4	12	16	9	1	1
Other countries	9	1	3	2	2	7	6	4	16
Total number of supplying countries	8	4	6	6	7	7	7	7	8
Sorghum									
India	21	46	21	29	25	9	28	9	45
Sudan	0	24	6	16	26	58	18	28	2
Australia	36	26	31	23	41	15	10	12	0
Ukraine	4	0	9	20	8	14	11	18	22
Ethiopia	39	0	19	1	0	0	0	0	0
Moldova, Republic of	0	0	0	0	0	0	5	6	21
Other countries	0	4	15	12	0	3	28	26	11
Total number of supplying countries	4	4	8	7	4	6	10	10	8

**Figure 4. Import shares of UAE's main wheat supplying countries (%).**



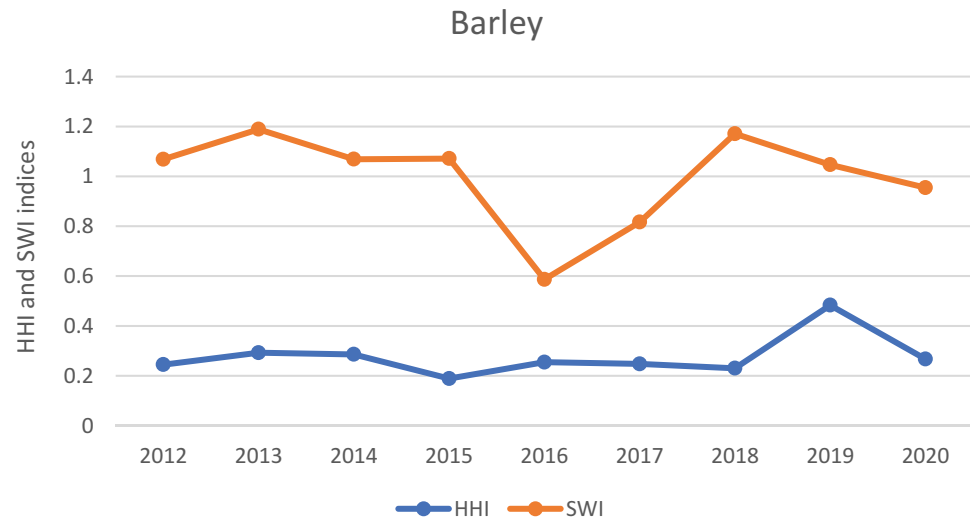
**Figure 5. External security of wheat supply indices for the UAE over 2012–2020.**



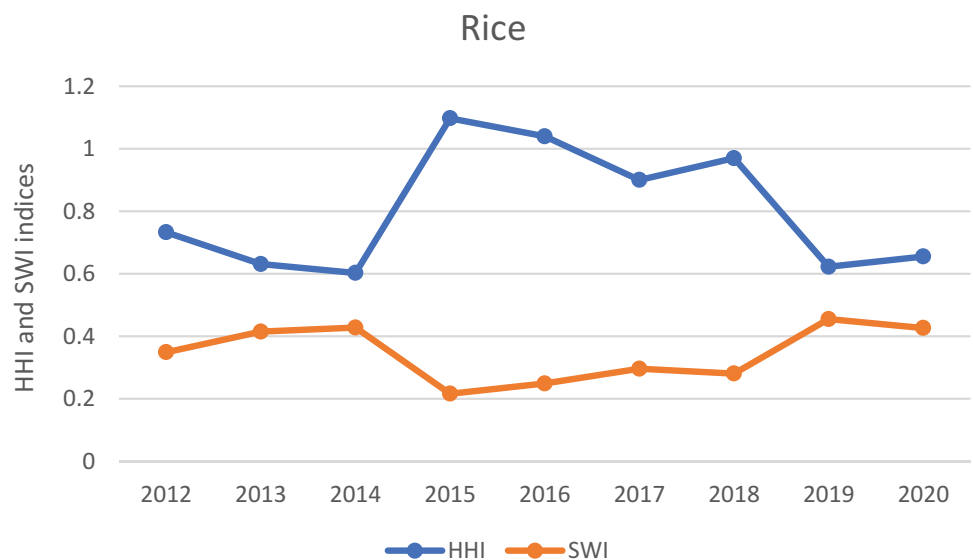
HHI values have remained stable (around 0.25) between 2012 and 2018. However, it increased to 0.48 in 2019 from 0.23 in 2018, which is a 113% increase. This implies that the external barley supply risk has increased in 2019; which was mainly attributed to the increase in the import dependency rate from 106% in 2018 to 152% in 2019. Moreover, the change in the import shares of supplying countries from a secured country (i.e. Australia, a supplier with a lower level of risk assessment value) to less secured country (i.e. Argentina, relatively with a higher level of risk assessment value) raised the external supply risk in 2019 (Table 2). The fluctuation in the number of UAE's barley supplying countries (e.g., decreased from 9 in 2015 to 3 in 2016, and then increased to 7 in 2018 (Table 2)) contributed to the fluctuation in the values of the SWI. This suggests that the lack of diversification of supplying sources has been the main driver of the highest external barley supply risk recorded in 2016 during the sample period (i.e. corresponding to the lowest SWI value).



**Figure 6. External security of barley supply indices for the UAE over 2012–2020.**



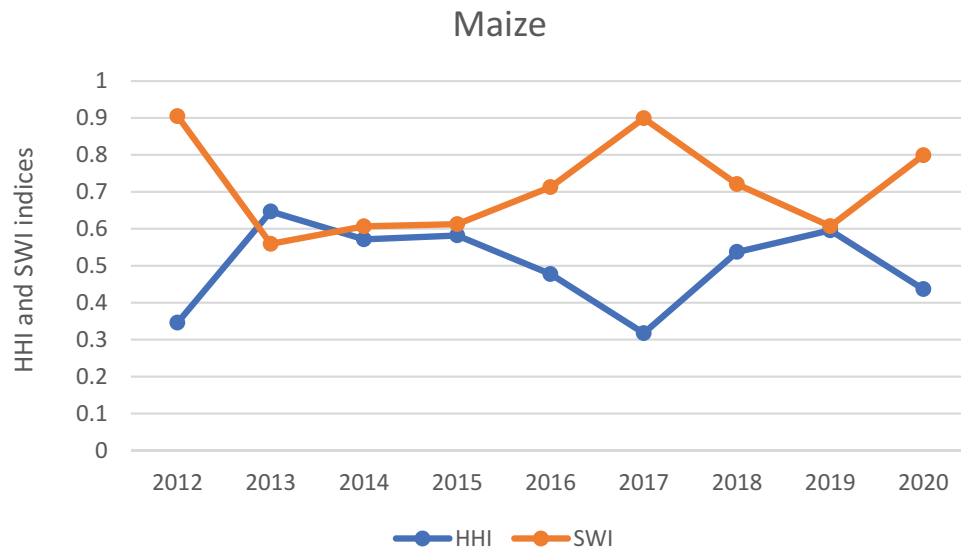
**Figure 7. External security of rice supply indices for the UAE over 2012–2020.**



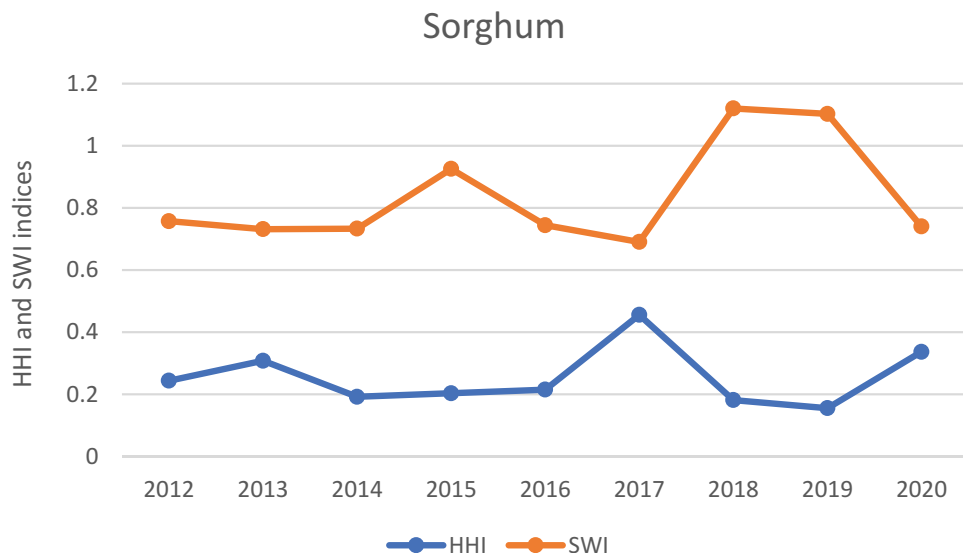
The HHI and SWI values over 2012–2020 for rice are presented in Figure 7. Both indices showed that external supply risk initially declined between 2012 and 2014, and then increased in 2015. However, the external rice supply risk declined in 2019 compared to the level in 2018. The main driver of such fluctuation in the security of rice external supply was the fluctuation in the import dependency rate (i.e. where it decreased from 133% in 2012 to 117% in 2014 and then increased to 159% in 2015, and again decreased from 142% in 2018 to 115% in 2019 (Figure 1)). The highest external rice supply risk recorded in 2015 is also attributable to the less diversification of supplying countries (i.e. the number of UAE's rice supplying countries decreased from 7 in 2014 to 4 in 2015 (Table 2)).

The HHI and SWI values over 2012–2020 for maize are presented in Figure 8. Both indices showed that the security of external maize supply has been fluctuating during the sample period. The external supply risk increased between 2012 and 2013, and decreased between 2013 and 2017, and then increased between 2017 and 2019. The main driver of this fluctuation in the external supply risk was the fluctuation in the import shares of UAE's main maize supplying countries. Specifically, UAE's strong reliance on Argentina as its main import source (e.g.,

**Figure 8. External security of maize supply indices for the UAE over 2012–2020.**



**Figure 9. External security of sorghum supply indices for the UAE over 2012–2020.**



accounting for 64% in 2013 and over 50% in 2018 and 2019), instead of diversification of import sources and importing from less risky countries such as Australia and USA, raised the external maize supply risk since Argentina is a country with a relatively higher risk assessment value. For example, the lowest external supply risk was recorded in 2017, which corresponds to the lowest import share of Argentina (30%; Table 2). On the other hand, the rise in the external supply risk between 2012 and 2013 is attributable to the decrease in the number of UAE's maize supplying countries from 8 in 2012 to 4 in 2013 (Table 2), where less diversification of supplies increases external supply risk.

The HHI and SWI values over 2012–2020 for sorghum are presented in Figure 9. The values of both indices remained somehow stable between 2012 and 2016. However, the external supply risk has been fluctuating since 2016 (where it increased between 2016 and 2017, and then decreased between 2017 and 2019, before rising again in 2020). The main driver of the fluctuation in the security of sorghum external supply was the change in import shares of the main supplying countries (Table 2). For example, the highest external supply risk recorded in 2017 corresponds

to the highest import share of Sudan, since Sudan is a source with a higher level of risk assessment value compared to the other main suppliers (e.g., India and Australia). Similarly, UAE's strong dependence on only two medium risk countries (India and Ukraine) in 2020 raised the external sorghum supply risk (i.e. less diversification of sources).

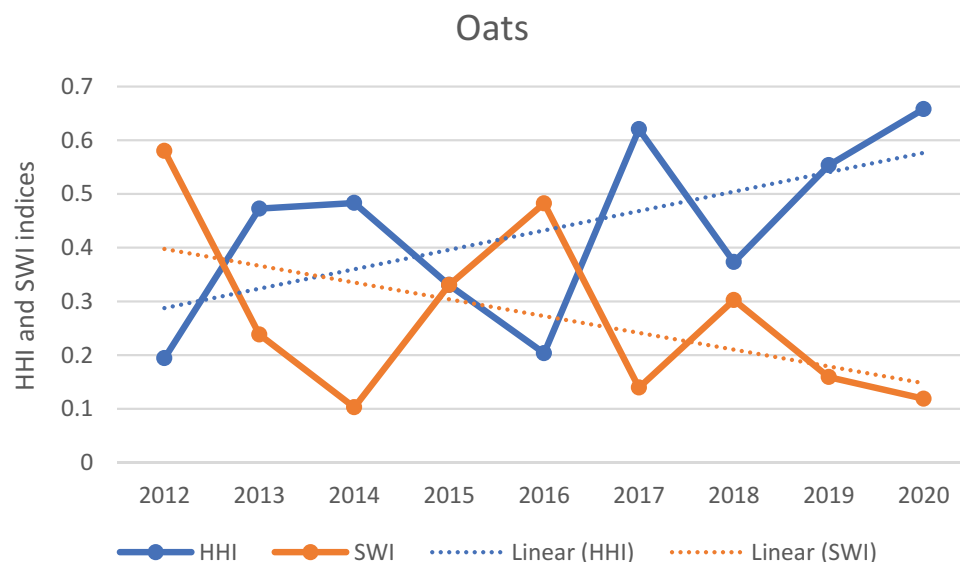
The indices for Oats and Other Cereals are presented in Figures 10 and 11, respectively. The external supply risk for Oats has increased during the sample period, although it has been fluctuating. The main driver of the fluctuation in Oats external supply risk was the fluctuation in the import dependency rate (Figure 1). On the other hand, the external supply risk for Other Cereals has remained stable between 2012 and 2018 (Figure 11). However, the level of external risk decreased from 2018 onwards, owing to the diversification of supplying sources.

#### 4. Discussion

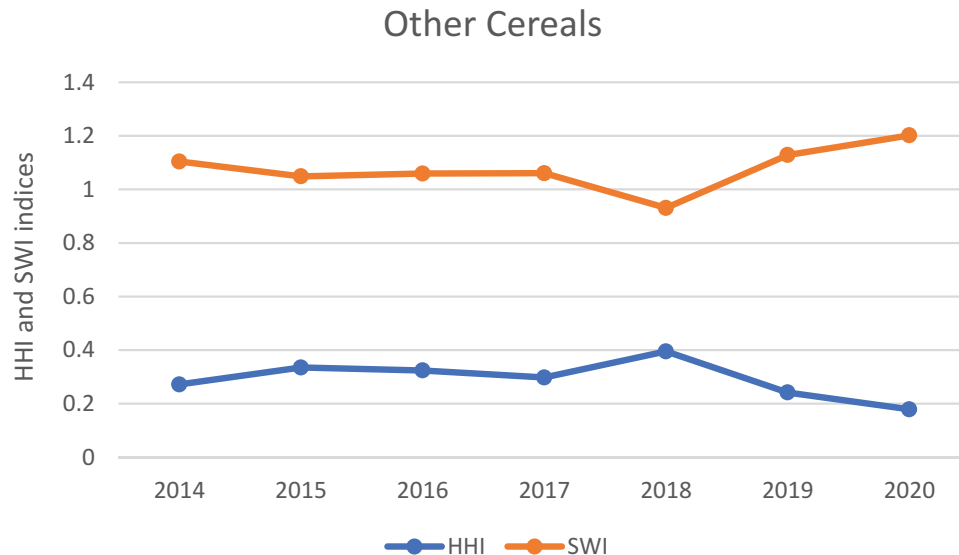
In this study, we measured the short-term external cereal supply risk of the UAE, by considering the degree of UAE's cereal import dependency, the political- and business-related risk levels of UAE's cereal supplying countries, the degree of consolidation of sources and transportation/transit risk into account. Our findings generally show that UAE's external cereal supply risk has been low during the sample period (2012–2020). This is in line with the findings of Kummur et al. (2020) that trade-related resilience indicators of the global food system have increased during the past three decades, implying the reductions in external supply risks. The results of the HHI and SWI values for wheat have been fluctuating during the sample period. The main driver of the fluctuation in the level of the external supply risk was the switch of UAE's import sources from distant (e.g., India) to nearby countries (e.g., Russia and Romania), and from relatively more secured countries (i.e. countries with lower level of risk assessment value, e.g., Australia) to risky countries (i.e. countries with relatively higher level of risk assessment values, e.g., Russia). Specifically, the increase in the import share of Russia from 25% in 2017 to 52% in 2019, by replacing imports from Australia, Romania and India raised UAE's external supply risk. This implies that the strong dependence on Russia as the main source of wheat imports is associated with a relatively higher external supply risk following from the consolidation of sources (less diversification of suppliers) and the higher risk status of Russia. Given the current Russia-Ukraine crisis and Russia being the main source of cereals for the UAE poses a serious threat to food security in the UAE.

The UAE government has identified different pathways, under its National Food Security Strategy 2051, including raising domestic production to improve food security. In the UAE and other GCC countries, the adoption of modern production technologies such as aquaponics, hydroponics and

**Figure 10. External security of Oat supply indices for the UAE over 2012–2020.**



**Figure 11. External security of Other Cereals supply indices for the UAE over 2012–2020.**

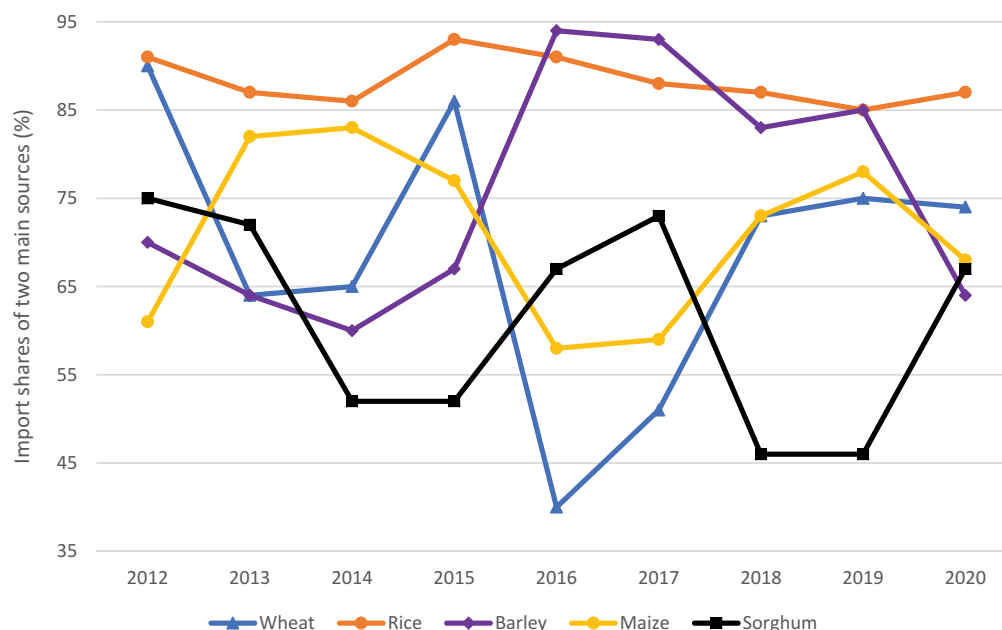


vertical farming have been identified as viable options for meeting the domestic food requirements for fish, fruits and vegetables (Woertz, 2020). Similar to the cereal import dependency related risks that have been discussed in this paper, the level of dependence of domestic production on imported inputs such as feed and fertilizers, and the associated external supply risks should be taken into consideration when analyzing food security (Hubbard & Hubbard, 2013). For example, Lehtikoinen et al. (2021) reported that Finland has become increasingly dependent on imported agricultural inputs although the country is relatively food self-sufficient, which makes its food system vulnerable to global input supply chains. Similarly, it is important for the UAE to take the degree of dependence of the identified alternative farming systems (aquaponics, hydroponics and vertical farming) on imported inputs and the level of external input supply risk into account for enhancing the resilience of its future food system.

In this study, we did not take the substitutability of the different cereal types into account when deriving the two measures of security of external supplies (HHI and SWI). Le Coq and Paltseva (2009) included *fungibility* of energy imports in their HHI, to account for the substitutability among the different energy types when measuring the security of energy imports. In this study, we omitted the *fungibility* measure in the construction of the indices due to lack of suitable data on the degree of substitutability between the different cereal types. If the degree of substitutability between the different cereal types is higher, the values of HHI would likely become closer to zero, implying that the adverse impacts of import disruptions of some cereal types could be easily managed by switching to the import of alternative cereals.

During the sample period, UAE has heavily been dependent on one or two external sources for its cereal imports (i.e. import sources have been less diverse; Figure 12), which reduces the security of its external cereal supply. For example, during the sample period, UAE has been relying on only two suppliers for sourcing at least 60% of its total cereal imports: rice (~90%), wheat (~70%), barley (~75%), maize (~70%) and sorghum (~60%). Specifically, rice import has heavily been reliant on only two countries: India and Pakistan. Although the share of UAE's two main suppliers of wheat fluctuated during the sample period (where supplies were more diversified in 2016), supplies have become less diversified since 2016. As can be seen in Figure 12, the degree of UAE's dependence on two countries for sourcing its cereal imports in 2020 were somehow similar to the degree of dependence in 2012. Our finding confirms the conclusion of a recent study by Kummu et al. (2020) that "... despite a growing number of people being heavily dependent upon imports, the number of import partners decreased more often than it increased". The authors

**Figure 12. Import shares (%) of UAE's two main supplying countries by cereal type over 2012–2020.**

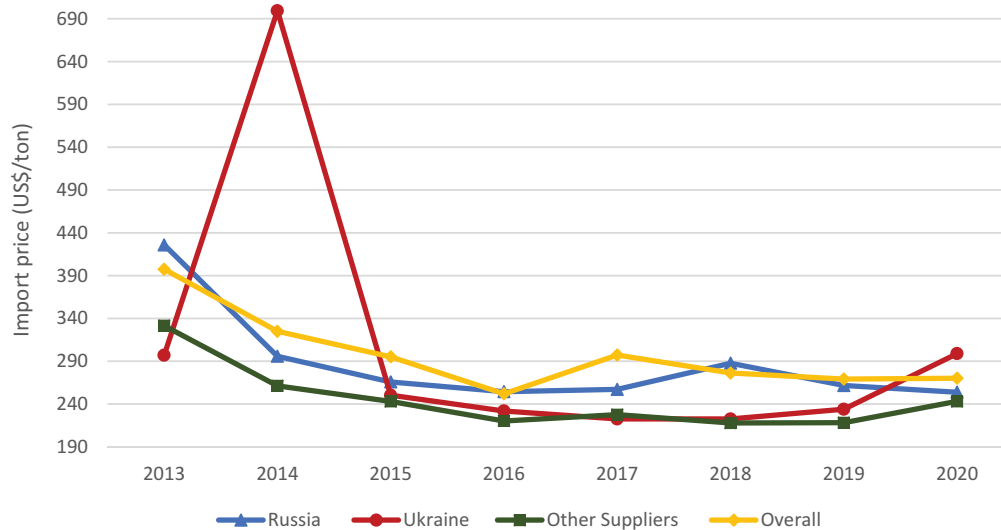


further noted that an increased food import dependency combined with a reduced number of import partners raises the vulnerability of the food security of import dependent countries to disruptions of food supply chains.

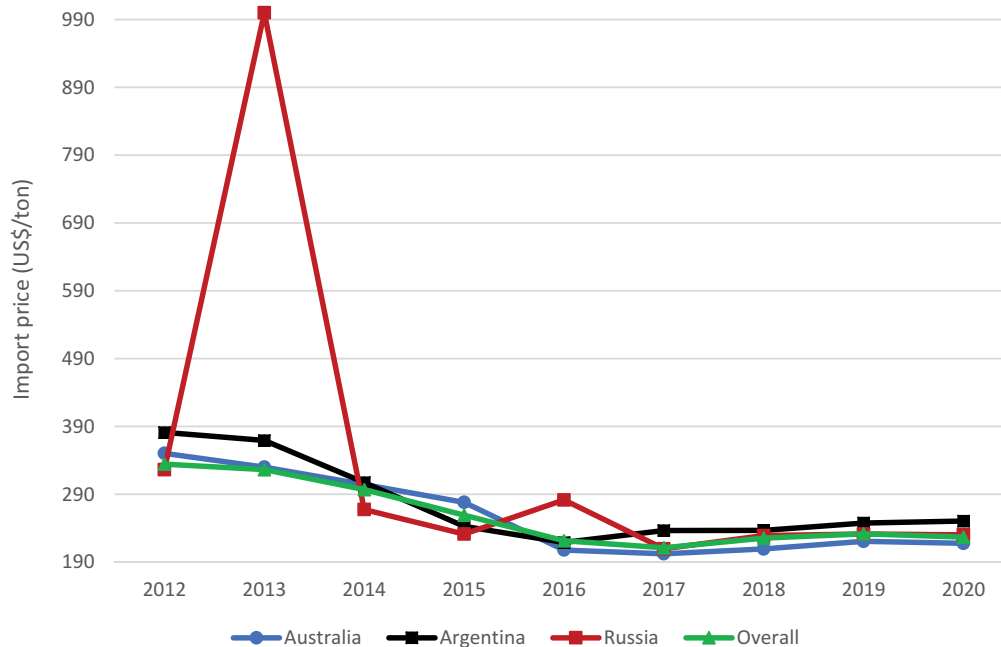
A country's level of diversifications of cereal supply sources might depend on the costs of diversification and other factors such as its trade policies, political environment, and supplier's capacity. Although diversification of supply sources reduces the external cereal supply risk, this might come at higher import prices. For example, the prominence of the Black Sea over the last 10 years as the main source of grains in the global market might be due to the competitive prices of wheat and other grains originating from Russia and Ukraine. It is therefore important to compare the costs of diversification of UAE's supplies to the benefits related to the reduction in external supply risk. We presented the unit import prices<sup>2</sup> of UAE's three major cereal imports over 2012–2020 by supplying country in Figures 13 to 15. Although Russia has been the main supplier of wheat to the UAE during the sample period (Table 2), Russia's wheat prices were not the cheapest compared to other supplies (Figure 13). Likewise, the unit import price of wheat from Ukraine was the highest in 2014 (which might be due to the political instability in 2014 following the annexation of Crimea by the Russian Federation). To sum up, UAE's strong dependence on a few countries (e.g., Russia) for sourcing its wheat imports during 2012–2020 was not mainly attributable to competitive wheat prices as can be inferred from Figure 13. On the other hand, UAE's strong dependence on Australia as the main supplier of its barley imports might be due to Australia's competitive barley prices throughout the sample period compared to other suppliers (Figure 14). For example, Russia's share in UAE's barley import has dropped from 38% in 2012 to almost zero in 2013 (Table 2), which might be due to the high import prices of barley originated from Russia (Figure 14). Similarly, UAE's strong dependence on India as its main supplier of rice might be due to its competitive rice prices during the sample period compared to other suppliers (Figure 15). Therefore, the competitive import prices provided by a few suppliers could have been the main reason behind UAE's less diversified cereal supplies.

Since the UAE heavily relies on Russia (and Ukraine) for its cereal supplies (Table 2), the Russian invasion of Ukraine will have severe implications for achieving food security both in the short- and long-term. Since the war directly and indirectly affects the global food market, the UAE needs to adopt different risk management tools for mitigating short- and long-term external supply risks.

**Figure 13. UAE's wheat import prices by source of supplying countries (Note: the unit prices are derived as import value divided by import quantity).**



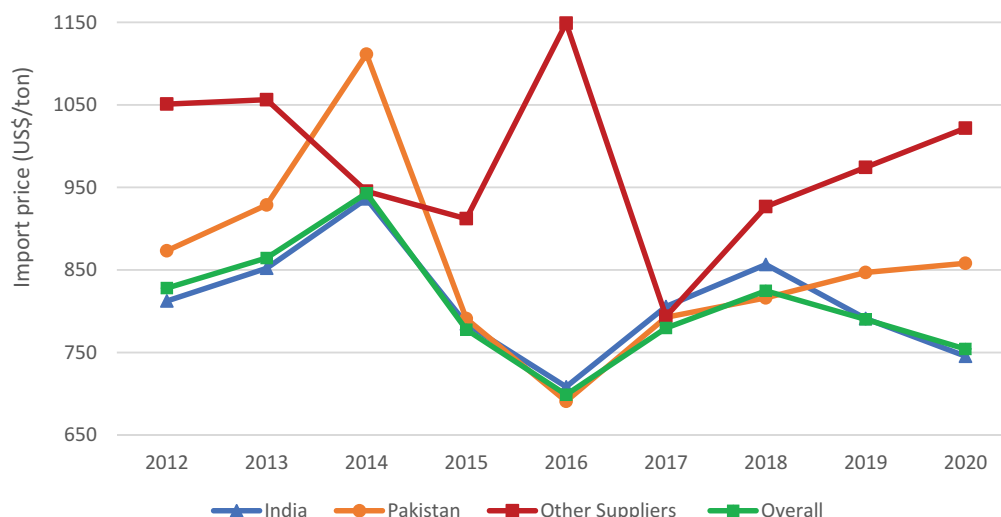
**Figure 14. UAE's barley import prices by sources of supplying countries (Note: the unit prices are derived as import value divided by import quantity).**



One of these risk management options is cereal stockpiling (Sadler & Magnan, 2011), which enables to mitigate both physical availability and price risks. As shown in Figure 1, the import dependency rates of the UAE are greater than 100% (where import dependency refers to the ratio between import and domestic consumption). This implies that the UAE has been importing more amounts of cereals than required for satisfying domestic consumption during a particular year. These extra imports normally raise UAE's grain stocks, which could be used during emergencies to mitigate availability and price risks. It has been shown that food security and social stability are strongly influenced by grain stock management, as seen during the "Arab Spring" revolts. The stock policies have to introduce actions to mitigate food security risks and uncertainty in UAE and the neighboring States. Foreign agricultural land acquisition has also been identified in the literature as one of the strategies to deal with cereal import dependency related risks (Pirani & Arafat, 2016; Sadler & Magnan, 2011; Woertz, 2020). However, this proxy



**Figure 15. UAE's rice import prices by sources of supplying countries (Note: the unit prices are derived as import value divided by import quantity).**



strategy for achieving food self-sufficiency in the GCC countries has failed due to the challenging local business environment, lack of infrastructure, and resistance by locals claiming land rights in the countries where the GCC countries invested in food production (e.g., Sudan; Woertz, 2020). Moreover, the lack of expertise in the GCC countries and the declining oil prices reducing the fiscal space to invest in foreign countries contributed to the failure of the land acquisition strategy (Woertz, 2020). Above all, in order to reduce the adverse impacts of external cereal supply risks, the GCC countries should adopt early warning systems for monitoring their food systems and their citizens' food security status (Manikas et al., 2022). It is also critical to give due attention to food value chain management, including using food diplomacy in multilateral frameworks such as the World Trade Organization to secure imports (Woertz, 2020). In addition, UAE and the other GCC countries should work on tackling food-related epidemics like obesity since food security is after all a nutrition security as highlighted by the COVID-19 pandemic (Woertz, 2020).

Since the past two years, achieving global food security has increasingly become challenging due to the COVID-19 pandemic, and the on-going Russia-Ukraine crisis. Particularly, the Russia-Ukraine war has posed serious food security challenges worldwide, and especially for the GCC countries who are vulnerable to trade shocks due to their high dependence on food import (Abay et al., 2022). Russia and Ukraine are key players in the world food market, with significant share in the world export market for wheat (34%), barley (27%), maize (17%) and sunflower oil (73%; Comtrade, 2022; FAO, 2009, 2022a, 2022b). Besides the disruptions of the flow of food supplies through the Black Sea region (e.g., due the blockage of Odessa—Ukraine's main port), the war and the sanctions have led to a surge in global food and fertilizer prices, posing a major risk to food security in the short term (Berkhout, Bergevoet and van Berkum 2022; Abay et al., 2022). The Food Price Index for March 2022 was, for example, recorded as the highest level of food price (159.3 points) since FAO started the publication of this index in 1990 (FAO, 2009). The medium- and long-term impacts of the war on food security is highly uncertain. The limited availability and the resulting increase in the prices of fertilizers will have an adverse impact on food availability across the world, especially in Sub-Saharan Africa and the MENA region as the world's food production is heavily dependent on nitrogen and potassium fertilizers from Russia and Belarus (IFPRI, 2022b). This will raise the external cereal supply risk of the UAE since cereal production by the supplying countries (other than Russia and Ukraine) will also be disrupted. Berkhout, Bergevoet and van Berkum (2022) identified five possible uncertain factors that the war and the subsequent sanctions adversely impact food security worldwide:

- decline in food production in Ukraine and possibly in Russia
- the length of the conflict
- the availability of fertilizers
- the availability of energy
- trade barriers (resulting from embargos on exports by individual countries or resulting from sanctions).

## 5. Conclusions

The coronavirus (COVID-19) pandemic and the Russian invasion of Ukraine have once again tested the resilience of food security of import-dependent economies, and exposed the vulnerability of their food systems to disruptions of food supply chains. Managing external food supply risks is therefore critical for these countries to reduce import-related adverse impacts on food security. This study assessed the short-term external cereal supply risks for the UAE by applying the Herfindahl–Hirschman Concentration Index (HHI) and the Shannon–Wiener Diversity Index (SWI). We measured the short-term security of UAE's external cereal supplies by taking the degree of UAE's cereal import dependency, the level of political- and business-related risks of UAE's cereal supplying countries, and the distance between UAE and the supplying countries into account. The results of the HHI and SWI values were found to be small, implying that the external cereal supply risk has on average been low during 2012–2020. The HHI and SWI values have been fluctuating for wheat during the sample period, and the level of external supply risk has been increasing since 2017. This was mainly attributable to UAE's increasing dependence on less secured countries, i.e. countries with higher level of risk assessment values. Specifically, the import share of Russia has increased from 25% in 2017 to 52% in 2019, by replacing imports from relatively secured countries such as Australia, Romania and India. During the sample period, UAE has heavily been dependent on one or two, mostly price competitive, external sources for its cereal imports, which also contributed to a rise in the external cereal supply risk following from the consolidation of sources. In general, the UAE's increasing dependence on Russia as the main sources of cereals and the increasing consolidation of sources pose a serious threat to sustaining food security both in the short and long term.

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## Notes

1. The food import dependency rates of the GCC countries can be retrieved from the Economist Intelligence Unit's Global Food Security Index (GFSI) 2021 publication under the Natural Resources and Resilience dimension.
2. The unit prices are derived as import value divided by import quantity of a particular cereal type for a particular year.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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