Yield Variability and Harvest Failures in Russia, Ukraine and Kazakhstan and Their Possible Impact on Food Security in the Middle East and North Africa

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Abstract

Exports from Russia, Ukraine and Kazakhstan (RUK) help to improve global wheat availability and, hence, global food security. During the past 15 years, however, RUK wheat exports have shown high variability, mainly because they have been repeatedly diminished by severe harvest failures. We present an outlook for RUK wheat production and exports up to 2027, taking into account possible yield variability and harvest failures, and focusing on the impact on food security in the Middle East and North Africa (MENA), the world’s major wheat importing region. For the analysis we use the stochastic version of the Aglink-Cosimo model. Simulation results show that wheat yields in RUK are a major source of uncertainty for international wheat markets. The projected substantial increases in world market prices due to limited RUK wheat exports threaten food security in MENA and highlight the need for both stabilising RUK yields and novel complementary food security approaches to decrease MENA’s vulnerability to disruptions in agricultural world markets.

Keywords: agricultural markets; food security; harvest failures; Yield variability.

JEL classifications: Q02, Q11, Q13, Q17.

1. Introduction

International trade plays a fundamental role in balancing deficits of net food importing countries with surpluses of net food exporters. Following FAO’s food security definition (FAO, 1996), trade can potentially contribute to each dimension of food

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security by improving availability, access (physical and economic), utilisation (improved nutritional outcomes) and stability (the ability to manage the other three dimensions over time). A stable flow of food from surplus to deficit countries is, therefore, essential for the food security in many net importing countries (Matthews, 2014; Brooks and Matthews, 2015; Wood et al., 2018), particularly in those developing countries where the lack of natural endowments constrain supply (Allouche, 2011; Fader et al., 2013; Porkka et al., 2013, 2017).

Notwithstanding the positive aspects, the relationship between trade and food security is complex, and the food security dimension of trade can have some negative side effects. For example, the ongoing intensification in food trade during the last decades has led to an increasing disconnection between consumers and the resources that sustain production (D’Odorico et al., 2014). Trade can also impede the development of some farming systems, especially poor smallholder agriculture in developing countries, if they cannot compete with lower prices or higher standards of imported goods, hence compromising the domestic potential to improve food security (Brooks and Matthews, 2015). Politically, movements advocating for food sovereignty and self-sufficiency (Nyéléni, 2007; Alonso-Fradejas et al., 2015), have a rather negative view on trade as a contribution to food security. Both concepts are concerned with a country’s capacity to produce food in sufficient quantities to meet domestic demand, but critical discussions point out that neither the concept of food self-sufficiency (Clapp, 2017) nor the food sovereignty movement (Burnett and Murphy, 2014) entirely reject trade. Moreover, in countries with scarce water and land resources relying mostly on domestic food production may simply not be feasible in the longer run, especially considering climate change (Fader et al., 2013). It follows that the analysis of the trade-food security nexus may become even more important in the future, especially as trade integration may also increase importing countries’ exposure to external instabilities related to, for example, extreme weather events (droughts, floods and frost) in exporting countries and related interruptions of trade flows and price volatility (Headey, 2011; Puma et al., 2015; Bren d’Amour et al., 2016). Considering the complexity of food security in the network of increasing trade dependencies and interconnectivity of international supply chains, the investigation of both commodity-specific networks and regions is crucial to highlight possible fragilities and solutions (Sartori and Schiavo, 2015).

In this context, we concentrate on one important commodity for food security (wheat) and how yield variability and harvest failures in an important net exporting region may affect a substantial net importing region. We focus on (i) the world’s major wheat exporting region, Russia, Ukraine and Kazakhstan (RUK), a region that in the past was characterised by yield variability and recurrent harvest failures, and (ii) the world’s major net importing region, Middle East and North Africa (MENA), a region with limited capacity for expanding its domestic production to meet domestic demand. We assess how yield variability and harvest failures could affect the future development of RUK wheat production and exports, and how this could impact MENA’s food security with respect to wheat availability and prices. To do so, we use the stochastic version of Aglink-Cosimo, a global recursive-dynamic, partial equilibrium, supply-demand model (OECD-FAO, 2015, 2018), which complements the OECD/FAO’s agricultural outlooks with a systematic examination of yield uncertainties.

The remainder of the paper is structured as follows. In section 2 we provide background information on the two focus regions and their role in international wheat markets, and section 3 outlines the modelling approach for the assessment. Results
are presented and analysed in section 4. Section 5 discusses the results in the context of existing literature, and section 6 concludes.

2. Background

Over the last two decades the international trade of wheat has substantially intensified, with global wheat exports increasing by 86%, from around 99 billion tonnes in 1996 to around 184 billion tonnes in 2016 (Food and Agriculture Organization of the United Nations, 2018). Wheat is a mainstay of the human diet, on average providing about 19% of daily caloric needs and 21% of dietary protein intake globally (Shiferaw et al., 2013). Wheat is the main staple food in the MENA region with a yearly intake per capita close to 140 kg, which is more than double the world average of 65 kg/capita. Egyptians, for example, get about a third of their daily calories and 45% of dietary protein from wheat. Accordingly, wheat plays a pivotal role in the food security of MENA countries. The MENA region\(^1\) comprises a heterogeneous group of countries, ranging from least developed countries such as Sudan, Yemen and Mauritania to high-income oil-exporting countries such as Qatar, United Arab Emirates and Saudi Arabia. During recent years, the socioeconomic development in the region has been hampered, with one part of MENA suffering from persistent instability and conflict (most intense in Iraq, Libya, Palestine, Syria and Yemen), and the other part being struck by the impacts of surrounding conflicts and fluctuating oil prices (Abdelaziz and Breisinger, 2018). Despite their heterogeneity with respect to general economic development levels, the countries in the MENA region share several characteristics, among them the high and growing dependence on imports of key staple food products. With a self-sufficiency ratio of about 45%, the supply of the domestic wheat demand in the MENA region largely relies on imports, and the region is the largest importer of wheat in the world. The region’s high dependency on wheat imports is mainly explained by the lack of natural resources, only 5% of the total land area in the MENA region is cropland (of which about 40% requires irrigation due to the dry climate), and a population growing above the world average. Moreover, the programmes adopted to increase self-sufficiency in the region have led to unsustainable agricultural development, as inefficient agricultural and environmental practices lead to energy, water and food losses, while bridging the supply-demand gap is further impacted by an uneven distribution of resources (FAO-ESCWA, 2017; Ninn-Pratt et al., 2018; World Bank, 2018).

The OECD-FAO (2018) agricultural outlook projects that the MENA region will further increase its dependency on wheat imports, and its self-sufficiency ratio (SSR) will decrease to about 44% by 2027 (Table 1). Within the region, countries/sub-regions well below the regional MENA SSR average are Saudi Arabia and the Gulf Region, both of which are extreme cases that already rely entirely on wheat imports. Saudi Arabia is an example of how past support policies lead to an exacerbation of the natural resource situation (groundwater) by supporting unsustainable agriculture. The deteriorating situation caused the Saudi government to gradually decrease the support for wheat cultivation in 2007/2008 and finally terminate it in 2015/2016. In Jordan, Yemen and Libya, the SSR is projected to be below 10% by 2027 due to the lack of natural endowments and limited resilience to weather shocks. In the Other

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\(^1\)See Table 1 for a full list of countries.
North Africa region, Algeria and Lebanon, SSRs are expected to remain low despite continuous production support. Close to the MENA SSR average are countries using high yield crop varieties (like Egypt) or countries where natural resources are less constrained (Iraq in the Mashrek region). The only country expected to be very close to self-sufficiency is Iran, but such development would require favourable weather conditions and a substantial improvement in yields and productivity gains. Table 1 presents the OECD/FAO projections for the MENA region for total domestic supply, net trade, SSR and share in total world imports of wheat by 2027.

As the world demand for wheat has increased, the Commonwealth of Independent States (CIS) countries have emerged as major players on international wheat markets, particularly due to exports from Russia, Ukraine and Kazakhstan (RUK). In the past, as part of the former Soviet Union, these countries focused agricultural supply on meeting domestic Soviet demand. After going through a transition phase and a restructuring of the agricultural sector, RUK wheat production rebounded during the 2000s and the countries became large wheat exporters. Taking the three-year average between 2013 and 2015, Russia had a share of around 13%, Ukraine 8% and Kazakhstan 4% of global wheat exports, i.e. aggregated wheat exports of RUK accounted for a quarter of total wheat traded on the world market. With more than 41 million tonnes, RUK wheat exports significantly exceeded exports of the European Union (33 mio t), US (about 25.5 mio t) and Canada (23.5 mio t) (OECD-FAO, 2018, Figure 1). RUK countries are major suppliers meeting the wheat import needs of MENA. For example, over the recent past, Russia and Ukraine have been the two biggest wheat exporters to Egypt, the largest wheat importer in the world (FAOSTAT, 2018).

### Table 1
Total domestic supply, net trade, self-sufficiency ratio and share in total world imports of wheat (projections for 2027)

| Region            | Domestic supply (1,000 t) | Net trade (1,000 t) | Self-sufficiency ratio (SSR) | Share in world imports |
|-------------------|---------------------------|--------------------|-------------------------------|------------------------|
| Egypt             | 10,091                    | −15,162            | 40.0%                         | 7.8%                   |
| Algeria           | 2,902                     | −9,588             | 23.2%                         | 5.0%                   |
| Morocco           | 7,603                     | −4,593             | 62.3%                         | 2.4%                   |
| Tunisia           | 1,390                     | −1,919             | 42.0%                         | 1.0%                   |
| Libya             | 179                       | −1,766             | 9.2%                          | 0.9%                   |
| Other North Africa* | 634                      | −4,068             | 13.5%                         | 2.1%                   |
| Saudi Arabia      | 3                         | −4,488             | 0.1%                          | 2.3%                   |
| Gulf Region†      | 3                         | −3,049             | 0.1%                          | 1.6%                   |
| Yemen             | 252                       | −4,128             | 5.8%                          | 2.1%                   |
| Jordan            | 30                        | −1,165             | 2.5%                          | 0.6%                   |
| Lebanon           | 158                       | −766               | 17.1%                         | 0.4%                   |
| Mashrek‡          | 6,058                     | −6,356             | 48.8%                         | 3.3%                   |
| Iran              | 15,713                    | −507               | 96.9%                         | 0.3%                   |
| MENA              | 45,014                    | −57,555            | 43.9%                         | 29.8%                  |

**Notes:** Net trade = exports – imports.

**Source:** OECD-FAO (2018).

*Includes Sudan and Mauritania.

†Includes Bahrain, United Arab Emirates, Kuwait, Oman and Qatar.

‡Includes Syria, Palestinian Authority and Iraq.
increase in RUK wheat production and exports has been mainly driven by rising input use and productivity increases due to improved management practices, especially in Russia (see, for example, Liefert and Liefert, 2017; Rada, Liefert and Liefert, 2019), which helped to significantly outperform expectations of earlier RUK wheat projections (e.g. van Leuwen et al., 2012; Salputra et al., 2013). According to the OECD-FAO (2018) agricultural market outlook, the importance of RUK for global grain markets will further increase over the next decade. Aggregated RUK wheat exports are projected to account for about 34% (68 mio t) of total world wheat exports by 2027, with Russia being the leading wheat exporter in the world with exports of over 40 mio t (Figure 1).

Wheat surpluses in the RUK region help to improve food security in the MENA region and other countries with deficits; however, it also exposes the importing countries to the uncertainties related to RUK wheat exports. RUK wheat production and exports have shown a high degree of variability during the last two decades (Sedik, 2017, cf. Figure 2). Production in the Russian Federation and Ukraine in particular was repeatedly hit by serious harvest failures due to severe droughts (Götz et al., 2013, 2016), while droughts and harsh winters also frequently diminished wheat

Figure 1. Major wheat exporting countries and their share in total world wheat exports.
Source: OECD-FAO (2018).

Figure 2. Historical and projected development of RUK wheat production and exports
Note: 1995–2016 historical data, 2017 estimate, 2018–2027 projections.
Source: OECD-FAO (2018).
production in Kazakhstan (Fehér et al., 2017). The high vulnerability of the RUK region to adverse weather conditions can at least in part be attributed to a lack of general investment in the agricultural sector (for example in infrastructure, machinery or irrigation capacity), still relatively low levels of fertiliser use, and inconsistencies and uncertainties in the regulatory framework of the agro-industrial sector (Kobuta et al., 2012; Müller et al., 2012; Schierhorn et al., 2014; Fehér et al., 2017; Keyzer et al., 2017; Sedik, 2017; Uzun et al., 2019). In addition, in years of harvest failure, RUK grain exports were further reduced by the implementation of temporary export restrictions by the governments of the RUK countries, increasing the entailed adverse effects on global food security by diminishing the world supply (Headey, 2011; Fellmann et al., 2014; Götz et al., 2016; Figure 2). The implementation of such measures created a high degree of uncertainty among domestic producers, acting as a disincentive with respect to input use (fertiliser and plant protection) and general investments (Fellmann and Nekhay, 2012; Kobuta et al., 2012; Götz et al., 2013; Keyzer et al., 2017; Sedik, 2017).

The fluctuations in RUK’s historical wheat production and associated exports indicate that the development of RUK wheat production and exports is subject to a great deal of uncertainty. This uncertainty is not reflected in the deterministic outlook of the OECD-FAO (2018, cf. Figure 2), which assumes steady yield development under normal weather conditions. In this article we assess how yield variability and harvest failures in the RUK countries could affect the future development of RUK wheat exports, especially focusing on how this could impact MENA’s food security with respect to wheat availability and prices. In contrast to the deterministic outlook provided by the OECD-FAO (2018), we use the stochastic version of the Aglink-Cosimo model for the empirical analysis which allows the specific consideration of yield uncertainty.

3. Methodological Approach

To quantify the impact of RUK wheat yield uncertainty on global markets, we employ Aglink-Cosimo, a global recursive-dynamic, partial equilibrium, supply-demand model. The model was developed by the OECD secretariat and the FAO to prepare medium-term agricultural market outlooks (e.g. OECD-FAO, 2018; EC, 2018), and to assess the impact of policies (e.g. Nekhay et al., 2012; Fellmann et al., 2014; Araujo-Enciso et al., 2016; Jensen et al., 2019) and general economic changes (e.g. Kavallari et al., 2014) on the agricultural sector in a consistent framework. Aglink-Cosimo covers the major regions and countries in the world, and calculates endogenously the development of annual supply, demand, trade, stocks and prices of the major agricultural commodities for domestic and world markets over a 10-year projection period. The underlying data series for the projections are taken from OECD and FAO databases, which mostly rely on information taken from national statistical sources. Price projections for the commodities are nominal prices (in local currency units). In its current version the model covers 82 individual countries and regions, 93 commodities and 40 world market clearing prices. Country and regional

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2The results of any analysis based on the use of the Aglink-Cosimo model by parties outside the OECD are outside the responsibility of the OECD Secretariat. Conclusions derived by third-party users of Aglink-Cosimo should not be attributed to the OECD or its member governments.
modules are maintained and further developed by the OECD and FAO secretariats, with important input in terms of data and analysis from country experts and national administrations. Country-specific information on agricultural, biofuel and trade related policies covers, for example, budgetary support measures, import and export duties, market intervention and supply management policies. This information is updated annually, which allows analysis of agricultural markets in a consistent framework that reflects up-to-date policy developments. Detailed descriptions of the Aglink-Cosimo model, including equations, variables and model properties, are provided in Araujo-Enciso et al. (2015) and OECD-FAO (2015).

An outlook for the development of agricultural markets and prices is provided annually in a joint publication of the OECD and FAO. The outlook is built on the basis of specific assumptions about the development of exogenous macroeconomic indicators (GDP growth, exchange rates, population growth, crude oil prices) provided by the OECD, IMF, UN and World Bank (OECD, 2007; OECD-FAO, 2015, 2018). The outlook for agricultural market developments is always conditional on the assumptions made on the exogenous variables, especially regarding weather conditions and macroeconomic developments. In particular, the ‘standard’ outlook projections with Aglink-Cosimo assume normal weather conditions (OECD-FAO, 2015, 2018).

To provide alternative development paths which account for uncertainties about exogenous variables, the European Commission (JRC Seville and DG AGRI) has developed a partial stochastic analysis as a complement to the deterministic Aglink-Cosimo baseline. The analysis is partial because it covers the uncertainty coming from yield variation and macroeconomic indicators, but not other sources of exogenous uncertainties such as, for example, animal disease outbreaks (Burrell and Nii-Naate, 2013; Araujo-Enciso et al., 2017, 2015).

In this article, we focus on and quantify the potential effects of crop yield variability on the general developments in wheat markets, and hence do not account for uncertainties surrounding the macroeconomic environment. The methodology for the partial stochastic analysis is extensively explained and tested in Araujo-Enciso et al. (2017) and, therefore, we only briefly outline the main three steps here.

1 Quantification of the past variability around the trend for each yield variable: The yield variation considered in the stochastic analysis is based on the observed historical variability in the period 1996–2017. The uncertainty approximation follows a semi-parametric method with non-parametric marginal (empirical cumulative distribution functions, ECDFs) and hierarchical Archimedean copulas (HAC) The HAC comprises nested bivariate copulas, with the advantage of flexibility in the choice of a marginal distribution. The method is semi-parametric because the marginal distribution is non-parametric, whereas the joint distribution has a functional form (Araujo-Enciso et al., 2017). The method has the advantage that it resembles the past uncertainty (i.e. the past deviation from expected standard yield development) in a more accurate way than previous methodologies (for a methodological discussion see Araujo-Enciso et al., 2017). The yield uncertainty is entered in the model as an exogenous shock that shifts the supply equation. Such a shift impacts the whole system of specifications for demand, trade and stocks, and a new equilibrium with price clearing is found. This method is the standard way of dealing with exogenous shocks in economic models and is described in detail in Artavia et al. (2015). For the approximation, regional blocks are created, representing the Black
Sea region (Russia, Ukraine and Kazakhstan), the EU (EU-15 and EU-N13), North America (Canada, Mexico and the US), South America (Argentina, Brazil, Paraguay and Uruguay), South East Asia (Indonesia, Malaysia, Thailand and Vietnam), Australia, China and India. The crop yield fluctuations are assumed to be correlated within each regional block (due to similar weather patterns), but they are assumed uncorrelated across regional blocks and across years (Burrell and Nii-Naate, 2013).

2 Generation of 1,000 sets of possible values for the stochastic variables: The second step in the stochastic analysis involves generating 1,000 sets of possible values for the stochastic variables, thus reproducing the variability determined in step (1) for each year of the projection period 2018–2027. Yield errors are separately included in the HAC framework to flexibly simulate the correlation of the variables inside countries and regional blocks, respectively. Generating 1,000 sets is considered a sufficient number of simulations to replicate accurately the empirical distributions used in the approach (Araujo-Enciso et al., 2017).

3 Execution of the Aglink-Cosimo model for each of the 1,000 possible alternative sets of values: The third step involves running the Aglink-Cosimo model for each of the 1,000 alternative ‘uncertainty’ scenarios generated in step (2). Out of the 1,000 simulations about 5% did not solve in the study at hand. This can occur because the model is a complex system of equations and policies, and if the shocks in one or several stochastic variables go beyond the constraints in the model and the solver capacities (they have a convergence tolerance) this may lead to infeasibilities (Araujo-Enciso et al., 2017, 2015).

4. Scenario Results and Analysis

The starting point for our scenario analysis is the reference scenario as specified by the OECD-FAO (2018) projection, which assumes normal yield development over the projection period up to 2027. We then first analyse the impact of general wheat yield uncertainty in all regions in the world and specific uncertainty in RUK wheat yields on the world markets. Second, we specifically focus on RUK harvest failures and assess their potential impact on selected domestic and international wheat markets. Our analysis here focuses on analysing the variation of production, consumption, exports, imports, stocks and producer prices. For this, the coefficient of variation (CV) is used, which can be interpreted as the proportional change (see Burrell and Nii-Naate, 2013).

In a first step, the Aglink-Cosimo model is run 1,000 times under three scenarios. The ALL scenario considers yield uncertainty in all regions in the world, the RUK scenario only considers yield uncertainty in the RUK countries, and the NoRUK scenario considers yield uncertainty in all world regions but no yield uncertainty in the RUK countries. Figure 3 shows the coefficient of variation in the year 2027 for the three scenarios.

Scenario results presented in Figure 3 show that the effect of the overall uncertainty on wheat markets is bigger than the effect of uncertainty coming only from the RUK countries. However, RUK wheat yield uncertainty has a major impact on the global wheat markets. This is also underlined by generally larger impacts when only RUK yield uncertainty is taken into account (RUK scenario) compared to the market effects with yield variation in the rest of the world without uncertainty in RUK (NoRUK.
scenarios. Projections for world wheat production deviate by about 2.7% when the uncertainty from yield variation in all regions is considered, by 2.2% if yield uncertainty only in the RUK countries is accounted for, and by 1.7% with yield variation in all countries but RUK. Owing to the variation in yields, world grain exports deviate by 4.7% considering yield variability in all regions and by 4% only accounting for variability in the RUK countries. Producer prices are most affected in the ALL scenario with deviation of 12.7%, but the RUK scenario shows that uncertainty in the RUK region has a substantial impact on the variation of world prices (8.1%), whereas prices only deviate by 4.5% in the NoRUK scenario. We note, especially, that the effects of negative yield shocks in one region can be partially offset by positive yield shocks in other regions, i.e. in the ALL scenario a harvest failure in RUK can be offset by a bumper harvest in North America or elsewhere, although these potentially offsetting effects are assumed to be uncorrelated in this stochastic version of the model.

To assess the impact of RUK harvest failures on the wheat markets, we analyse a subsample (subset) of observations for which the wheat yields are below the deterministic projection values. The range corresponding to the yield values below the deterministic projection ranges from the 0th to the 49th percentile, where observations of wheat yields in all three RUK countries are below the deterministic average yields. For the analysis of RUK harvest failures, therefore, wheat yields in Russia range between 1.55–2.94 t/ha, in Ukraine between 1.39–4.58 t/ha and in Kazakhstan between 0.58–1.35 t/ha (Table 2).

| Region            | Baseline | 0th percentile | 49th percentile |
|-------------------|----------|----------------|-----------------|
| Russian Federation| 2.94     | 1.55           | 2.94            |
| Ukraine           | 4.77     | 1.39           | 4.56            |
| Kazakhstan        | 1.39     | 0.58           | 1.35            |
| World             | 3.72     | 3.54           | 3.72            |

Table 2
Selection criteria for the simulations with below average yields (t/ha in 2027)
Based on the selection criteria (Table 2), Figure 4 depicts the spread of the yield uncertainty accounted for in the model in the projection year 2027. The solid (upper) line is the baseline projection and the dotted (lower) line represents the average of the subset. Accordingly, light grey dots (concentrated in the lower part) belong to the subset and the dark grey dots (concentrated in the upper part) represent the remaining simulations. For the ALL and RUK scenarios the yield uncertainty in RUK countries is the same (left-hand plot), whereas at global level wheat yield uncertainty is bigger when yield variability in all regions of the world is considered (ALL; right-hand plot). In contrast, the NoRUK scenario underlines the importance of RUK yield uncertainties in the global context, as the spread of global yield uncertainty is considerably lower and the average yield of the subset somewhat higher without the RUK countries (NoRUK; right-hand plot).

To test if world yield uncertainty is significantly different among the three scenarios, we compared them with a Kruskal-Wallis test. The test implementation uses all the simulations, those considered as harvest failures in the subsets and the remaining ones. The results suggest no significant difference, and the conclusion is that yield uncertainty in the three scenarios belongs to the same distribution. To confirm this finding we performed pairwise-comparisons, with the Wilcoxon signed-rank test, finding no significant differences in the uncertainty (distribution) between the three pairs. At first glance, this is an indication that yield uncertainty is not significantly different among the three scenarios. This does not, however, imply that the risk of harvest failure is the same. For this, we compare only the simulations considered as harvest failure or contained in the subset among the three scenarios. When accounting only for harvest failure simulations, the Kruskal-Wallis test indicates a significant difference. To identify which pairs are different, we perform the pairwise Wilcoxon test. The results confirm significant difference for the pairs ALL-NoRUK and RUK-NoRUK, whereas the pair ALL-RUK shows no difference. This indicates that the RUK region significantly influences the risk of harvest failures in our simulations. Moreover, that
the NoRUK scenario is significantly different from the ALL and RUK scenarios indicates that its relevance for a harvest failure is lower than the RUK region (Table 3).

Following these tests, and as we are focusing on the effects of RUK yield uncertainty, the next parts of the analysis focus mainly on the subset of the RUK scenario (but also results for the other two scenarios are presented in the next tables for comparison). Table 4 presents the market balances in the baseline projections and the average relative difference of the subset sample compared with the baseline for the RUK and MENA countries and the world market. Simulation results show the substantial impact of lower RUK yields (i.e. harvest failures) on world markets. In the subset reflecting lower yields in RUK, wheat production is on average 9.9% lower in Russia, 12.3% in Ukraine and 15.3% in Kazakhstan compared with the baseline. The total decrease in RUK wheat production amounts on average to \(-14.6\) million tonnes and with some non-EU countries showing an increase in production (+0.8 million tonnes) – total world production decreases by about 1.7%. The actual impact on world markets is substantial, as the harvest failures lead to considerably lower RUK exports, with wheat net exports in Russia being 15.4%, Ukraine 18.3%, and Kazakhstan 25.5% below the projected net exports in the baseline. The RUK scenario shows a higher impact on total world exports (–3.3%) than the ALL (–2.9%) and NoRUK (–1.9%) scenarios.

On the one hand, this underlines the importance of RUK exports for the global wheat markets, but on the other hand, this also shows the possible offsetting effects through yield variability in other world regions in the ALL and NoRUK scenarios.

Following the decrease in RUK wheat exports, net imports in the MENA region decrease the most in Iran (–21%), i.e. the country with the lowest dependency on imports and the highest SSR of the region (Table 4). Similarly, in Morocco, with a SSR above the regional average, imports decrease by about 6.5%. In contrast, the two largest importers, Egypt and Algeria, reduce imports only by about 2.2% and 2.4%, respectively, which reflects their high dependency on the world markets. The decrease in wheat imports is the lowest in the Gulf Region and Lebanon, both countries have a per capita GDP above the regional average which allows continuous imports despite increasing prices. In the other MENA regions, net imports decrease between 1.5–3.5%. To some extent decreases in imports are compensated by releasing stocks of about 3% in all countries.3 As supply in the region mostly responds to

Table 3
Kruskal-Wallis and Wilcoxon test results

| Sample           | Test       | Combination     | P-value |
|------------------|------------|-----------------|---------|
| All simulations  | Kruskal-Wallis | ALL-RUK-NoRUK  | 0.66    |
|                  | Wilcoxon   | ALL-RUK         | 0.57    |
|                  |            | ALL-NoRUK       | 0.42    |
|                  |            | RUK-NoRUK       | 0.56    |
| Harvest failure  | Kruskal-Wallis | ALL-RUK-NoRUK  | 0.00    |
|                  | Wilcoxon   | ALL-RUK         | 0.16    |
|                  |            | ALL-NoRUK       | 0.00    |
|                  |            | RUK-NoRUK       | 0.00    |

3Stock accumulation/release is a function of the lagged stocks, lagged and contemporaneous prices and contemporaneous demand.
Table 4

Wheat baseline projections for 2027 and subset average relative change in the scenarios compared with the baseline in the RUK countries, MENA region and world

| Group  | Region            | Supply |          |          | Demand |          |          | Net Trade |          |          | Stocks |          |          |
|--------|-------------------|--------|----------|----------|--------|----------|----------|-----------|----------|----------|--------|----------|----------|
|        | BAS mio t         | ALL % | RUK %    | NoRUK %  | BAS mio t | ALL % | RUK % | NoRUK %   | BAS mio t | ALL % | RUK % | NoRUK %   | BAS mio t | ALL % | RUK % | NoRUK % |
| RUK    | Russian Federation| 83.9  | −9.8     | −9.9     | 0.1    | 44.1    | −2.2   | −2.2     | −0.3     | 39.8    | −15.2 | −15.4    | 1.0     | 9.3   | −11.0 | −11.5 | −2.8 |
|        | Ukraine           | 30.6  | −12.4    | −12.3    | −0.2   | 11.3    | −1.1   | −1.1     | −0.4     | 19.4    | −18.4 | −18.3    | 0.2     | 1.4   | −5.8  | −5.8  | −2.5 |
|        | Kazakhstan        | 16.5  | −15.4    | −15.3    | 0.2    | 8.0     | −1.4   | −1.4     | −0.3     | 8.4     | −25.7 | −25.5    | 1.8     | 3.6   | −6.5  | −6.5  | −2.3 |
| World  |                   | 832.5 | −1.6     | −1.7     | −1.1   | 823.7   | −0.7   | −0.8     | −0.2     | 198.6   | −2.9  | −3.3     | −1.9    | 279.7 | −2.0  | −2.4  | −1.6 |
| MENA   | Egypt             | 10.1  | 0.3      | 0.2      | 0.2    | 25.2    | −0.5   | −0.5     | −0.3     | −15.2   | −2.3  | −2.2     | −1.6    | 5.0   | −3.3  | −3.3  | −2.3 |
|        | Algeria           | 2.9   | 0.8      | 0.6      | 0.5    | 12.4    | −0.5   | −0.4     | −0.2     | −9.6    | −2.5  | −2.4     | −1.9    | 4.4   | −3.2  | −3.2  | −2.2 |
|        | Morocco           | 7.6   | 0.5      | 0.4      | 0.4    | 12.1    | −0.6   | −0.6     | −0.3     | −4.6    | −6.9  | −6.5     | −5.2    | 6.1   | −3.1  | −3.1  | −2.1 |
|        | Tunisia           | 1.4   | 0.4      | 0.3      | 0.3    | 3.3     | −0.6   | −0.5     | −0.3     | −1.9    | −1.7  | −1.5     | −1.2    | 0.2   | −3.4  | −3.4  | −2.4 |
|        | Libya             | 0.2   | 1.2      | 0.7      | 0.9    | 1.9     | −0.7   | −0.6     | −0.3     | −1.8    | −1.9  | −1.8     | −1.3    | 0.5   | −3.5  | −3.5  | −2.3 |
|        | Other North Africa | 0.6   | 1.2      | 0.7      | 0.8    | 4.6     | −0.4   | −0.4     | −0.2     | −4.1    | −2.6  | −2.5     | −2.0    | 2.4   | −3.2  | −3.2  | −2.2 |
|        | Saudi Arabia      | 0.0   | 1.1      | 0.8      | 0.7    | 4.5     | −0.2   | −0.2     | −0.1     | −4.5    | −2.5  | −2.5     | −2.1    | 3.2   | −3.0  | −3.0  | −2.0 |
|        | Gulf Region       | 0.0   | 1.2      | 0.9      | 0.7    | 3.0     | −0.2   | −0.2     | −0.1     | −3.1    | −1.1  | −1.1     | −0.9    | 0.8   | −3.1  | −3.1  | −2.2 |
|        | Yemen             | 0.3   | 0.1      | 0.7      | −0.4   | 4.3     | −0.7   | −0.6     | −0.4     | −4.1    | −3.6  | −3.5     | −2.9    | 3.2   | −3.4  | −3.3  | −2.3 |
|        | Jordan            | 0.0   | 0.7      | 0.5      | 0.4    | 1.2     | −0.5   | −0.4     | −0.2     | −1.2    | −3.6  | −3.5     | −2.8    | 1.0   | −3.2  | −3.2  | −2.1 |
|        | Lebanon           | 0.2   | 0.7      | 0.5      | 0.4    | 0.9     | −0.5   | −0.5     | −0.3     | −0.8    | −1.4  | −1.3     | −1.0    | 0.1   | −3.4  | −3.3  | −2.3 |
|        | Mashrek           | 6.1   | 0.6      | 0.4      | 0.3    | 12.4    | −0.2   | −0.2     | −0.1     | −6.4    | −2.0  | −1.9     | −1.4    | 2.1   | −3.0  | −3.0  | −2.1 |
| Iran   | 15.7             | 0.3   | 0.3      | 0.1      | 0.1    | 16.2    | −0.2   | −0.2     | −0.1     | −0.5    | −20.2 | −21.0    | −13.7   | 1.1   | −2.2  | −2.4  | −1.7 |

Notes: BAS = Baseline; Net trade = exports – imports.
*Includes Sudan and Mauritania.
†Includes Bahrain, United Arab Emirates, Kuwait, Oman and Qatar.
‡Includes Syria, Palestine and Iraq.
incentive prices and general technology improvements, and as possibilities to increase production within the season are limited, a harvest failure in RUK has a rather negligible impact on supply. Similarly, demand is rather inelastic, in part because wheat is a major component of the diet in the MENA region and can hardly be substituted by other food, including other types of cereals or staples such as pulses or roots and tubers. The decreases in MENA net imports are almost the same in the RUK and ALL scenarios, whereas they are less pronounced in the NoRUK scenario, which underlines the importance of RUK as a wheat provider for MENA.

Table 5 summarises the impact of the harvest failures on average producer prices and the variation or uncertainty at the end of the period (CV2027). Specifically, the RUK countries have the largest variation, with average price increases over and above the deterministic baseline projections ranging from 9.1% in Russia to 12.5% in Kazakhstan, whereas world prices increase by an average of 7%, which is closely in line with the changes in Russia, the largest world wheat exporter in 2027. The world price uncertainty is almost entirely passed through to the MENA region, and therefore producer prices adjust at very similar levels to the world markets, ranging between 6% and 6.9%, except for Iran (least dependent on the world market) where the price increases only by 5%. The world price variation is also passed through to the MENA region, with the countries showing a price variation (CV2027) between 5.9% (Morocco) and 6.5% (Gulf Region), whereas global price variation is 6.6%. These results partially reflect the world price, which is used as the benchmark to determine support prices in most MENA countries. While the ALL scenario has the highest impact on prices, the RUK scenario follows in terms of magnitude, and the NoRUK scenario impacts are lowest. Note that in the NoRUK scenario, prices in the RUK region also increase as a consequence of the yield shocks in the other regions. Moreover, in the NoRUK scenario the changes in the RUK and MENA regions are mostly in line, indicating that both markets are better integrated without uncertainty in RUK.

Figure 5 shows the spread of the simulated prices when accounting for yield uncertainty. The solid (lower) lines represent the baseline prices and the dotted (upper) lines represent the average producer prices in the subset. The light grey dots are the prices belonging to the subset and the dark grey dots represent the prices in the remaining simulations, with the solid and dotted bars showing the baseline and mean stochastic price in each case. The box on the left shows prices for the RUK regions. For all regions the price simulations of the subset are concentrated in the upper part, reflecting how a harvest failure in the RUK countries is likely to cause an increase in prices. Light grey points below the baseline level indicate cases where the harvest failure in RUK is offset by positive harvest shocks (bumper crops) in other regions. These cases are very few (as expected, since these are assumed to be uncorrelated), i.e. assuming that the possibility of compensating the deficit in the RUK wheat supply with a surplus from elsewhere is low and merely random. Russia plays a crucial role in ameliorating the impact of a harvest failure, as prices are below the world levels and also price variation is lower. Ukraine and Kazakhstan have a larger degree of variation, but as their export quantities are lower, they also have less impact on the world market. The MENA region shows a quite homogeneous pattern, reflecting a high degree of integration with the world markets, mainly driven by large imports (with the exception of Iran, as noted above).

Table 6 shows the average increase in the wheat production and trade values that the countries in the MENA region would face in our harvest failure scenarios. The results of the RUK scenario show a total increase in MENA’s production and import
Table 5
Wheat baseline and scenario prices, price changes and price variability in 2027

| Group       | Region                  | Baseline Price (USD/t) | Avg Scenario Price (USD/t) | Price Change (%) | CV 2027 (%) | Avg Scenario Price (USD/t) | Price Change (%) | CV 2027 (%) | Avg Scenario Price (USD/t) | Price Change (%) | CV 2027 (%) |
|-------------|-------------------------|------------------------|----------------------------|------------------|-------------|-----------------------------|------------------|-------------|-----------------------------|------------------|-------------|
| RUK         | Russian Federation      | 163.1                  | 180.7                      | 10.8             | 12.9        | 177.9                       | 9.1              | 8.2         | 172.1                       | 5.5              | 7.6         |
|             | Ukraine                 | 200.5                  | 225.6                      | 12.5             | 14.2        | 222.1                       | 10.8             | 9.7         | 211.6                       | 5.6              | 7.7         |
|             | Kazakhstan              | 200.5                  | 229.0                      | 14.3             | 14.3        | 225.4                       | 12.5             | 10.2        | 211.2                       | 5.3              | 7.6         |
| World       | World                   | 229.0                  | 249.0                      | 8.7              | 12.0        | 245.2                       | 7.0              | 6.6         | 241.9                       | 5.6              | 7.7         |
| MENA        | Egypt                   | 257.7                  | 279.2                      | 8.3              | 11.7        | 275.0                       | 6.7              | 6.3         | 271.5                       | 5.4              | 7.6         |
|             | Algeria                 | 257.7                  | 279.1                      | 8.3              | 11.7        | 274.9                       | 6.7              | 6.3         | 271.4                       | 5.3              | 7.6         |
|             | Morocco                 | 257.7                  | 276.9                      | 7.4              | 11.0        | 273.1                       | 6.0              | 5.9         | 270.0                       | 4.8              | 7.3         |
|             | Tunisia                 | 257.7                  | 279.5                      | 8.4              | 11.7        | 275.3                       | 6.8              | 6.4         | 271.7                       | 5.4              | 7.6         |
|             | Libya                   | 257.7                  | 279.4                      | 8.4              | 11.7        | 275.2                       | 6.8              | 6.4         | 271.7                       | 5.4              | 7.6         |
|             | Other North Africa*     | 257.7                  | 279.0                      | 8.3              | 11.6        | 274.9                       | 6.6              | 6.3         | 271.3                       | 5.3              | 7.6         |
|             | Saudi Arabia            | 257.7                  | 279.0                      | 8.3              | 11.7        | 274.8                       | 6.6              | 6.3         | 271.3                       | 5.3              | 7.6         |
|             | Gulf Region†            | 257.7                  | 279.9                      | 8.6              | 11.9        | 275.6                       | 6.9              | 6.5         | 271.9                       | 5.5              | 7.7         |
|             | Yemen                   | 257.7                  | 278.5                      | 8.1              | 11.4        | 274.4                       | 6.5              | 6.2         | 271.0                       | 5.1              | 7.5         |
|             | Jordan                  | 257.7                  | 278.5                      | 8.1              | 11.5        | 274.4                       | 6.5              | 6.2         | 271.0                       | 5.1              | 7.5         |
|             | Lebanon                 | 257.7                  | 279.6                      | 8.5              | 11.8        | 275.4                       | 6.8              | 6.4         | 271.8                       | 5.4              | 7.6         |
|             | Mashrek‡                | 257.7                  | 279.3                      | 8.4              | 11.8        | 275.1                       | 6.7              | 6.4         | 271.6                       | 5.4              | 7.7         |
|             | Iran                    | 229.1                  | 242.4                      | 5.8              | 11.3        | 240.5                       | 5.0              | 6.2         | 238.3                       | 4.0              | 7.7         |

Notes: Avg = average; CV2027 = coefficient of variation in 2027.  
*Includes Sudan and Mauritania.  
†Includes Bahrain, United Arab Emirates, Kuwait, Oman and Qatar.  
‡Includes Syria, Palestine and Iraq.
values of 6.3%, and 4%, respectively. In absolute terms the region’s production value increases by over 0.7 billion USD, with Iran (187 million USD) and Egypt (180 million USD) being the two countries contributing more than half of the MENA increase as they also have the highest production levels in the baseline. Total MENA net imports value increases by 525 million USD. As can be expected, the absolute increase is highest for the biggest net importers Egypt (161 million USD) and Algeria (97 million USD). The increase in net import values in the scenario considering yield variation in ALL world regions is highest, but this scenario also shows how influential the RUK exports are for the MENA region, as the MENA net imports value increases by 5.2% (682 million USD), i.e. only about one percentage point more than in the RUK scenario.

Even though the MENA production and net import values increase, this is not necessarily a signal that prices will increase evenly across the supply chain. The wheat supply chain is highly regulated in the MENA region (Ninn-Pratt et al., 2018) and, depending on the policies or action of the different stakeholders, the allocation of the price increases between producers, consumers, traders and government is likely to vary. The Aglink-Cosimo model works with average national figures and, therefore, it is not possible to provide any projections of the absorption distribution of the price increases. Moreover, in situations when wheat prices were high in the past, MENA governments often implemented ‘ad hoc’ interventions, which makes it even more difficult to identify who will be most affected in the simulated scenario.

5. Discussion of Results and Policy Implications

Our scenario results highlight the substantial impact of RUK wheat yield variability and harvest failures on global and MENA markets. Regarding price fluctuations, our results are in line with Kornher and Kalkuhl (2013), who show that international price
| Region                  | Production Value | Net Imports Value | Total Supply Value |
|-------------------------|------------------|-------------------|--------------------|
|                         | Baseline (mio $) | ALL RUK Change %  | ALL RUK Change %   |
|                         |                  |                   |                   |
| **Egypt**               | 2,601            | 8.5               | 6.9               | 5.5               | 3,472 | 5.9 | 4.6 | 3.9 | 6,073 | 7.0 | 5.6 | 4.6 |
| **Algeria**             | 748              | 9.1               | 7.3               | 5.9               | 2,196 | 5.7 | 4.4 | 3.6 | 2,940 | 6.6 | 5.1 | 4.1 |
| **Morocco**             | 1,959            | 7.9               | 6.4               | 5.2               | 1,050 | 0.3 | −0.2 | −0.1 | 3,009 | 5.3 | 4.1 | 3.3 |
| **Tunisia**             | 358              | 8.8               | 7.2               | 5.7               | 440   | 6.5 | 5.3 | 4.3 | 798   | 7.6 | 6.2 | 4.9 |
| **Libya**               | 46               | 9.7               | 7.5               | 6.3               | 404   | 6.4 | 5.1 | 4.2 | 450   | 6.7 | 5.3 | 4.4 |
| **Other North Africa‡** | 163              | 9.5               | 7.4               | 6.1               | 932   | 5.5 | 4.3 | 3.4 | 1,095 | 6.1 | 4.7 | 3.8 |
| **Saudi Arabia**        | 1                | 9.4               | 7.5               | 6.0               | 1,028 | 5.6 | 4.3 | 3.4 | 1,028 | 5.6 | 4.3 | 3.4 |
| **Gulf Region†**        | 1                | 9.8               | 7.9               | 6.3               | 699   | 7.3 | 5.8 | 4.6 | 699   | 7.3 | 5.8 | 4.6 |
| **Yemen**               | 65               | 8.1               | 7.3               | 4.7               | 945   | 4.3 | 3.2 | 2.5 | 1,010 | 4.5 | 3.4 | 2.6 |
| **Jordan**              | 8                | 8.7               | 7.0               | 5.6               | 267   | 4.3 | 3.1 | 2.5 | 274   | 4.4 | 3.2 | 2.6 |
| **Lebanon**             | 41               | 9.1               | 7.4               | 5.8               | 175   | 6.9 | 5.6 | 4.5 | 216   | 7.3 | 5.9 | 4.7 |
| **Mashekr‡**            | 1,561            | 8.9               | 7.2               | 5.7               | 1,456 | 6.3 | 5.0 | 4.1 | 3,017 | 7.6 | 6.1 | 4.9 |
| **Iran**                | 3,599            | 5.8               | 5.2               | 4.1               | 117   | −17.0 | −16.7 | −10.1 | 3,717 | 5.5 | 4.6 | 3.7 |
| **MENA**                | 11,150           | 7.7               | 6.3               | 5.1               | 13,181 | 5.2 | 4.0 | 3.3 | 24,328 | 6.4 | 5.1 | 4.1 |

**Notes:**

*Includes Sudan and Mauritania.
†Includes Bahrain, United Arab Emirates, Kuwait, Oman and Qatar.
‡Includes Syria, Palestine and Iraq.
volatility significantly impacts domestic price volatility. Our findings are also supported by other studies that found cointegration among the world, Black Sea and MENA region wheat markets (Goychuk and Meyers, 2014; Ianchovichina et al., 2014; Kalkuhl, 2016; Unal et al., 2018). However, although MENA production and net import values increase in our scenarios, this is not necessarily a signal that prices will increase evenly across the supply chain. As the wheat supply chain is greatly regulated in the MENA region (see e.g. Ninn-Pratt et al., 2018), the allocation of the price increases between producers, consumers, traders and government can vary. As pointed out by FAO et al. (2011), the short-term shocks of substantial price fluctuations, even if they are tolerable on average, make both smallholder farmers and poor consumers more vulnerable to long-term poverty traps. In this context it has to be stressed that the Aglink-Cosimo model uses yearly price averages, and therefore monthly and weekly price fluctuations and spikes can be hidden in the yearly average. It is likely that the short-term price effects of RUK wheat production variability are greater than the annual averages depicted in our analysis. Accordingly, in the event of RUK harvest failures, the monthly and weekly price spikes may be significantly greater than the ones identified here, which increases the pressure on global and MENA food security.

As discussed in the introduction, the historical high yield variability in the RUK region is mainly attributable to the combination of extreme weather events and low resilience to it. Other studies show that global wheat markets could considerably benefit in terms of lower variability in RUK’s grain production if RUK governments create a reliable policy environment and provide access to a well-functioning agricultural credit and finance infrastructure (see Fellmann and Nekhay, 2012; Fellmann et al., 2014; Schroeder and Meyers, 2017; Sedik, 2017). Further improvements in agricultural management practices (such as fertiliser application and the use of high-yield seed varieties) would likely benefit a reduction of RUK yield variability and gaps. Moreover, this could help to realise additional RUK crop production potentials (Schierhorn et al., 2014; Ryabchenko and Nonhebel, 2016; Saraykin et al., 2017; Swinnen et al., 2017), which implies that RUK countries could well outperform the production and export projections of the OECD-FAO (2018) by 2027. This, in turn, could lead to decreases in average global crop prices (Deppermann et al., 2018) and hence further benefit food security in net importing countries. In this respect, the Russian and Kazakh governments recently initiated several reforms to direct agricultural policy support towards the stimulation of farm investment and technical modernisation of agriculture, in the case of Russia including subsidised short-term and investment loans (OECD, 2018). Conversely, agricultural sector support and access to finance in the Ukraine continues to struggle with deteriorating capital stocks, likely caused by economic and political uncertainties (Keyzer, 2017; OECD, 2018).

Our projections show a further increase of the MENA region’s dependency on RUK wheat imports by 2027. The reliance on imports also further exposes the countries to the uncertainties related to the RUK exports. As our results show, RUK harvest failures in particular can have substantial impacts on wheat prices and hence the import bill in most MENA countries. Wheat markets and supply chains in the MENA region are generally characterised by interventions of the governments aiming at keeping prices steady and under control. Our results underline, however, that controlling prices will continue to be challenging because of the high integration with fluctuating world prices. Trade is controlled by most MENA countries, with imports regulated by quotas and licences, and state trade companies concentrating a large share of the
trade, usually selling at subsidised prices (Ninn-Pratt et al., 2018). Following our findings, increasing world prices could augment the losses that the state trading companies must absorb (see e.g. Laajimi et al., 2016). MENA wheat production is also generally influenced by supporting farmers with minimum reference prices, often linked to the world price. Accordingly, upward pressure on world prices could potentially increase support prices, which would have a negative impact on the national budget. Finally, processors like wheat mills and bakeries are also often supported and subsidised, with the government either selling wheat and wheat flour at preferential prices or reimbursing processors to compensate for losses (WFP-ODI, 2015; FAO-ESCWA, 2017), i.e. the related costs for the governments would also be augmented in the case of increasing prices. Conversely, despite the domestic price increases, MENA countries’ domestic supply remains almost unchanged in our scenarios, because (i) natural production constraints limit the production potential in the region, and (ii) the price is only one element affecting the planting decision, and other elements like subsidies and costs remain fixed in our simulation scenarios.

Thus, according to our results, budgetary costs for MENA governments could substantially increase due to yield volatility and harvest failures in RUK. Correspondingly, the results strengthen the calls for further policy reforms in the MENA region. The Egyptian government, for example, following budgetary pressures and longstanding criticism, introduced transformational reforms to the subsidy system since 2014, with wheat subsidies being reduced and subsidised bread better targeted towards the poor population via a Smart Card system (McGill et al., 2015; Abdalla and Al-Shawarby, 2018; Wally and Beillard, 2018). Similarly, Jordan replaced its bread subsidy programme with targeted assistance, setting price caps for bread but no longer directly subsidises bakeries (Khraishy and Beillard, 2018). Like Egypt and Jordan other MENA countries are also successively reforming their subsidy systems related to agriculture and food (Sdralovich et al., 2014; FAO-ESCWA, 2017). While these reforms should ease the budgetary burden for the government if wheat prices increase due to harvest failures in net exporting countries, the subsidy systems still face substantial challenges, including continued distortions in the market (FAO-ESCWA, 2017).

Our scenario results suggest that diversifying the countries of origin of imported wheat could help MENA countries to better balance shortages arising from RUK harvest failures. Furthermore, the results also support findings of other studies that highlight the importance of wheat stocks and other risk management options to smooth the impact of international price spikes on food-deficit countries (Sadler and Magnan, 2011). Several MENA countries already hold strategic stocks, like for example Egypt, Jordan, Saudi Arabia and the United Arab Emirates. However, such a food stock policy is rather costly and hence might not be feasible for all MENA countries. A coordinated regional cooperation for strategic stock reserves could help to reduce the investment costs and provide greater price stability (FAO-ESCWA, 2017). For example, Wright and Cafiero (2011) and Larson et al. (2013) find that the MENA region is sufficiently large to hold strategic reserves that could help to counteract an increase in world market prices. In our scenarios, stocks react with similar magnitudes driven by the prices, but in reality, new policies could accelerate such releases, resulting in a different impact on the domestic markets. In this regard, timely and accurate information on current and forecasted global food production (Fritz et al., 2019) could help MENA countries to find alternative providers and better prepare for disruptions in food supply and global crop market price fluctuations.
6. Conclusions and Final Remarks

Taking into account yield variation based on the observed historical variability in the period 1996–2017, our simulation results with the stochastic version of the Aglink-Cosimo model demonstrate that international wheat markets could also be considerably affected by yield uncertainty from RUK countries, world wheat production and exports could deviate from the standard deterministic projections by 2.2% and 4%, respectively, resulting in a deviation of about 8% in world prices. The substantial impact of lower RUK yields (i.e. harvest failures) on world markets is revealed when analysing a sub-sample (subset) of observations for which wheat yields are below the deterministic projection values. In the subset reflecting lower wheat yields in RUK, wheat production is, on average, 10% lower in Russia, 12% lower in Ukraine and 15% lower in Kazakhstan compared with the baseline. These harvest failures lead to substantially lower RUK wheat net exports (–15.4% in Russia, –18.3% in Ukraine and –25.5% in Kazakhstan) and result in an increase in the wheat world market price of 7% compared with the baseline projections. The world price increase due to harvest failures in RUK is almost completely translated into a respective price increase in the MENA region, which is due to the region’s high import dependency. The increase in wheat prices leads to a reduction in MENA’s total wheat imports. Nevertheless, the total net imports value increases by 4%, i.e. 525 million USD, which is most pronounced (in absolute terms) in the countries with the highest wheat imports in the baseline, namely Egypt and Algeria. The reduction in wheat imports is lowest in the Gulf Region and Lebanon as these countries have a per capita GDP above the regional average, which allows continuous imports despite increasing prices.

Our results highlight the importance of RUK wheat production for the world markets and the substantial impact of yield variability and harvest failures on global and MENA food security with regard to food availability and prices. The results support calls for a more predictable and investment-friendly environment for the agricultural sector in RUK to reduce yield variability. Regarding the MENA region, projections show a further increase of the region’s dependency on RUK imports by 2027 and, hence, also a further exposure to the uncertainties related to the RUK exports. RUK harvest failures in particular could substantially increase the wheat import value in most MENA countries, which potentially increases both the food price pressure for the most vulnerable and the budgetary burden for the governments. The results clearly suggest that MENA countries should seek to diversify the countries of origin of wheat imported, as this would help to better balance shortages arising from harvest failures in specific net exporting countries like RUK. Moreover, our results support calls for a coordinated regional MENA cooperation for strategic stock reserves to counteract shortages and world market price pressures. Conversely, our scenario results indicate that farmers in the MENA region could actually benefit from increasing wheat prices. While this could potentially trigger increases in domestic wheat production, such increases are considered to be limited due to the natural production constraints in the region. In this context it has to be noted that our analysis does not explicitly take climate change effects into account. The MENA region is expected to be exceedingly vulnerable to the impacts of climate change, with warmer temperatures, more climate extremes, and additional stresses on water resources, putting additional challenges on wheat production in the region (World Bank, 2014; WFP-ODI,
2015; Waha et al., 2017). In the climate change context it is also important to point out that the RUK yield uncertainty considered in our analysis is based on past variations in yields. Climate change, however, is associated with more extreme weather events (IPCC, 2012), which can lead to higher yield variations in the future and hence increase the impacts shown in our analysis. This further underlines the need for both stabilising RUK yields and novel complementary food security approaches to decrease MENA’s vulnerability to disruptions in agricultural world markets.

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