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Safeguard global supply chains to protect food security during the COVID-19 pandemic

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Global food security is under severe pressure, from COVID-19 impacts on agricultural supply chains[1] and farm labor availability[2,3] to the locust upsurge threatening local crop production and livelihoods[4]. At the same time, stocks of the main staple foods are currently high, which tend to stabilize food systems. Under these contrasting conditions, we quantify the impacts of various threats to world food supply and prices for three major food crops: wheat, rice and maize. Our analysis suggests that local production declines have only moderate impacts on prices and supply. However, trade restrictions and precautionary purchases by only a few key exporting countries would be sufficient to create global food price spikes, with widespread disruptions in international supply chains. Thus, we believe a two-pronged approach is needed to protect food systems: a proactive strategy to maintain food availability and accessibility in food insecure regions and a concerted effort to enable continued exports from key food producers.

In response to market uncertainties triggered by the COVID-19 pandemic and dryer-than-normal weather conditions threatening crop losses in Europe and South America[5,6], some major food producing countries have restricted exports in the past months[7] to ensure domestic food security, and more are pondering this idea. In addition, the locust infestation endangers food security and livelihoods in the Horn of Africa and parts of the Middle East and South Asia[4]. Keeping the damages at a minimum will require rapid and coordinated responses by national governments and the international community[8]. Any additional stress such as adverse weather events, or a second wave of COVID-19 outbreaks, might result in a compound event requiring immediate responses to protect the food system[9]. The direct impacts COVID-19 related lock-downs may be felt most in regions with high employment in agriculture and labor intensive crops such as rice. For instance, the Ebola outbreak in West Africa in 2014 reduced labor availability for farming and led to a 20% decline in rice production[10].

To help underline the importance of uninterrupted supply chains, we quantify the impact of these various threats to world food supply and prices. For that, we combine an analysis of impaired supply in the world food web with a global model for prices at agricultural commodity markets[11] accounting for trade policies and storage. To quantify the impacts of crop failures, we developed scenarios that impose, for each of crops, i) a 1-in-5-year production decline due to drought and lock-down effects in three major exporting countries and ii) a 1-in-20-year decline in production in the countries currently most affected by the locust infestations and compare them to a baseline scenario accounting for FAO supply and demand forecasts for 2020/21, which do not factor in these production shortfalls. In contrast to the years preceding the two last world food crises in 2007/08[12] and 2010/11, in this year the stock-to-use ratios of wheat and rice are at historically high levels; although the maize stock-to-use ratio has been falling for several years, it is still about twice as high as ten years ago (Supplementary Fig. 5). In consequence, we find that these production failures would cause local food security problems in the affected countries by impairing domestic supply (Fig. 1a). For instance, a 1-in-20-year shortfall means a loss of about 15% of the average maize harvest in Kenya, or of around 7% of the average maize harvest in Pakistan. While Pakistan would be able to buffer production-induced supply losses by tapping into domestic reserves, Kenya would face impaired availability without additional imports or food assistance (for details see Tabs. 6-8 in Supplementary Information (SI)). However, the impacts of these production declines on the stability of the global food web would be only moderate. The world market prices of wheat would be driven up by roughly 10%, of maize by about 7%, and of rice by less than 5% (Fig. 1b). Indeed, due to high stock levels, even massive production shortfalls of the same size as those preceding the recent world food price crises in 2007/08 and 2010/11 are unlikely to create a global shortage, though local food insecurities may arise in some countries with little integration in global markets.

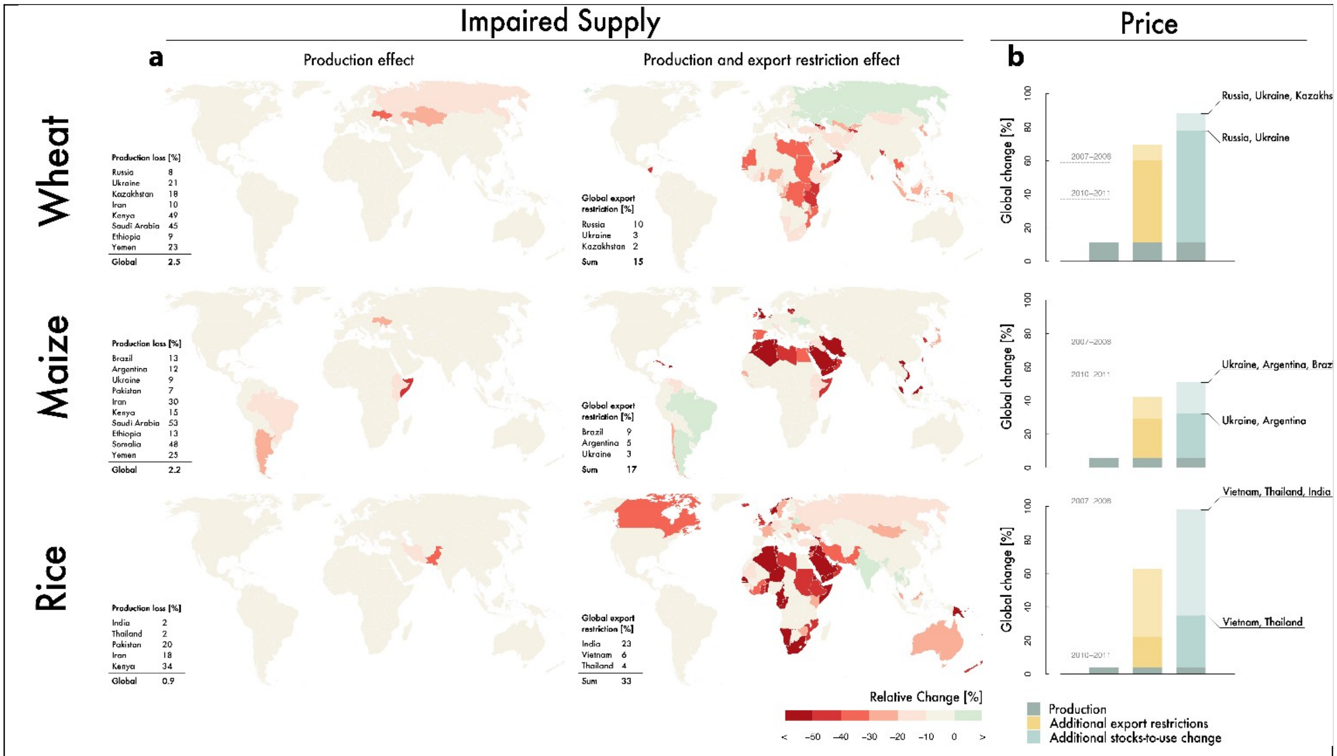

Fig. 1| Food security impacts of production failures and unilateral trade policies. a, domestic supply changes due to potential production declines (left) and due to additional export restrictions (right). Supply changes do not consider changes in trade or use of reserves and therefore represent the "impaired supply" that must be recovered; inset tables detail production and export assumptions. **b**, estimated changes in world market prices arising from production declines (gray bars), additional export restrictions (yellow bars), and additional consumer stock-up attempts (green bars). Dashed lines indicate price levels during the 2007/08 and 2010/11 food price crises. See supplementary information for details on data and methods.

The social distancing measures enacted during the COVID-19 pandemic are leading to labor shortfalls in agriculture and supply chains. Widespread lock-downs across the world have raised concerns about the stability of the global food system due to disruptions in the international as well as regional supply chains[13]. On the demand side, surge purchases have temporarily emptied the shelves of supermarkets around the world[3], and wealthy importing countries have increased their imports of staple crops in an attempt to ensure domestic food security. We explore the impacts of trade restrictions and increased demand through a set of stylized scenarios. We select three major exporting countries for each of the three main staple crops that together account for over 13%, 16%, and over 33% of global production and for over 34%, 59%, and 55% of global exports for wheat, maize, and rice, respectively. Because these crops represent 43% of the calories consumed around the world and provide 37% of the global supply of protein[14], these countries form the backbone of global trade in staple crops, with high importance for food security. Although, the World Trade Organization prohibits export restrictions except to prevent or relieve critical domestic shortages of foodstuffs, major exporters have frequently employed such policies to insulate their domestic markets from world market price volatility and as a precautionary measure to protect domestic food supply when harvest failures loom[15]. While stock levels are much higher today than before the recent food crisis, export restrictions and aggressive stock up attempts still have the potential to send world grain prices soaring[16]. For instance, the International Grains Council's rice commodity price index increased by 15% between January and May 2020 (Supplementary Fig. 9). Assuming that three major exporters of each main staple grain ban exports in the current agricultural year, we estimate that the price for wheat would rise by 70% between the scenario and baseline price in next agricultural year, which is an even larger price hike than during 2007/08 (Fig. 1b). For maize and rice, prices would rise by over 40% and over 60%, respectively. Countries that normally depend on imports from these large exporters would need to find substitutes (Fig. 1a). Many countries in Asia and Africa would be suddenly stripped of more than a third of their annual supply. Most countries that cannot buffer a decline in supply due to production losses and export bans with their national reserves are low-income and lower-middle-income countries in Africa and Asia (77.3%, 87%, and 66.6% for wheat, rice, and maize, respectively (country specific details available in SI, Tabs. 11-13). These countries would need to rely on other exporters or international food aid to ensure domestic food security. Low-income countries with high import dependencies for grain are especially vulnerable to increased trade restrictions, compounding their domestic agricultural production challenges during the COVID-19 pandemic, because they may be outbid by wealthier importers in times of high world market prices. Devaluation of domestic currencies during the COVID-19 crises could aggravate this problem.

During the COVID-19 pandemic a two-pronged approach is required to prevent a major decline in food security: a proactive strategy to maintain food availability and accessibility in food insecure regions and a concerted effort to enable continued exports from key food producers. The first prong is generally known, as international institutions like the World Food Program are focused on raising awareness on the plight of food-insecure countries in Africa and Asia and the risks to international and local food supply chains. Indeed, the estimated peak number of people in need of emergency assistance is up 25% from the pre-COVID-19 level of 113 million people earlier in 2020, and far higher than the last three years, which had 84 million (2017), 80 million (2018) and 86 million people (2019)[17]. Fortunately, stock levels of the major grains are high, and the upcoming harvests are likely to be sufficient to meet this year's world demand, even if substantial production shortfalls arise. Thus, the focus should be on demand side policies such as cash transfers to maintain food accessibility for those whose incomes have been lost due to COVID-19 restrictions, as well as protection of the critical stages of food supply chains.

In contrast, the second prong is less well recognized. Consider Ukraine and Argentine, two middle-income exporting countries that are crucial for the global food system yet have domestic instabilities; Ukraine was the 5th largest wheat exporter and 4th largest maize exporter, while Argentine was the 6th largest wheat exporter and 3rd largest maize exporter in 2018/19. Besides the COVID-19 crisis, these countries are grappling with domestic instabilities, including underlying political, economic, and security pressures, which may threaten their export capacity. For example, Ukraine depends heavily on foreign credit and is struggling with an ongoing low-intensity war in the Eastern part of the country. Likewise, Argentina has experienced severe increases in poverty, currency devaluation, high inflation rates and now bankruptcy. Furthermore, these countries have relatively little reserves compared to their domestic consumption. A back-of-the-envelope calculation suggests that they would not be able to buffer the moderate 1-in-5-year production declines that we computed for our analyses (see SI for details of the calculations). However, the impact of complete export restrictions would not only put the stability of the global food system at risk, but also harm local producers by reducing their sales opportunities at world markets. In contrast, moderate consumer support policy measures, as for instance, a temporary reduction of import tariffs or moderate restrictions in export volumes changing the import-export balance of those countries by only a few percent, would likely be sufficient to ensure domestic food security and help avoid the spread of precarity from these countries to the rest of the world through international commodity markets and trade. Thus, the international community, including international institutions, agri-businesses, and countries, must cooperate to bolster vulnerable countries, importers and exporters alike, to keep trade flowing in order to ensure affordable staple grains for the world's poor and avert a humanitarian crisis.

Methods

We use a year-to-year supply-demand model that includes consumer and producer stocks to estimates the global export price of grains[11]. At the equilibrium price (P), the market clears and the supplied quantity (Q_s) equals the demanded quantity (Q_d),

$$Q_s \propto P^{e_s}, \tag{1}$$

$$Q_d \propto P^{e_d}, \tag{2}$$

where e_s and e_d denote price elasticities of supply and demand, respectively. The supply (producer) and demand (consumer) side of the market functions include carryover grain stock from the previous time step,

$$I_p(t) = I_p(t-1) - Q_x(t) + H(t), \tag{3}$$

$$I_c(t) = I_c(t-1) + Q_x(t) - Q_{out}(t), \tag{4}$$

where I_p and I_c is the producer and consumer storage, respectively, Q_x is the quantity sold/bought, H is the production (harvest) and Q_{out} is the consumption (see Ref. 11 for details.). The model is driven exogenously by annual timeseries of global production and consumption and calibrated individually for wheat, rice and maize using data from the from the PSD database[18] of the United States Department of Agriculture (USDA) for the period 1975-2019. For the baseline scenario, we use the global projections provided in the OECD-FAO Agricultural Outlook 2019-2028 report [19] to estimate the world market (WM) price for the agricultural year 2020/21.

We model three different types of impacts:, i) regional production failures are modelled by reducing the projected world production for 2020/21 but keeping consumption fixed to the projected value, ii) export restrictions are modelled by reducing WM supply and demand by the domestic consumption of the countries issuing the export restrictions for one timestep and transferring the corresponding amount of grain to the producer site storage, and iii) stock-up attempts are modelled by increasing the consumer target storage level. Price changes are given with respect to the WM price of the baseline scenario. Details on how the different scenarios are derived on the basis of USDA data from the last 20 years are provided in the SI.

In addition to the price modelling, we study the supply balances at the country level. For that, we consider the annual balance of wheat, rice and maize commodities (separately) in kilocalories for each country,

$$S = P + I - E, \tag{5}$$

where S, P, I and E denote *domestic supply*, *national production*, *imports* and *exports*. We use country-to-country trade and country level production data from the FAOSTAT database[20] of the Food and Agricultural Organization of the United Nations and reserves data from the USDA[18] averaging over the years 2015-2017 (2017 is the last year for which bilateral trade data are available). We estimate the country level impact of export restrictions by setting the export of the countries issuing the restrictions to zero, further, we model production losses in major producing countries and locus threatened countries. For each scenario, the combined impact of these disturbances is estimated by computing the domestic "impaired" supply as the absolute value of the difference between the supply in the baseline scenario (cf. Eq.(5(5) and in the perturbed scenario. Change in impaired supply is then compared to the size of the domestic reserve in order to determine which of the countries cannot buffer the impaired supply by their reserves.

Data availability

The data that support the findings of this study are all obtained from publicly available databases (see SI for details).

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Author contributions

T.F., C.O., J.S. and M.J.P. conceived the concept and developed the scenarios. T.F. preformed the price simulations and M.J.P. made the country level trade balance calculations. J.J. Produced the figures. T.F., J.S., C.O. and M.J.P. co-wrote the paper. J.J., M.Ko. and M.Ku. contributed to editing the manuscript. T.F., C.O., J.S., M.J.P. J.J., M.Ko. and M.Ku. contributed to data interpretation. T.F. wrote the Supplementary Information. B.W. provided policy advice.