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International trade and the stability of food supplies in the Global South

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Abstract

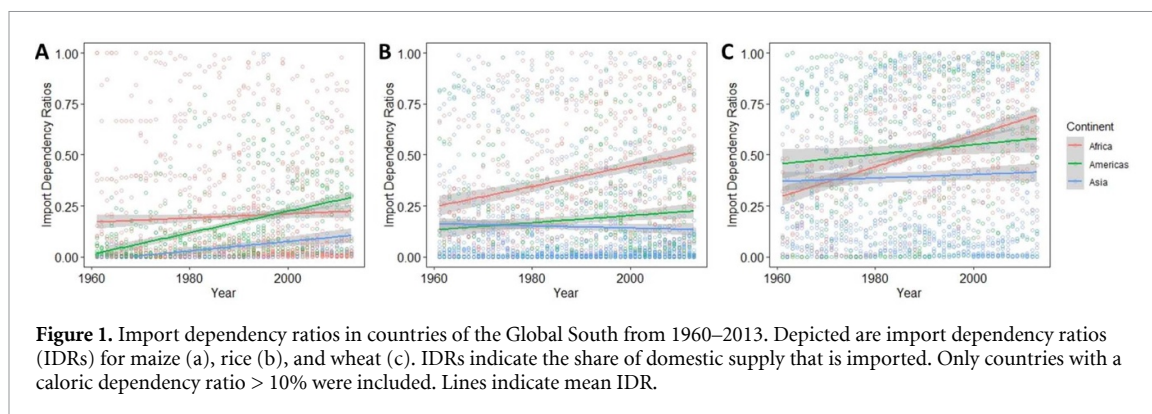
Many countries in the Global South depend increasingly on imports to provide food for their rising populations. Trade is a key mechanism to address distributional issues, especially in countries with limited biophysical resources. In theory, by pooling the risk of crop failures via global trade, trade should stabilize food supplies. In practice, however, an over-reliance on imported food may be detrimental to domestic food stability. Here, we disentangle the role of imports from that of domestic production in countries in the Global South for three staple crops: maize, rice, and wheat. First, we use FAO data to differentiate between exposure to production variance in exporting countries, domestic production variance, and total supply variance. Next, we analyze trade relationships and assess the biophysical capacities of countries to investigate why some countries have more unstable supplies than others. We find that food imports have been a source of food supply instability—in particular for maize in Southern Africa, wheat in Central Asia, and rice more generally. But the reason that imports lead to instability is not the same across regions or crops and imports are at times necessary due to limited available water and land resources. Furthermore, the source of imports may be important in the case of co-occurring crop failures in both importing and exporting countries, or exporters with high export variance. Finally, we find that the increasing prevalence of global trade from 1985–2010 has increased exposure to food supply variance in some regions, although it has not increased exposure to supply variance in all regions. These results provide guidance for future analyses to focus on regions that are vulnerable to imported food supply disruptions of important staple crops, and inform debates about the risks associated with food trade in the Global South.

1. Introduction

In recent decades more people have had access to a sufficient number of calories than ever before. But increasingly countries are dependent on food imports to meet basic caloric demands as opposed to consuming food produced in-country (Porkka *et al* 2013). The trend towards an increased dependence on international trade is expected to continue due to population growth, barring significant changes to diets, cropland expansion, or production intensity (Fader *et al* 2013). While importing food to

meet domestic supply can be a means of improving food availability for food insecure populations, its effectiveness is disputed (Clapp 2015). Provided the increasingly important role food imports play in food supply, the vulnerabilities of import-dependent systems need to be further explored.

At the global scale, food supply stability can be decomposed into the contribution from different regions (Ben-Ari and Makowski 2014), which is informative from the perspective of global food availability. But the way food production shortfalls affect national-scale food availability depends not



only on global markets, but also on the underlying trade networks (Puma *et al* 2015, Tamea *et al* 2016, Gephart *et al* 2016) and domestic production. The question of how food trade has affected country-level food supply stability, therefore, necessitates a country- and crop-specific analysis of the causes of food supply instability. Here we focus on wheat, rice, and maize imports in the Global South. We aim not to analyze food security directly, as food supply shortages may be managed in a number of ways, but rather to better understand what conditions are conducive to frequent supply shortages.

The importance of food imports across the Global South has increased since 1960 (figure 1). Countries in Africa (figures 1(b) and (c), red line), in particular, import a much larger share of their rice and wheat supplies. Importantly, figure 1 only depicts countries whose caloric dependency ratio exceeds 10%, i.e. countries that get at least 10% of the total calorie supply through the specific crop. For wheat, average import dependency ratios (IDR) in Africa almost doubled from 1960 to 2013, from about 0.25 to almost 0.5. These numbers are not problematic per se; however, they indicate an increasing reliance on imported staple crops of countries in the Global South and potentially problematic exposure, for example to teleconnected food supply shocks (Bren d'Amour *et al* 2016).

This increasing reliance on imports further underlines existing concerns regarding the stability of food supplies (Wheeler and von Braun 2013, Renard and Tilman 2019). In theory, by pooling the risk of crop failures via global trade, trade should stabilize food supply. In practice, however, the concentration of production in a limited number of regions and the predominance of bilateral trade agreements may invalidate any notion of pooled risk. In some countries, trade may well increase the variability of food supplies while in others it stabilizes total food supply (Suweis *et al* 2015). Understanding how trade is affecting food supply stability requires understanding the relative contribution of (1) shortfalls in domestic crop production and (2) crop failures in exporting countries to total variability in food supply.

Here, we aim to explore the question of how food trade has affected the stability of food supplies in the

Global South. We address this question in three parts: first, we investigate historical supply variabilities (imported, domestic, total) for three staple crops and identify the degree to which trade has exposed countries to food supply variance. In the second part of this paper, we investigate why some countries have higher or lower variabilities than others. To this end, we analyze the biophysical capacities of countries to potentially increase domestic production. We investigate if countries can alter their current supply strategies, for instance in case of high domestic production variabilities switch to higher imports from exporters with low domestic production variabilities. In the third part of the paper, we analyze how an increasing dependence on food imports has changed the variability in food supply to which countries are exposed. We close with a discussion on the implications of food supply variabilities in increasingly globalized food systems, and detail the solution space for countries with unstable food supplies and their respective limitations.

2. Materials and methods

2.1. Data

For data on caloric consumption, crop production, exports, and imports, we rely on FAO food balance sheets (FAOSTAT 2015). We calculate domestic food supply for each crop as production + imports – exports in each year. Data on biophysical redundancy is taken from Fader *et al* (2016), which estimates the amount of land that is currently unused for agriculture but is suitable for growing crops. We use the most recent available data, which in this case is from 2012. In our exposure to imported variance analyses, we use data from FAOSTAT for country-level crop yields and harvested area (FAOSTAT 2019). Trade matrices for 1985–2010 are derived from bilateral trade matrix estimates of the FAO for wheat, maize, and rice. Included in the analysis are all countries from Africa, Asia, and the Americas (excluding the US and Canada).

2.2. Terminology and definitions used in this study

Here, we use 'stability' to imply the absence of variability. Stability is a key temporal determinant of food security (Gross *et al* 2000), and affects the physical

flow of food, associated with three dimensions: availability, accessibility, and utilization. We furthermore use the import dependency ratio (IDR) to estimate the relative importance of imports. IDR is calculated as the ratio of imports to total domestic supply (sum of production and imports, which also include food aid, net of exports, in tons). The caloric dependency ratio (CDR) is calculated as the ratio of calories derived from a crop to the of total per capita calorie supply. This is the only metric that is based on calories and provides an indication of the relative importance of a crop for the consumption of an average household of a country. We use the CDR to identify countries for which the respective crop is a relevant source of calories (here defined as all countries with a CDR > 10%). Both ratios are dimensionless.

2.3. Approach

We calculate crop yield, import, and export anomalies by removing the long-term trend in each country using a low-frequency Gaussian filter with a kernel standard deviation of three years, which is similar to a nine-year running mean. Absolute anomalies are calculated as deviations from this long-term trend, which represents changes in management and technology.

To calculate exposure to imported variance, we assume that crop production anomalies in an exporting country are distributed amongst importers proportionally to the fraction of exported crop sent to each country. This is equivalent to a fixed percent reduction on exports to all importing nations. We use the time-averaged trade matrix for each time period to determine the import/export relationships. We then use the historical record of crop production anomalies and the fixed trade matrices to calculate imported production anomalies in each year for each country, from which we can calculate imported production variance for each country.

To analyze the effect of evolving trade patterns, we compute the variance of total supply of the key crops analyzed under two theoretical scenarios: one in which exposure to supply variance is calculated assuming international trade relations remain fixed as they were during the 1985 to 1990 period (averaged), and one in which supply variance is calculated assuming international trade as it was from 2005 to 2010. This analysis is designed to isolate the effect of the changing patterns of trade by using the average trade matrix from six-year periods in combination with the observed crop failures over the entire period, thus asking what a response to the same crop failure events would be with different trade networks. Note that we do not include derivative products in this portion of the analysis. The six-year averages are used to limit the influence of one-off trades/outliers to create a robust network representative of that time period.

In our analysis, we use metrics that are based on the standard coefficient of variation (CV), i.e.

standard deviation over the mean: (i) Imported CV, i.e. coefficient of variation based on imported variability, defined as standard deviation of detrended imported anomalies over the expected mean domestic supply quantity; and (ii) Total CV, i.e. coefficient of variation of total supply, defined as standard deviation of total domestic supply over the expected mean domestic supply quantity. These metrics normalize the variation by the mean, the main difference to the standard CV being that the different variations (imported, domestic production, total supply) are all normalized by the same mean, namely the expected mean domestic supply quantity. The resulting metrics are dimensionless and allow to compare across countries.

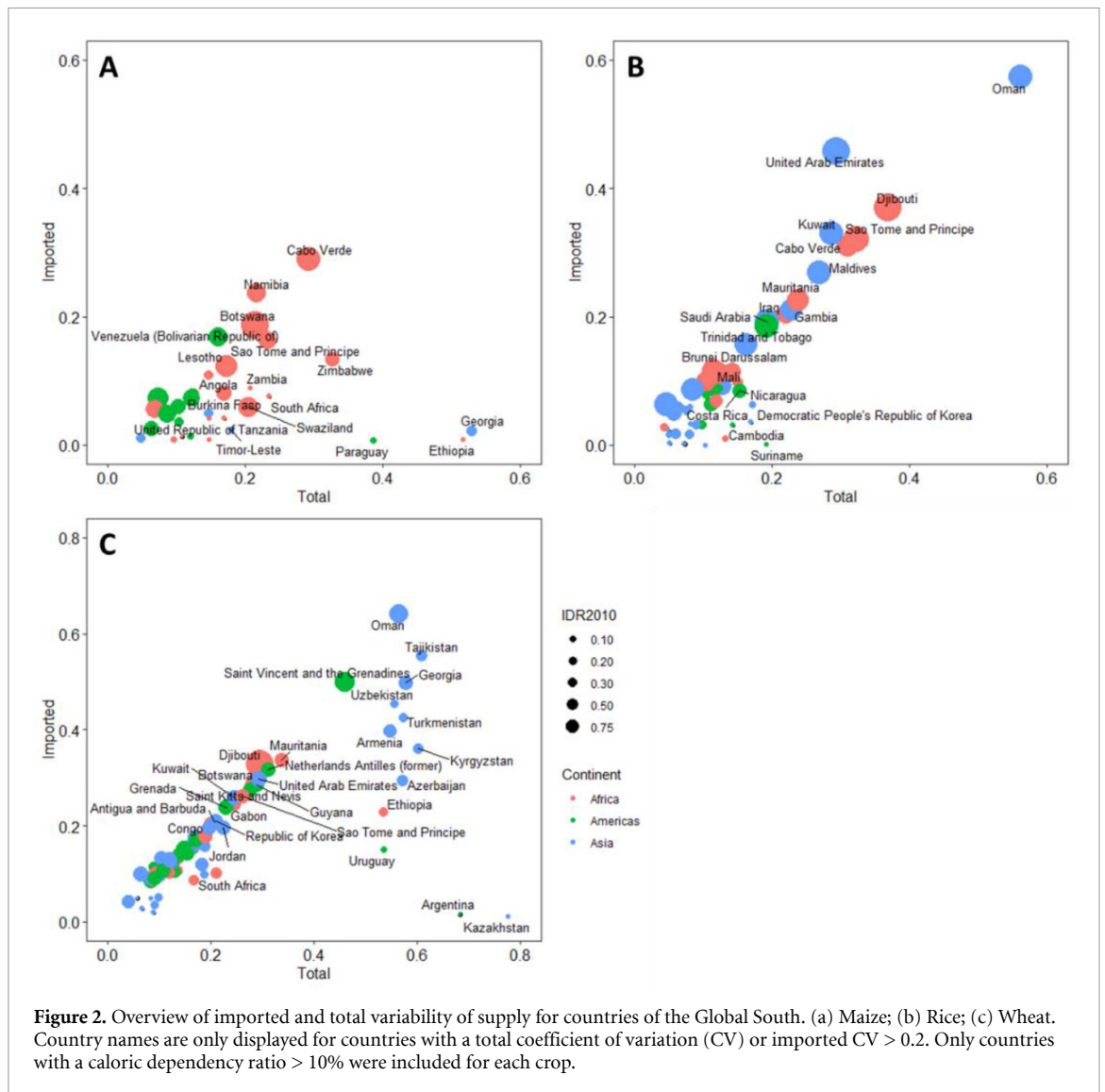
3. Results

3.1. Identifying unstable food supplies

In figure 2, we show how much of the variance in a country's domestic food supply is a result of its variance in imported food for maize, wheat, and rice. We find that for rice, nations that have the highest total supply variability are import dependent nations in which variability of rice imports accounts for nearly all of the variability of total domestic supply, while for wheat and maize countries with high total supply variance tend to only import a fraction of that variance (figure 2). Generally, we observe a geographical clustering of countries with similar profiles, which differ depending on the crop.

For maize, exposure to supply variance comes as a mix of domestic production variance and imported variance. Countries with higher total supply CV (> 0.2) are mostly located in Southern Africa (figure 2(a)). Both reliance entirely on local production and reliance entirely on imports can lead to high domestic food supply CV. We see countries with high total CV along both the 1:1 line (i.e. all variation in domestic supply comes from imports) and along the x -axis (i.e. almost all variation in domestic supply comes from variations in local production, as is the case for Paraguay, Ethiopia, and Georgia).

Zimbabwe is interesting in that it has a high total CV of maize supply, indicating unstable domestic supply of food, and yet it has ostensibly diversified its source of maize by both importing and producing domestically. Upon closer inspection, however, the source of maize is not diverse from an abiotic stress perspective. Zimbabwe sources the vast majority of its maize from South Africa. Synoptic-scale droughts driven by, for example, the El Niño Southern Oscillation are large enough to affect both regions simultaneously, which is why major crop failures occur simultaneously throughout the region (Funk *et al* 2018, Anderson *et al* 2019). An analysis of the crop yield anomalies and food supply anomalies confirms this (see Figure S1 (stacks.iop.org/ERL/15/074005/mmedia)). Diversifying domestic



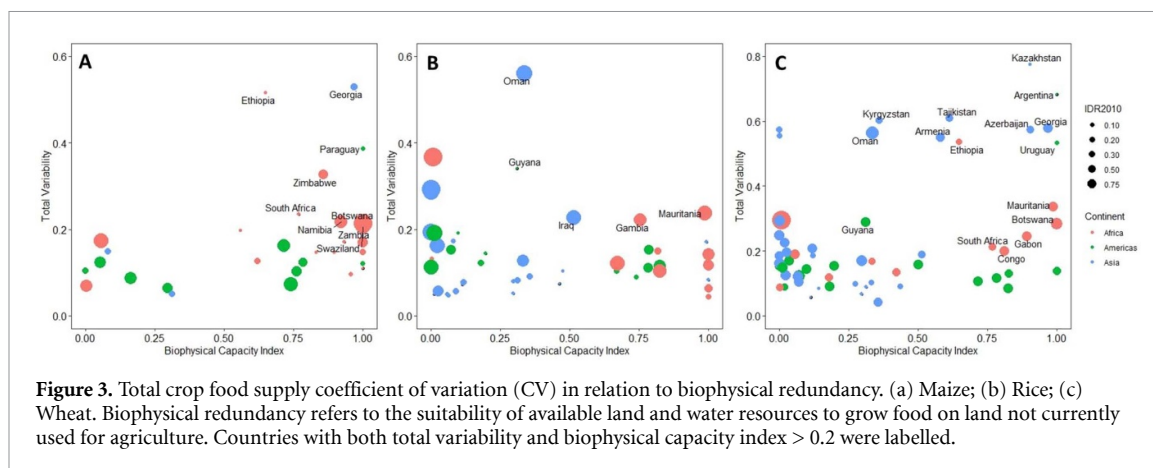
food supply, therefore, requires that a country import from somewhere that does not tend to experience crop failures in the same years.

For rice, countries with higher total supply CV (> 0.2, figure 2(b)) generally import their variability. These countries are either from arid regions in the Middle East and North Africa, such as Oman or Djibouti, or are small island states, such as Cape Verde or Sao Tome and Principe. Importantly, there are no countries with higher total supply CV that comes through domestic production instead of imports. This indicates that rice production in self-sufficient and exporting countries of the Global South has been generally stable over time. Interestingly, supplies have also been comparatively stable (total supply CV < 0.2) in countries in Western Africa, a region that is particularly prone to food supply shocks (Bren d'Amour *et al* 2016), with the exception of Gambia and Mauritania in Northwest Africa.

For wheat, countries in Central Asia tend to have the highest CV due to a mix of imported variance and variance of domestic supply (figure 2(c)). In Central

Asia, both countries that rely exclusively on domestic production and those that import between a fraction or most of their food supply have CVs above 0.5. However, while the total CV is comparable for most of the countries from Central Asia, the CV of imports varies substantially. While this is unique to wheat, there are similarities to e.g. rice for countries with a total supply CV > 0.2 and < 0.5. Countries that fall into this category are generally highly import dependent and import all of their variability. Countries from North Africa are notably absent in the sense that they have total supply CV < 0.2. This is noteworthy since these countries have been identified as very vulnerable to wheat supply shocks (Bren d'Amour *et al* 2016).

The heterogeneity in our results indicate that there is no clear answer to our research question of *what are the consequences of increased trade for the stability of wheat, maize, and rice supply*. In some cases, imports are responsible for high overall variability in supply. In other cases, the answer is less clear. Here, countries might have a high IDR and import most of



their variation. Still, the overall variability in supply might be low. These findings raise the question of what can countries do to stabilize food supplies? For instance, could countries that largely import their variability in supply grow more of their own food or do they import by necessity?

3.2. Grow your own

To explore these questions, we analyze a country's potential for agricultural production, which depends on its biophysical capacities, i.e. the amount of available land, available water and climate of a country relative to what is needed to grow food.

We find that a country's biophysical capacity does not generally explain high import dependency and/or high variability in total supplies (figure 3). In fact, with the possible exception of rice, there is no clear relationship between the biophysical capacity of a country, its reliance on imports, and the variability of total food supply. For instance, we find that countries with high import dependencies (> 0.5, indicated by the bubble size) do not necessarily have low biophysical capacities, as the examples of Botswana and Namibia (figure 3(a)) show. For maize, we further find that very high biophysical capacities do not lead to stable supplies, as exemplified by Georgia and Paraguay.

For rice, the countries with the highest import dependency have close to no biophysical capacities, such as Djibouti, indicating that they are doing so largely out of necessity (figure 3(b)). Further, we find that countries from West Africa that are import dependent ($IDR > 0.5$) have ample biophysical capacities. However, with the exceptions of Mauritania and Gambia, the total supply variability is comparatively low (< 0.2), indicating that the necessity to substitute imports by domestic production is low.

We find that many countries that are importing wheat are not necessarily doing so out of necessity (figure 3(c)). Countries from Asia and Africa that have low biophysical capacities import more than 50% of their supplies, but Botswana, for example, also imports more than 50% of its supplies despite having sufficient biophysical resources. Furthermore,

high biophysical capacity does not lead to more stable total supplies, as the spread of countries with a biophysical capacity index > 0.75 indicate.

In theory, high biophysical capacity should enable countries with high IDR (> 0.5) and higher total supply variability (> 0.2) to import less and increase domestic production for domestic consumption. Countries that fall into the same category but have low biophysical capacity, however, do not have this option. These countries could reduce exposure to supply variance by re-examine trading partners in light of exporting countries production variance.

3.3. Stability of exports

To get an understanding of the stability of exports, we compared the variability of yields and exports of the top ten exporters (table 1). The exports markets of these crops are highly concentrated: the top ten exporting countries combine for 90%, 88%, and 78% of all exports for maize, rice, and wheat respectively. The stability of exports coming from these countries is hence highly important for import dependent countries and we can see a lot by just looking into the top ten.

Our findings show that exports of the top ten exporters have been comparatively unstable over time (table 1). With the exception of North American and some Western European countries, the CV of exports has been high (> 0.2) for most countries for both maize and wheat. We further find that the variation in export quantities cannot always be explained by the variability of yields. Brazil, for example, has exceptionally stable maize yields (with a standard deviation of percent yield anomalies of 7%) yet has amongst the highest variation in exports (CV of export of 0.74). This could indicate that big producers such as Brazil react to market dynamics, for example by substituting the production of maize with soybeans.

Table 1 does, however, demonstrate some remarkable differences between major exporting nations that could affect the stability of food supplies importing from these countries. For wheat, for example, Australia and Central Asian exporters have much higher

Table 1. Variability of crop production and exports in key exporting countries, and their share of total global exports. Average shares of exports are computed using FAO trade data for 2000–2010.

	Country	Average percent of exports	Variation in Exports	Standard dev. of percent yield anomaly
Maize	United States of America	50.28	0.16	8.8
	Argentina	13.05	0.23	11.4
	Brazil	6.60	0.74	7.2
	France	6.24	0.21	10.5
	Hungary	3.29	0.65	15.7
	China, mainland	3.24	0.64	5.3
	Ukraine	2.95	0.54	10.3
	India	2.00	1.44	8.4
	Paraguay	1.41	0.84	9.9
	South Africa	1.27	0.57	23.7
	Share of total maize exports:	90.3		
Rice	Thailand	26.92	0.18	3.8
	Viet Nam	16.99	0.50	4.8
	India	11.44	0.51	5.7
	United States of America	11.44	0.11	3.7
	Pakistan	9.94	0.24	6.7
	China, mainland	2.93	0.38	3.9
	Egypt	2.44	0.37	3.4
	Uruguay	2.37	0.19	9.3
	Italy	2.30	0.18	7.6
	Myanmar	1.63	0.53	4.1
	Share of total rice exports:	88.39		
Wheat	United States of America	18.53	0.15	5.6
	France	11.69	0.15	7.3
	Canada	11.20	0.15	12.8
	Russian Federation	8.02	0.57	10.6
	Australia	7.94	0.21	18.8
	Germany	5.50	0.20	5.9
	Argentina	5.43	0.36	11.5
	Ukraine	3.95	0.66	16.7
	Kazakhstan	3.94	0.59	25.3
	Italy	2.08	0.22	6.7
	Share of total wheat exports:	78.3		

yield variance and variations in exports as compared to exporters in North America and Europe. This may contribute to why countries in Central Asia have such high total supply variance. It would also imply that countries with high total supply variance that import from Australia or Central Asia could diversify their supply by importing from regions with more stable crop yields and exports.

3.4. Exploring the effect of evolving trade networks

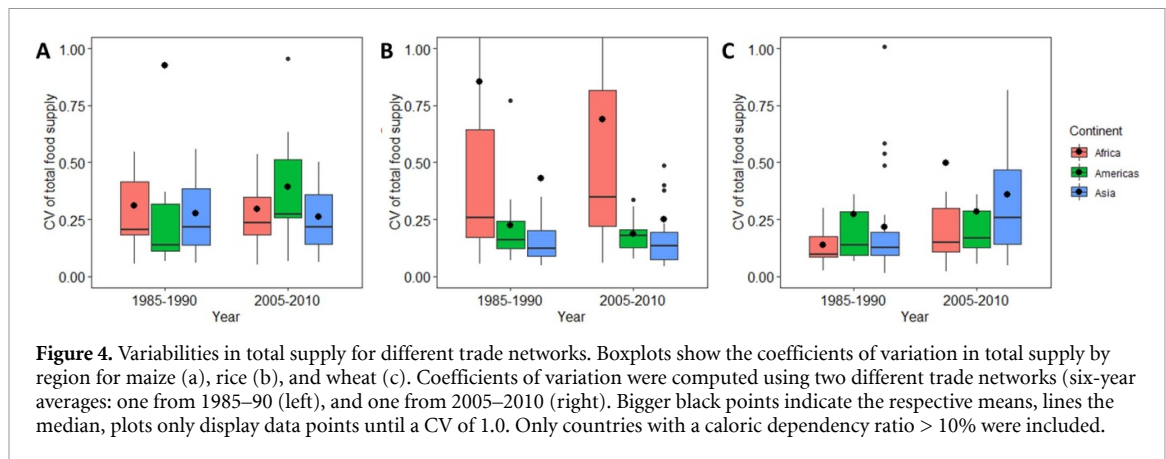
Up to this point we have identified where supplies are unstable, and how both imports and domestic production can lead to supply instability (figure 2). Owing to the contribution of domestic production to food supply instability, it is not immediately clear how an increasing dependence on wheat, maize, and rice imports (figure 1) affects food supply stability.

In figure 4 we model the CV of total supply for two scenarios using different trade networks, each representing a network averaged over a different time period (figure 4). The 1985–1990 period of trade represents a time with more countries producing a greater fraction domestically. The 2005–2010 period represents a more import-dependent world.

Holding all else equal, changes in trade networks have generally increased exposure to domestic food supply variance in the Global South, although the effect has been heterogeneous (figure 4). In some cases, for example maize in Africa and Asia, the median overall food supply variances remain largely unchanged (figure 4(a)). The median total supply variance of maize in the Americas, on the other hand, has increased notably, which indicates that changes in trade patterns have exposed the region to greater food supply variability. The median total supply variation has also increased for rice in Africa and for wheat in Asia. Figure 4 demonstrates that changing patterns of global trade have led to an increased supply variance for some crop/region combinations, even after accounting for changes in the frequency of crop failures over time.

4. Discussion

In this analysis we explored the source of food supply variability for countries in the Global South. We find that the effect of food imports depends on the region



and the crop; highly unstable domestic food supplies may be a result of variable food imports, domestic crop failures, or a mixture of the two. We further find that the trend towards increasing dependence on food imports from 1985–2010 has increased exposure to higher food supply variance in at least one region for all crops, although not in all regions.

The effect of food imports depends on the region and the crop. Countries with unstable rice supplies for domestic consumption tend to import rice, while countries that rely on domestic production have more stable supply. Countries dependent on rice imports, however, are often dependent out of necessity as they lack the resources to produce rice domestically. In contrast to rice, countries with unstable supplies of wheat and maize may have supply variability that originates in either domestic production, imported supply, or both.

The geographic source of imports and crop yield variance in exporting regions may furthermore affect the relationship between domestic food supply instability and food imports. For example, co-occurring crop failures in Zimbabwe and South Africa, from which Zimbabwe imports the majority of its maize, causes supply shortfalls in Zimbabwe (figure S1). But we acknowledge that such a simplistic relationship is not operating globally or even locally in most regions. Overall, food supply variability is an interconnected response of the dynamic global food system to variations in production, management decisions, and trade. These factors, in turn, are affected by numerous drivers, including, amongst others, conflict (Messer and Cohen 2007), restrictive trade policies (Fellmann *et al* 2014), or climate extremes (Devereux 2007).

It is important to note that our primary aim is to identify the source of domestic food supply variability (i.e. whether it is due to local production or imported) and not the drivers (e.g. why is local production more variable), nor any measures implemented to mitigate the effects of supply variability. That is why we exclude analysis of stocks. Stocks may stabilize supplies (Marchand *et al* 2016) and should not be discounted as an important tool to improve food

security, but they are a response to supply variability, not a source, and are comparatively small and variable in the Global South (Laio *et al* 2016). We do, however, control for countries' biophysical resources to understand their hypothetical potential to be more self-sufficient in their supply of the respective crops.

The evolution of the global trade network, and the increasing dependency on imports of countries in the Global South (as demonstrated in figure 4) specifically, have raised concerns about vulnerabilities of the world's poor to disruptions in supplies (Bren d'Amour *et al* 2016, Kummur *et al* 2020). Our analysis, however, illustrates that the narrative that import dependency threatens food supplies is not uniformly true across crops or regions. We find evidence of both the instances in which food imports have contributed significantly to the instability of domestic food supply of staple crops, as well as those where imports account for a major portion of domestic food supply but do not contribute to the instability of that supply. These results provide guidance for future analyses to focus on regions that are vulnerable to imported food supply disruptions of important staple crops and inform debates about the risks associated with food trade in the Global South (Clapp 2015).

4.1. Supply variabilities in globalized food systems

The implications of food supply variability are far-reaching. The absence of stable supplies has important ramifications for food security (Wheeler and von Braun 2013), mostly by threatening food availability. It is important to recognize, however, that food supply variability also affects other dimensions of food security and may be amplified or mitigated by any number market forces. Supply variations, in particular supply shortages, may affect prices (Kornher and Kalkuhl 2013) as well as price volatility (Timmer 2008, Tadasse *et al* 2016), and therefore the accessibility dimension of food security. High prices can further affect production by determining what producers grow (Haile *et al* 2015), and might therefore also contribute to variabilities in supply. Faced with supply shortages, consumers might substitute crops with other crops (Benson *et al*

Table 2. Solution space to stabilize supplies for countries with high total CV. Different options are discussed using case studies. The list is illustrative and not exhaustive, countries' solution spaces are highly context-specific.

Proposed solution to stabilize supplies	Useful for countries with ...	Example	Opportunities for interventions	Limiting factors
(i) Stabilize domestic production	High domestic CV, sufficient biophysical resources	Ethiopia (maize; see figures 2(a) and 3(a))	Deficit or Supplemental Irrigation promises to stabilize yields Introducing improved varieties	Technological, Institutional, Resources (Financial, Irrigation capacities)
(ii) Increase imports	High domestic CV	Ethiopia (maize; see figure 2(a))	Import from stable countries Decrease exports	Institutional Financial (e.g. lack of foreign currency reserves)
(iii) Decrease import dependence by increasing domestic production	High imported CV, sufficient biophysical resources	Cote d'Ivoire/Liberia (both rice; see figures 2(b) and 3(b))	Increase domestic production, including new varieties (NERICA) Expand irrigation and irrigation management for wetland rice cultivation	Political, technological, Institutional Resources (financial, irrigation capacities)
(iv) Revisit import suppliers	High imported CV, insufficient biophysical resources	Djibouti (wheat; see figures 2(c) and 3(c)) Zimbabwe (maize; see figures 2(a) and 3(a))	Import from partners that are not affected by the same synoptic scale droughts Diversify suppliers	Distances Historical trade relation Political (incl. conflict), institutional
(v) Resilience building	All		Regional food distribution networks Grain reserves Waste reduction Gender equity	Technological, Institutional, Resources (Financial, capacities)

2008, Dorosh *et al* 2009). These implications highlight the importance of finding stabilizing measures in an increasingly globalized food system.

4.2. Reducing exposure to domestic food supply shocks

A number of measures can help to reduce variabilities in domestic food supply (table 2). Depending on factors such as biophysical capacities, countries can try to (i) stabilize their domestic production, (ii) increase their imports to decrease their dependence on unstable domestic production, (iii) increase their domestic production to decrease dependencies on imports, (iv) change their import suppliers, or (v) introduce measures to increase the resilience of the food system.

Implementing measures to stabilize domestic production (ad i) is primarily an option for countries with sufficient biophysical resources. These countries, exemplified by Ethiopia, are typically largely self-sufficient in their supply of the respective crop (here maize; see figures 2(a) and 3(a)), and not import dependent in most years. Rather, they depend on their domestic production, which is highly variable. Generally, measures such as deficit or supplemental irrigation promise more stable yields (Oweis *et al* 1998, Zhang and Oweis 1999), as do improved varieties. However, while there is irrigation potential in Ethiopia and SSA in general (Xie *et al* 2018), there are several scale-up constraints,

including inadequate funding, human capacity constraints and limited private sector involvement (Awulachew 2019), and associated sustainability concerns (Rosa *et al* 2018).

Some of these factors can also constrain a country's option to increase imports in order to decrease the dependence on unstable domestic production (ad ii). Generally, the ability of countries like Ethiopia to engage in international trade may be limited by high transaction costs (Smale *et al* 2011), a lack of foreign currency reserves (Van Ittersum *et al* 2016), and poor institutional settings (Hatzenbuehler 2019).

At the same time, there are countries that are highly import dependent and import the variabilities in their supplies despite having sufficient biophysical resources (ad iii). This is true for Cote d'Ivoire and Liberia (see figures 2(b) and 3(b)), both of which import a large share of their rice supplies (Balasubramanian *et al* 2007). Since the vast majority is produced on rainfed drylands in both countries (78% in Cote d'Ivoire and 92% in Liberia, see Balasubramanian *et al* 2007), any effort to increase domestic production would have to also address (i). Potential measures could include improved rice varieties (Lançon and Erenstein 2002), or increasing the amount of irrigated wetland rice production.

High variability, import dependent countries with insufficient biophysical resources, could reconsider their import suppliers (ad iv) provided the

large discrepancy in the stability of exports between even the most major exporters (see table 1). In order for imports to stabilize domestic supply, importing countries need access to stable supply of exports. These countries should therefore seek to import from suppliers with stable domestic production, stable exports, and uncorrelated crop failures.

Additional strategies to stabilize food supplies can be measures that promote food system resilience (ad v), such as the introduction of regionalized food distribution networks, stocks and grain reserves, or waste reduction (Schipanski *et al* 2016, Laio *et al* 2016).

5. Conclusion

Ensuring food supply stability is a key aspect of food security (Wheeler and von Braun 2013). Our analysis demonstrates that food imports have been a major source of domestic food supply instability in the Global South—in particular for maize in Southern Africa, wheat in Central Asia, and rice more generally. But the reason that imports lead to instability is not the same across regions or crops. Furthermore, imports are at times necessary, due to limited water and land resources, and are likely to become more important in the future (Porter *et al* 2014).

We have focused on a historical analysis of wheat, maize and rice in the Global South, and further research is needed to better understand the heterogeneous effects of future increases in food trade on food supply stability. Overall, concerns regarding the stability of food supplies should become a clearer priority as climate change places an increasing stress on food systems (Porter *et al* 2014, Gaupp *et al* 2019). The stabilizing measures and tools are largely known. A successful implementation of these measures in the Global South, however, is constrained by biophysical, institutional, and economic factors. These constraints need to be addressed by sensible policies to guarantee availability of and access to safe and nutritious food to all, at all times.

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Data availability statement

The data that support the findings of this study are openly available. They are provided by the Statistical Division of the Food and Agriculture Organization of the United Nations (FAO) and can be accessed under <http://www.fao.org/faostat/en/#home>.

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