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Yield risks in global maize markets: Historical evidence and projections in key regions of the world☆

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ABSTRACT

Simultaneous worldwide crop failures stemming from a more unstable climate may reduce the scope for international trade to compensate food shortages and stabilize food prices across the various regions of the world. Understanding the effects of changes in crop productivity on global markets requires knowledge about the extent to which crop yields may be systematically related across producing and consuming centers. This short communication contributes to this knowledge by investigating the potential changes in the strength of two key sources of supply risks in global maize markets: yield variance and cross-country yield correlation. We focus on the largest producing and consuming countries of the world. We capitalize on yield projections from the Global Gridded Crop Model Intercomparison project. Exploratory analysis of the skill of the underlying GGCMI models in reproducing key moments of the distribution of observed yields reveals that they overstate observed variances but faithfully reproduce observed patterns of cross-country correlations. We find no evidence of an increase in the degree of cross-country dependency of maize yields. We also find a higher incidence of what would be considered extremely low maize yields by present-time standards stemming from the projected downward trend in yields levels toward mid-century. The weak dependency of maize yields across countries, an the possibility of reducing the higher incidence of extremes through policies aimed to reverse the climate-induced downward trends in yields, suggest that international trade can become a valuable tool to ameliorate the effects of more unstable crop yields.

1. Introduction

The potential effects of food supply disruptions occurring simultaneously in many parts of the world has been the subject of recent interest (Benton and Bailey, 2015; Lunt et al., 2016). The main concern is that in the event of worldwide supply shortages, international trade would not be able to alleviate imbalances between the demand and supply of agricultural products, leading to price spikes and limited food availability (Lunt et al., 2016). Simultaneous supply shocks may be the consequence of climate teleconnections, such as El Niño/Southern Oscillation, which could result in concurrent agricultural yield reductions across regions of the world (Rosenzweig and Hillel, 2008). More generally, global climate models project increases in the frequency of extreme events occurring simultaneously in the main food growing regions of the world (Diffenbaugh and Scherer, 2011; IPCC-AR5, 2014).

The possibility of simultaneous reductions in agricultural yields is important because the extent to which international markets are a reliable source for stabilizing agricultural commodity prices depends on the degree to which climate shocks are uncorrelated across countries (Williams and Wright, 1991). Intuitively, trade stabilizes markets via the movement of products from where they are abundant to where they are relatively scarce (Burgess and Donaldson, 2010). Thus, regions with positive correlation of supply shocks would simultaneously experience abundance or scarcity, thus reducing the scope for international trade to stabilize agricultural prices.

In this article, we investigate the variability and correlation of growing season climate and agricultural yields across the largest maize producing and consuming countries of the world. We focus on maize because it is a major staple, a source of feed, and a crop that is widely produced and traded. We also focus on a reduced number of countries that are central to the global trading network of maize. Variability and correlation are two main determinants of the extent to which economic shocks in a member of a network can translate into systemic risks (Acemoglu et al., 2012). For example, a large negative supply shock in the

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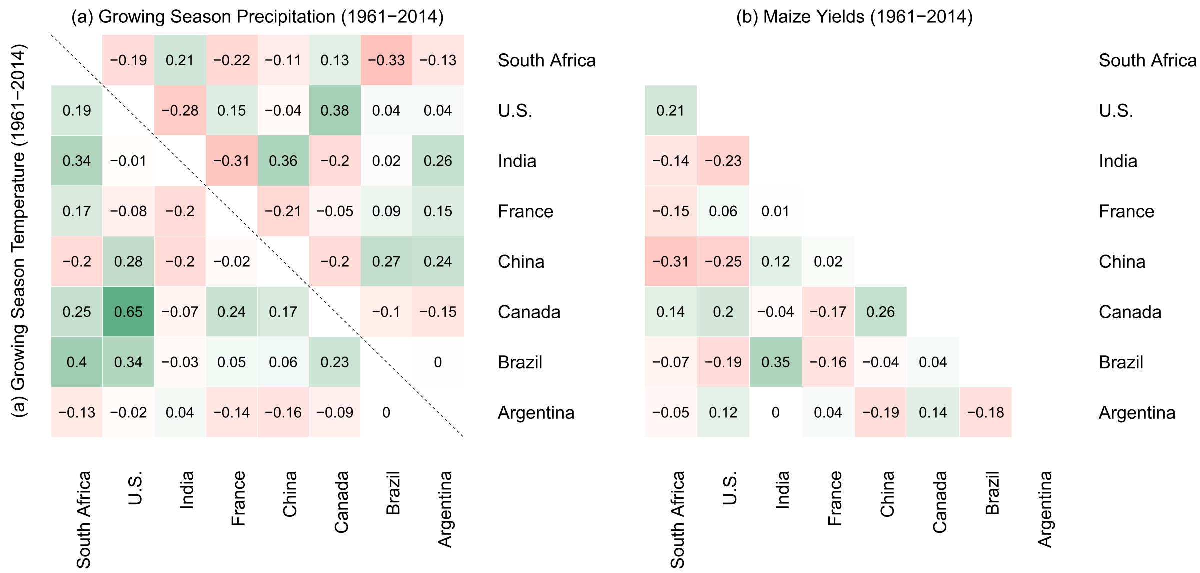

Fig. 1. Cross-country correlations of observed FAOSTAT maize yields and of growing season temperature and precipitation (Mitchell and Jones, 2005; Harris et al., 2014) during 1961–2014. Note: Coefficients in the figure are statistically significant at a 90% significance level if their absolute value exceeds 0.23.

U.S., which is the largest node in the trading network of maize, has the potential to destabilize global markets and reduce food availability in remote regions connected to the U.S. through international trade (d'Amour et al., 2016). Correlations in yield shocks are important because even if supply shocks in individual countries are moderate, the occurrence of food shortages in many locations at the same time would decrease the scope of international trade to help to mitigate price spikes through the redistribution of output. Methodologically, our approach consists of cross-country comparisons of correlations and variances in the historical records of maize yields and temperatures as well as in a subset of the ensembles of climate and crop model projections from the Global Gridded Crop Model Inter-comparison (AgMIP-GGCMI) initiative of the Agricultural Model Intercomparison and Improvement Project (Elliott et al., 2014b; Rosenzweig et al., 2014).

2. Data

Brooks et al. (2013) identify three main hubs in the trading network of maize: the U.S., which accounts for around a third of world production and exports; South Africa, an important maize supplier for countries in Southern Africa; and France, which is central to Europe. We also include Argentina and Brazil, which together account for around a fourth of world exports and are both large producers located in the Southern Hemisphere. China is also considered as it accounts for a fifth of global maize production, and its role as an opportunistic trader in response to crop shortages or surpluses has the potential to temporarily destabilize markets (Allen and Lutman, 2009). We also include India, where maize cultivation has been growing recently and accounts for 2.4% of global production. Finally, we include Canada, which even though is a minor player in global maize markets, is geographically close to the U.S. and thus provides an opportunity to explore the extent to which correlations are affected by geographic proximity.

National data on maize yields observed during 1961–2004 for the focus countries come from FAO (2016). Historical temperature and precipitation come from the Climatic Research Unit (CRU) monthly time-series, Version 3.23 (Mitchell and Jones, 2005; Harris et al., 2014). The data on both climate and maize yield projections come from the Global Gridded Crop Model (AgMIP-GGCMI) inter-comparison project (Elliott et al., 2014b; Rosenzweig et al., 2014) and were obtained using AgMIP-GGCMI's downloading facilities at Geoshare (Villoria et al., 2016, 2018). The AgMIP-GGCMI archive contains simulated yields from seven crop models (GEPIC, EPIC, pDDSAT, PEGASUS, LPJmL, LPJ-GUESS, and GAEZ-IMAGE) to 2099, in some cases dating back to as early as 1961. Yields from each crop model have been simulated using temperature and precipitation from five climate models (HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, GFDL-ESM2M, and NorESM1-M)[1] and adjusted (bias-corrected) by Hempel et al. (2013) so their historical runs preserve observed monthly means and daily variability around those monthly means. In addition, each climate-crop model combination is available for four different Representative Concentration Pathways (RCP) scenarios (Moss et al., 2010).

Each climate-RCP-crop model combination in the AgMIP-GGCMI archive is available for scenarios with and without CO_2 fertilization as well as with and without water constraints. Data availability restricted our model selection to all the climate runs of two crop models: LPJmL (Bondeau et al., 2007) and pDSSAT (Elliott et al., 2014a).[2] We use yield projections under RCP 2.6 (most benign scenario) and 8.5 (most extreme scenario). We further restrict our study to the AgMIP-GGCMI scenarios that reflect water constraints (no irrigation) and consider projected yields with and without CO_2 fertilization. This implies that for each country, RCP and CO_2 fertilization scenario, we have two model ensembles of ten (two crop models times five climate models) sets of projected yields for 2006–2049. In the analysis below we use the simulated yields from these two models for 1961–2004 to evaluate their skill in reproducing the patterns of variances and cross-country correlations in the observed yields from FAO (2016). For analyzing future changes we focus on projected yields for the period 2006–2049. It is important to keep in mind that the projected yields are solely driven by climate drivers and therefore do not consider any potential technological improvement during 2006–2049.

[1] Throughout the paper we refer to the climate models as HadGEM, IPSL, MIROC, GFDL, and NorESM for short.

[2] LPJml and pDSSAT historical simulations provided the largest coverage, as they start in 1961. In contrast, EPIC is available only since 1980 and GEPIC and PEGASUS from 1970. Variances and correlations calculated with such small samples would be very imprecise. Moreover, the comparisons of skill performance across models discussed below would be invalidated by using different sample sizes. LPJmL and pDSSAT are also the only models with continuous information during 2006–2049 for both RCP 2.6 and 8.5 and with/without considering the effects of CO_2 fertilization.