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Reconstructing the 1816 year without summer to assess the resilience of today's global food system: an interdisciplinary modelling approach

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Introduction

The eruption of the Indonesian volcano Tambora in 1815, in conjunction with other circumstances, caused a severe and global climate anomaly. The year following turned out to be extremely cold and brought heavy rain to some and draught to other parts of the world. "The year without summer" (YWS), as it was nicknamed in Europe and North America, saw very poor plant growth and poor harvests which, in combination with other factors, led to hardship, extreme food crisis and starvation in various regions of the world, including China, Germany, India and the US.

Undoubtedly, advances in research and development in agriculture, transportation, and other fields as well as globalization have changed the global food system tremendously since then. Nevertheless, regional specialisation and reliance on global availability of food supply and trade put into question whether today's global food system would also be resilient against such climate shocks which are of global nature: How resilient is today's global food system with respect to such extreme climate events? To what extent would it be capable of compensating the widespread harvest failures? How fragile is national food security with respect to protectionist trade policy reactions?

To shed light on these questions, we combine global climate, crop yield and computable general equilibrium (CGE) models for simulating the impact of a climate anomaly nowadays that is comparable to the one observed in 1816.

Methodology

Climate reconstructions are used to gain insights into climate variability of the past few hundred years and allow us not only to understand past extreme weather events but also to use these reconstructed data sets to develop a historic volcanic scenario for today’s climate (YWS2011).

For this study we use different global atmospheric datasets of historic weather reanalyses to place current atmospheric circulation patterns into a historical perspective to obtain dynamical reanalysis of the global atmosphere which cover the year 1816 following the Tambora eruption. For the crop modelling we debiased temperature and precipitation to account for differences in the data sets in the year 2011, which was chosen as a reference. After determining the corrections for 2011, the same corrections were applied to the year 1816. To obtain a volcanic scenario for today’s climate, we account for temperature trends between 1816 and the present.

The impact of the constructed volcanic scenario in 2011 on crop yields is determined by using a well-established dynamic global crop model called LPJmL (Lund-Potsdam-Jena with managed Land), which is well suited to simulate the growth and productivity of both natural and agricultural vegetation, linked by their water, carbon and energy fluxes, under changing climate conditions. More precisely, we incorporated the two sets of climate data into the dynamic crop model to spatially simulate crop changes between the 2011 observation year and YWS2011 for a range of different crops. Both simulations are based on today’s crop system, including crop varieties, fertilisers, management, etc. Thus, the dynamic crop model translates the reconstructed climate shocks of the volcanic scenario in the 2011 data into regional yield shocks that are then fed into the CGE model.

For the economic analysis, we use the Global Trade Analysis Model (GTAP) version 7 and the underlying version 10 of the GTAP database with the base year 2011. Agricultural and food commodities are considered as disaggregated as possible, while the other sectors are aggregated into food services, transportation, and other services, other primary and manufacturing commodities. In addition, 107 out of 141 countries are considered, while the remaining countries and regions have been aggregated according to their geographical proximity.

Experiment design

The analysis of the resilience of today's food system is carried out in the short run, i.e., in the year 2011, which implies that the economy can hardly react to this shock, as the planting decisions have been made, land, labour and capital are already allocated to certain tasks to a large extent. Rebalancing of food markets therefore occurs largely via prices and the demand side - and globally through trade.

Taking international price and trade reactions comprehensively into account, this YWS shock is evaluated with respect to its impacts on various dimensions of food security, most importantly, the supply of nutritional energy. Additional simulations consider a more protectionist global trading system as well as potential trade policy responses of national governments to the occurring food shortages, like those experienced during the 2007/08 world food price crisis, to further investigate how this affects the resilience of the global food system.

Results

The analysis of the food security consequences for examples of individual countries will reveal whether today's global food system is well equipped to cope with a catastrophe that had devastating consequences in 1816. The results will gauge the state of resilience of today's global food system, the dependency of the resilience on trade and trade policy and point to policy recommendations.