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Building a statistical emulator for prediction of crop yield response to climate change: a global gridded panel data set approach

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There is widespread concern that trends and variability in weather induced by climate change will detrimentally affect global agricultural productivity and food supplies. Reliable quantification of the risks of negative impacts at regional and global scales is a critical research need, which has so far been met by forcing state-of-the-art global gridded crop models with outputs of global climate model (GCM) simulations in exercises such as the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP)-Fastrack.

Notwithstanding such progress, it remains challenging to use these simulation-based projections to assess agricultural risk because their gridded fields of crop yields are fundamentally denominated as discrete combinations of warming scenarios, GCMs and crop models, and not as model-specific or model-averaged yield response functions of meteorological shifts, which may have their own independent probability of occurrence. By contrast, the empirical climate economics literature has adeptly represented agricultural responses to meteorological variables as reduced-form statistical response surfaces which identify the crop productivity impacts of additional exposure to different intervals of temperature and precipitation [cf Schlenker and Roberts, 2009]. This raises several important questions: (1) what do the equivalent reduced-form statistical response surfaces look like for crop model outputs, (2) do they exhibit systematic variation over space (e.g., crop suitability zones) or across crop models with different characteristics, (3) how do they compare to estimates based on historical observations, and (4) what are the implications for the characterization of climate risks?

We address these questions by estimating statistical yield response functions for four major crops (maize, rice, wheat and soybeans) over the historical period (1971-2004) as well as future climate change scenarios (2005-2099) using ISIMIP-Fastrack data for five GCMs and seven crop models under rain-fed and irrigated management regimes. Our approach, which is patterned after Lobell and Burke [2010], is a novel application of cross-section/time-series statistical techniques from the climate economics literature to large, high-dimension, multi-model datasets, and holds considerable promise as a diagnostic methodology to elucidate uncertainties in the processes simulated by crop models, and to support the development of climate impact intercomparison exercises.