*Work in progress*

# Climate Change and Heat Stress Impacts: Does Seasonality of Labor Matter?

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## Introduction

Agriculture is an economic activity that is highly dependent on weather, and thus a seasonal operation. Climate change *inter alia* is expected to result in substantial increases in average temperatures and changes of precipitation patterns. Most of the literature assessing the impacts of climate change on agriculture has so far largely focused on future availability of water and changes in crop yields (e.g., Rosenzweig et al., 2004; Wiebe et al., 2015). However, in most countries of the world, agricultural production technologies are still characterized by high labor intensity. According to recent research the impact of heat stress on labor productivity is an important and understudied channel of how climate change will impact agricultural production and rural livelihoods (Hertel and Lima, 2020). This particularly holds for low-income countries, where agriculture is labor intensive and where adaptation responses, e.g., the use of air-conditioned tractor cabins, are largely uneconomic and unavailable.

We hypothesize that the literature assessing the impacts of heat stress on agricultural labor productivity has itself neglected another important factor, the role of seasonal fluctuations in the demand for agricultural labor. Given that the impacts of heat stress are not constant throughout the year, i.e., they are seasonal, implies that the labor productivity in certain seasons is subject to a higher heat stress shock than in others. Yet, farmers face a rigid crop calendar which leaves little possibility for intertemporal substitution across seasons (Feuerbacher et al., 2020). A possible strategy of farmers to cope with seasonal heat stress could be to allocate more time to agricultural operations, at the expense of time spent on seasonal leisure activities, which in practice maybe only partially realistic as heat stress is not only associated with lower productivity, but also with negative health consequences (Kjellstrom et al., 2009; Lundgren et al., 2013).

## Method and Data

In this paper, we investigate the relevance of seasonal labor when assessing the impacts of climate change induced heat stress. We use a 2012 social accounting matrix for the South Asian country Bhutan (Feuerbacher, 2019), which provides a unique model database as it includes data on seasonal labor and leisure disaggregated in monthly time intervals and by the three main agroecological zones. Further the data splits non-agricultural labor into skilled and unskilled labor. We employ this data in a single-country, recursive-dynamic computable general equilibrium (CGE) model (McDonald and Thierfelder, 2020) to simulate the seasonal impacts of heat stress on labor productivity from 2015 and 2050. The model baseline is generated using projections of gross domestic product and population growth using the concept of shared socioeconomic pathways (SSPs) (O'Neill et al., 2014), which also provides projections for Bhutan. The projections for different levels of education and urban shares of population are matched with the labor accounts of the model database. In order to isolate the role of seasonal rural labor markets we rerun the model using the identical model calibration and specification except now with an annualized labor market (i.e., all seasonal labor accounts are aggregated on an annual level).

**Scenario**

To compute the heat stress scenarios we principally follow the approach described in Orlov et al., 2020, which is based on historical and projected climate simulations provided by the GFDL-ESM2M general circulation model made available through the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) (Warszawski et al., 2014). The climate data on air temperature, relative humidity, wind speed and solar radiation is available at a 0.5° x 0.5° geographic grid level resolution. Using this data, we calculate two different intensities of wet bulb global temperature (WBGT) as follows. The WBGT for indoor or outdoor under shade (WBGTshade) for lower intensity of heat stress is calculated following Lemke and Kjellstrom (2012) and Bernard and Pourmoghani (1999). The WBGT under direct sun exposure (WBGTsun) indicates a higher intensity as workers outdoors are exposed to additional stress due to heat radiation and is computed approximating the approach by Liljegren et al. (2008) as described in Orlov et al. (2020). The WBGTshade and WBGTsun are calculated on a daily basis for each grid cell for the climate projections associated with the representative concentration pathway RCP6.0, which presents a moderately severe scenario of global warming. The "high occupational temperature health and productivity suppression" (Hothaps) exposure-response function (see Kjellstrom et al., 2018 for more details) is applied to estimate the productivity losses due to heat stress at different work intensities, which is described by metabolic rates measured in Watts (W) (see Orlov et al. (2020)).

For the productivity shocks on seasonal labor, which is predominantly demanded by agricultural activities, we use the WBGTsun and the highest level of work intensity, which is 400 W. This is reasonable given that agricultural workers perform physically demanding activities outdoors. For unskilled and skilled workers, we assume that they work mostly under shade (WBGTshade) and that their work intensity is moderate (300 W) or low (200 W), respectively. The productivity shocks are then calculated on a daily basis for each skill level and grid cell. For the historical reference period the spatiotemporal data on reductions in labor productivity is weighted by gridded UN WPP-adjusted population count data (CIESIN, 2017), while spatial population projections for each SSP (Jones and O'Neill, 2016) are used to weight the impacts under the RCP6.0. The final labor productivity shock is calculated computing the difference in changes in worker productivity in the historical reference period and the RCP6.0. For the seasonal workers, the gridded shocks are averaged for each of the three respective agroecological zones.

*Please note, this is work in progress: Results, Discussion and Conclusion will follow.*

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