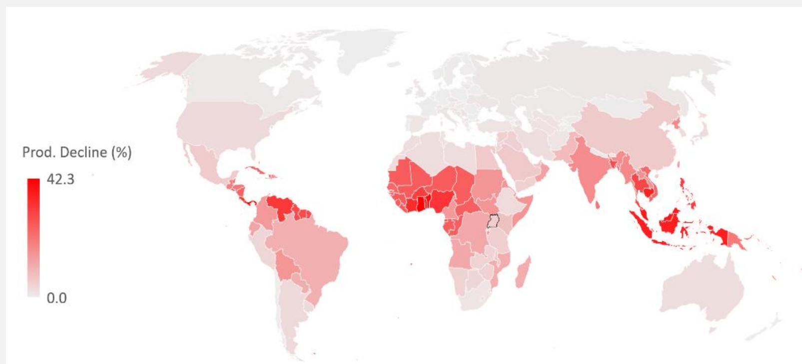
ABSTRACT

Heat Stress, Agricultural Labor and Poverty Impacts of Climate Change

In this paper, we use the GTAP-POV framework to assess the potential poverty impacts of human heat stress caused by global warming. The impacts of global warming on the agricultural sector have been widely studied, however, most of this research has focused exclusively on the impact of climate on plants – in particularly crop yields. Largely ignored is the transmission of climate change impacts through elevated heat stress on people – specifically the agricultural labor force. High heat and humidity coupled with direct exposure to solar radiation – in other words farming in much of the tropics – can significantly reduce the capacity for work. Figure 1 shows that heat stress can cause labor productivity to decline by as much as 40% in several tropical countries across Central America, West Africa, and Southeast Asia.

In a recent study, Lima et. al. (forthcoming) compare the economic consequences of climate change impacts on plants vs. people for key crops and find that heat stress on the labor force is the dominant cause of welfare losses in Sub-Saharan Africa. In this paper, we extend this work, focusing on the economic impacts of heat stress on people and the subsequent implications for poverty; an area that is not well-studied. Under the scenario where global mean temperatures increase by 3°C or more, 69 million more unskilled workers are drawn into agriculture globally with these increases concentrated in only a few regions, including Sub-Saharan Africa, South- and Southeast Asia (Lima et. al.). In other words, regions where much of the world's poor reside see substantial labor re-allocations. This increased demand for labor can have disparate poverty results: on the one hand increased demand for labor can raise returns to labor, when labor is in short supply, moving poverty outcomes in a positive direction. On the other hand, returns to land and capital are reduced when labor productivity falls, causing reduced earnings and exacerbating poverty outcomes. The net effect on poverty is therefore ambiguous and we can expect disparate poverty outcomes across different countries driven by differences in factor earnings shares in agriculture.

Figure 1: Decline in productivity of unskilled labor in crops at 3°C+ mean global warming[1]



Source: Authors' calculation based on estimates from de Lima et. al. (forthcoming)

The literature on how heat stress in humans affects economic outcomes at a macroeconomic scale is growing. Several recent works employ macroeconomic modelling approaches and estimate the potential GDP losses that could result from the labor productivity losses caused by heat stress. A study by Orlov et. al. 2020 utilizes labor productivity response functions and the– GRACE model: Global Responses to Anthropogenic Changes in the Environment to estimate global GDP decline by 2100. A study by DARA (independent, international organization based in Madrid) estimates GDP losses due to losses in labor productivity using physiological impacts and labor productivity losses estimated by Kjellstrom et. al. (2009). Finally, Lima et. al. (forthcoming) assess the welfare losses caused by human heat stress (labor productivity losses) relative to losses caused by plant heat stress (yield losses caused by climate change) using the GTAP framework.

This paper adds to this growing research by estimating poverty impacts in addition to other macroeconomic impacts using a modified version of the GTAP-POV framework. To our knowledge the poverty implication of labor productivity losses in agriculture have not yet been assessed. GTAP-POV is a macro-to-micro approach where changes in prices and wages determined using the macro model are used as inputs into a microdata-based module that estimates the poverty implications. However, in the 'standard' GTAP-POV model, household around the poverty lines are divided into income-source based strata where each stratum's sources of income are implicitly assumed to be fixed. However, we can expect that households will respond to heat stress and the resulting loss of productivity in agriculture by re-allocating labor between agriculture and non-agriculture. In other words, we can expect that some specialized agricultural households could in fact become diversified, or vice versa, thus potentially mitigating output losses and poverty impacts.

More formally, in the ‘standard’ GTAP-POV model change in real income, for each stratum, given changes in factor and commodity prices predicted by the main GTAP model is determined by the following equation:

$$\hat{y}_{rs} = \sum_{j} \alpha_{rsj}\left(\widehat{W}_{rj} - \hat{C}_r\right) \tag{1}$$

where hats indicate proportional changes; α_{rsj} is the share of income obtained from factor j by households in the neighborhood of poverty in stratum s of region r; $\widehat{W}_{rj}$ is the proportional change in factor prices (after tax factor earnings); and $\hat{C}_r$ is the “true cost of living at the poverty line”. To account for the re-allocation of labor within each stratum, we modify equation (1) to:

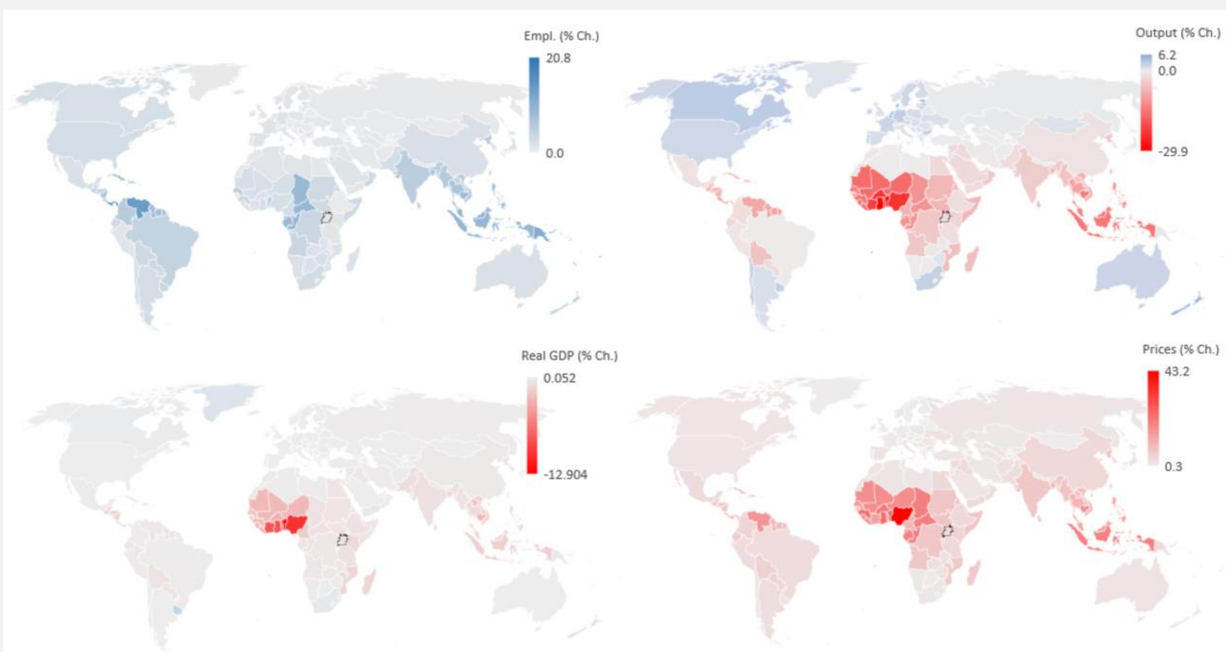
$$\hat{y}_{rs} = \sum_{j} \alpha_{rsj}\left(\widehat{W}_{rj} + \hat{L}_{rsj} - \hat{C}_r\right) \tag{2}$$

where $\hat{L}_{rsj}$ is the proportional change in the employed endowment of factor j held by the representative household at the poverty line for stratum s in region r. In equation 1, this term ($\hat{L}_{rsj}$) was implicitly assumed to be zero.

In this modified GTAP-POV framework, we simulate the productivity losses associated with 3°C mean global warming and the resulting heat stress as measured by the Environmental Stress Index (ESI). Labor capacity losses are estimated at the crop level within each country, where labor capacity losses are estimated using the methodology of Dunne et. al. (2013). To capture the uncertainty around climate change, we simulate productivity losses for three cases: upper, median, and lower thus providing a range around possible outcomes. Median results are reported in this abstract.

Figure 2 shows changes in a few key macroeconomic variables. As productivity of labor in crops declines, we see that employment of labor, in other words demand for labor increases, in general. This is because as each unit of labor becomes

Figure 2: Global percentage changes in key macroeconomic variables under 3°C mean global warming (median case)



Source: Simulation results. Notes: ***Top-left*** panel shows changes in employment of unskilled labor in the cropping sector, ***top-right*** panel shows percentage changes in the output of crops, ***bottom-right*** shows percentage changes in the aggregate (weighted-average) price of crops, ***bottom-left*** shows changes in the real GDP.

less productive, more labor is needed in order to minimize output losses. We however observe heterogenous labor responses. For example, while West Africa is among one of the hardest hit regions (see Figure 1), its employment response is muted (Top-left panel, Figure 2). This is explained by the fact that West African countries already employ much of their in agriculture ex-ante, leaving little room for re-allocation once heat stress is introduced. Thus, countries’ abilities to adapt in terms of labor re-allocation varies. Where this adaptive response is constrained, output declines are sharper as shown in the top-right panel of Figure 2. In turn, larger output declines translate into correspondingly large price increases and ultimately GDP declines (bottom panels, Figure 2).

Implications for poverty in 27 regions (countries for which household survey data have been incorporated in the GTAP-POV database) are assessed in Table 1. As noted earlier, in GTAP-POV households are divided into income source-based strata – since a household earning its income primarily from agricultural self-employment would be affected differently by changes in different factor returns than a household that is transfer-dependent. We observe disparate results across regions: e.g., within the agricultural stratum, while Indonesia sees a poverty decline, in Uganda there is a relatively large poverty increase. This heterogeneity across regions (within the same household-type) is driven by the underlying earnings shares, as well as disparate employment responses. In the case of Indonesia versus Uganda, earnings shares (not shown) vary: self-employed agricultural households in Indonesia draw a large portion of their earnings from unskilled labor. Heat stress causes demand for and hence returns to labor to increase, thus improving earnings and poverty. In Uganda on the other hand, the underlying micro-data suggest that unskilled labor makes up a small portion of agricultural households' earnings; much of their earnings is attributed to land and capital which see returns fall. Hence, the adverse poverty outcome in this case.

Table 1: Changes in the poverty headcount (nos.) due to human heat stress

	Household Stratum							Total
	Agricultural	Non-Agricultural	Urban Labor	Rural Labor	Transfer Dependent	Urban Diversified	Rural Diversified	
Indonesia	-281,745	117,464	27,200	50,053	15,434	17,205	80,242	25,853
Phillipines	74,385	9,055	1,173	994	4,043	70,772	75,184	235,606
Thailand	0	0	0	0	0	0	0	0
Vietnam	-338	4,639	2	0	436	1,768	4,858	11,367
Bangladesh	-18,192	25,651	2,413	1,409	7,423	16,555	18,846	54,105
Mexico	-896	312	1,861	678	788	1,881	574	5,199
Bolivia	-451	892	-10	45	7	707	-600	591
Brazil	-2,270	828	1,107	563	2,217	-10,736	-1,675	-9,967
Chile	-3	0	-5	0	17	-346	-29	-366
Colombia	-17,662	665	1,581	300	3,638	-7,216	-1,921	-20,615
Ecuador	-1,077	78	-2	-61	0	127	-1,005	-1,939
Paraguay	-775	9	-355	-109	1	-61	-944	-2,232
Peru	-5,360	136	56	14	1	-243	-799	-6,196
Uruguay	0	0	0	0	-1	-1	-9	-12
Venezuela	-8,176	21,607	15,388	3,674	4,727	33,203	1,300	71,723
Costa Rica	63	22	-1	-4	78	6	135	299
Guatamala	-213	798	18	-22	619	1,079	-559	1,719
Honduras	-2,297	995	-128	42	608	2,864	-6,275	-4,192
Nicaragua	-20	193	-9	25	28	297	-106	408
Pananma	-619	211	38	46	345	2,825	-376	2,469
El Salvador	-305	170	-134	-49	4	515	11	212
Dominican Republic	-122	55	14	3	1	235	-79	108
Jamaica	-254	148	7	8	0	3	-1	-89
Mozambique + Madagascar	614	11,417	1,718	3,068	9,314	6,807	7,192	40,129
Malawi	-13,699	1,051	-71	-139	714	-240	-3,670	-16,055
Uganda	1,917,351	509	27	123	76	1,439	1,040	1,920,565
Zambia	-6	2,275	910	277	10	960	431	4,857

Source: Simulation results.

In short, the poverty implications of human heat stress are likely to be heterogenous across regions. The key underlying parameters that will determine how an economy fares when labor is impacted by heat stress are: its ability to draw more labor into agriculture (or conversely how constrained an economy is in its ability to re-allocate labor to agriculture) which in turn depends on how large crops are into the economy; and the earnings shares of poor households.

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