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THE IMPACT OF A CARBON TAX ON FOSSIL FUELS ON THE WEF NEXUS

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INTRODUCTION

The Global Community tries to make progress on 17 Sustainable Development Goals (SDGs) that UN member states adopted in 2015. Key among these are SDG 2: "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture"; SDG 6: "Ensure availability and sustainable management of water and sanitation for all; and SDG 7: "Ensure access to affordable, reliable, sustainable, and modern energy for all". However, as a result of growing natural resource scarcity, it has become clear that achievements in one of these three SDGs cannot be achieved without impacts—positive or negative—on one or both other SDGs and several other development goals. To understand these interlinkages, reduce negative feedback effects and strengthen positive or synergistic linkages, the concept of the Water-Energy-Food Nexus has been developed. This policy note summarizes the results of a global economic analysis of these interlinkages simulating the introduction of a carbon tax on fossil fuels that was published as Ringler et al (2016).[1]

METHODOLOGY AND SCENARIO SPECIFICATION

The modeling methodology links two global economic modeling tools, the global computable general equilibrium (CGE) model GLOBE and a global partial equilibrium model, IFPRI's IMPACT version 3 to jointly assess the impact of an energy price shock on water and food security.

Table 1 Carbon Tax Scenarios

Scenario	Specification
1a Baseline without climate change (BasenoCC) 1b Baseline with climate change (BaseCC)	BAU (SSP2): 9.1 billion people in 2050 BAU (SSP2) with high emissions scenario (RCP8.5); HadGEM2-ES
2a High fossil fuel price without CC (HEPnoCC) 2b High fossil fuel price with CC (HEPCC)	Fossil fuel taxes in GLOBE impacting GDP and price of agricultural chemicals (70% tax on coal, 50% on crude oil; 30% on natural gas) Additional changes in IMPACT: Gradual reduction of GW withdrawal capacity over 2015-2050; by 2050 20% lower than baseline to reflect adverse impacts of higher fuel prices on GW pumping
3a High fossil fuel price with increased biofuel use and increased hydropower production w/o CC (HEPadaptnoCC) 3b High fossil fuel price with increased biofuel use and increased HP production with CC (HEPadapCC)	Same as Scenario 2 plus Increase in First GEN biofuel demand to compensate for reduced fossil fuel availability, doubled by 2050 (GLOBE and IMPACT) Gradual, linear increase in hydropower production (10% by 2050) with associated 10% increase in storage and SW withdrawal capacity

[1] Ringler, C., D. Willenbockel, N. Perez, M. Rosegrant, T. Zhu and N. Matthews. 2016. Global linkages among energy, food and water: an economic assessment. Journal of Environmental Studies and Sciences: 6(1): 161-171.

IMPACT3 is a modular integrated assessment model, linking information from climate models, crop simulation models, and water models with a global, partial equilibrium, multimarket model centered on the agriculture sector. The global CGE model is an extended recursive-dynamic version of the comparative-static GLOBE model. Apart from the incorporation of capital accumulation, population growth, labor force growth, and technical progress, the extended model features a detailed representation of the technical substitution possibilities in the power sector.

To assess linkages across the water-energy-food nexus (WEF), we develop three alternative scenarios that are described in Table 1. Scenario 1 (Base) describes a business-as-usual development path suggesting that trends from the recent past in the water, energy and food sectors will continue. Scenario 2 (HEP) assumes a strong push toward addressing climate change with a focus on a gradual phase out of fossil fuels through the introduction of a carbon tax by 2050 of 70% for coal, 50% for crude oil and 30% for natural gas. Higher prices for fossil fuels induce substitution toward renewable energy sources and investments in more energy-efficient technologies. Regions that are both net importers of primary fossil fuels and net exporters of refined petrol, such as India and high-income Asia enjoy terms-of-trade gains under this scenario, while regions that are net exporters of primary fossil fuels and net importers of refined petrol, including Oceania, parts of East Africa, West Africa and Central America suffer pronounced terms-of-trade losses, as do some net importers of both (those who are mostly net importers of refined petrol) and net exporters of both (those who are mostly net exporters of crude oil).

Terms-of-trade gains are associated with real income gains for the region and terms-of-trade losses with real income losses (Table 2). As groundwater irrigation largely depends on fossil fuels, this scenario also imposes a gradual decline in the pumping of groundwater-based irrigation, equivalent to a 20% decline in groundwater pumping by 2050 compared to the baseline. The third scenario (HEPadap) assumes the same fossil fuel tax as Scenario 2, but introduces a series of mitigating measures to enhance water and food security. This includes an increase in first-generation and later on, second-generation biofuel feedstock demand such that by 2050 demands are 100% larger than in the baseline. In addition, hydropower development accelerates slightly over baseline investment levels, adding 10% additional storage to the overall surface storage portfolio by 2050. All three scenarios are run with and without climate change.

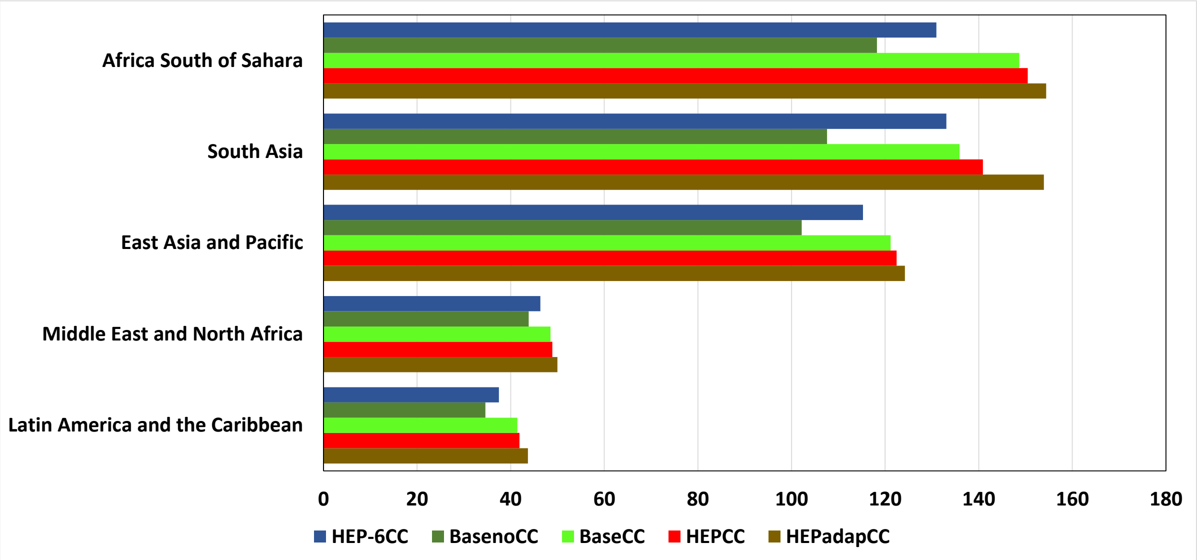
Table 2 Changes in Terms of Trade

	No Climate Change		With Climate Change	
	HEP	HEPadap	HEP	HEPadap
Oceania	(2.7)	(2.6)	(2.7)	(2.5)
China	0.9	0.9	0.9	0.8
O EastAsia	(1.2)	(1.2)	(1.2)	(1.2)
India	6.6	6.6	6.5	6.5
O SouthAsia	(3.9)	(3.9)	(3.9)	(3.9)
HIAsia	5.2	5.1	5.1	5.0
N America	2.0	2.0	2.0	2.1
C America	(2.2)	(2.2)	(2.1)	(2.1)
S America	(1.1)	(0.9)	(1.1)	(0.8)
MENA	(6.0)	(6.1)	(5.9)	(6.0)
W Africa	(10.8)	(10.8)	(10.7)	(10.7)
E Africa	(5.1)	(5.1)	(5.1)	(5.1)
S Africa	1.6	1.6	1.5	1.5

RESULTS

What are the impacts of changes in energy prices on food and water security? The carbon tax under HEPCC adversely affects GDP, with the exception of high-income Asia and thus the capacity of populations to purchase food products. This, in turn, dampens food demand and food prices with small feedback effects increasing agricultural production. Higher fertilizer prices and reductions in fossil-fuel driven groundwater pumping also increase food prices, but the key impacts are through lack of household income to purchase food. The pressure on food prices is slightly larger under the climate change scenario; upward pressure is particularly high for wheat and rice. Figure 1 presents the impacts of increased fossil fuel prices on the population at risk of hunger. The increase is largest between a no climate change baseline and a climate change scenario. As a result of the income decline due to higher fossil fuel prices, food insecurity increases slightly in all developing country regions. The largest increase is in South Asia, at 5 million people.

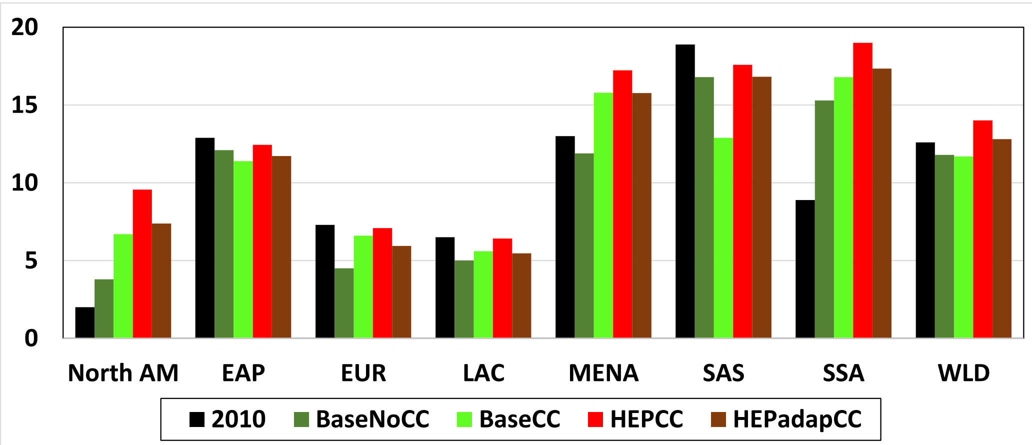
Figure 1 The impact of a carbon tax on the population at risk of hunger, alternative energy scenarios, projected 2050



The share of unmet water demands changes over time in response to changes in water infrastructure, population growth and associated demands for water resources. In 2010, the share of unmet water needs is largest in the South Asia (SAS) region, followed by the Middle East and North Africa (MENA) region. By 2050, the share of unmet needs declines in several regions, but raises dramatically in Africa south of the Sahara (SSA). The fossil fuel price increase further raises the share of unmet water demands globally by 20% (HEPCC scenario compared to the baseline). The increase is largest in those regions that depend on groundwater as a main source for domestic, industrial, and irrigation supplies with counter-vailing effects from reduced irrigation activities as a result of dampened food demands. Unmet water demands increase particularly in North America (NA), by 43%, and in the SAS region, by 36%. The increase is much smaller in Sub-Saharan Africa, at 13%.

Under the third scenario, HEPadap, the supply of alternative energy sources is accelerated, i.e. biofuels and hydropower. source alternatives considered. The additional biofuel demand using first-generation technologies in HEPadap raises nominal agricultural prices—directly for the feedstock commodities and indirectly for other agricultural commodities—via upward pressure on land rents). This reduces the real purchasing power of household nominal income. As a result of the increased use of biofuels for energy production, global staple food prices increase compared to the baseline scenario and also compared to HEP. On the other hand, the increased use of surface water through increased reservoir storage, improves water-for-food outcomes slightly but not sufficient to compensate for the declining food security situation caused by biofuel demand. In response to these measures, the number of people at risk of hunger grows globally by a further 23 million compared to the HEPCC scenario to 578 million people. Projected increases are largest in the SAS region, at 13 million people, followed by Africa south of the Sahara, with 4 million people. Under the HEPadap scenario, the share of unmet water demands declines by 1.2 percentage points in response to the continued decline in food demand and small increase in surface water storage. Declines in the share of unmet water demands are largest in the NA, MENA and SSA regions.

Figure 2 Share of unmet water demands, alternative energy scenarios, projected 2050



CONCLUSIONS

We find that carbon taxes geared toward mitigating climate change have small negative impacts on food security, through reducing food production and increasing food prices. The number of people at risk of hunger increases by 9 million people. However, substantially expanding biofuel production to compensate for the carbon tax on fossil fuels increases the number of food-insecure people substantially. Bad adaptation, as represented in the HEPadap scenario, can thus substantially worsen food, and possibly also water outcomes, and here increases the number of people at risk of hunger by 31 million people.

What if carbon taxes dramatically reduce climate change? If the fossil fuel tax, as proposed, would shift the world from the modelled, aggressive Representative Concentration Pathway (RCP) from IPCC's 5th Assessment Report of 8.5 to a more moderate emissions growth path of RCP 6.0, then outcomes for food security would be highly positive. As shown in Figure 1, under a HEP6-CC pathway, the number of people at risk of hunger would be below the baseline climate change impact levels for all developing regions and much closer to a no-climate change baseline scenario. This lends further support to the introduction of fossil fuel taxes to reduce emissions and climate change while improving food security outcomes.

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