Global Economic Response to Water Scarcity

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Introduction

This study investigates the likely regional impact of global changes in water availability on crop production, international trade of agricultural commodities, and overall economic production by 2030. The study compares the results of different regional and sectoral aggregations of ENISAGE model (van der Mensbrugghe, 2008) to different regional and sectoral aggregations of GTAP-BIO-W model (Liu et al., 2014). We employ the core structure of GTAP-Water Database by Haqiqi et al. (2016). The Data Base and models are modified to minimize the discrepancy.

Background

The amount of irrigation depends on climate conditions, economic system, and water application efficiency. Irrigation (blue water) is applied mainly when the rainfall and soil moisture (green water) are not adequate to meet the crop water requirement given salinity and fertilizer. So, any change in rainfall and soil moisture is highly likely to affect evapotranspiration (ET) and thus irrigation needs. On the other hand, the change in the social and economic system may require changes in crop production; with a higher yield of irrigation production, it may cause variations in irrigation scope.

Considering high share of irrigation in total water withdrawal, any increase in irrigation will put high pressure on water resources. It is expected that the irrigation intensity changes around the planet. Population change, TFP growth, dietary shifts, and globalization will lead to a different pattern of crop price, land use, and production (Baldos and Hertel, 2014). And predicted changes in water resources and crop yields suggest a shift in irrigation pattern around the world

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(Liu et al., 2014). This highlights the need of a comprehensive analysis of water-economy interactions.

Methods and Materials

To measure the impacts of global water scarcity on irrigation, we need to know how important is water in irrigated crop production. How may a reduction in water availability affect irrigation, food production, and irrigation technology in different regions of the world? Which regions are more affected and by how much? And which adaptation pathway is more important in each region?

Water is an important input to agriculture and food production. Water shocks will affect irrigation, food production, and irrigation technology by changing food prices, production costs, and trade patterns, which are intensified with economic and population growth. The magnitude of the changes depends on the initial contribution of irrigation technologies and size of the shock. When prices rise, countries with a higher food share in total expenditure are more affected than those with lower food cost share. Labor wages are also affected as production revenue falls.

The effects of climate change on water availability are expected to be different across river basins, agricultural products, ecological zones, and countries. In addition, water requirements for crops are widely different across regions and crops. For example, the water requirement for wheat in a hot dry area is much higher than in a moderate humid area. Thus, the impact of a reduced water supply is likely more severe in a dry area than in a humid area. Even in one location, the water requirement is different among crops and agricultural products. It means the production of crops with higher water requirement are expected to change more than crops with lower water requirement. The production technology is another important factor. Some countries use more efficient technology for producing crops and use less water. These countries are going to be more affected than low-efficiency countries because there is little room for efficiency improvement. The impact on household categories (farm labor, nonfarm labor, land owner) also is not the same. An accurate analysis needs to consider heterogeneity among regions, agricultural crops, irrigation type and ecological zones.

In addition, a shock in agricultural production due to water scarcity will have indirect economy-wide impacts; change in price of agricultural products will affect prices and production in food industry and some manufacturing industries; change in labor demand in agriculture affects labor supply to other sectors; this will affect non-farm labor wages; due to change in prices and income, the optimum decision of farmers, producers, and consumer will change; the equilibrium price and quantity in labor market, capital market, and wide range of commodity markets will adjust accordingly. There are many other indirect general equilibrium effects. An analysis that does not consider the indirect general equilibrium impacts might ignore important channels. Considering major general equilibrium impacts provides better insights of the consequences and it is more appropriate for policy recommendations.

For an accurate economic analysis of water, we need an Integrated Assessment Model (IAM). However, the IAM practices by economists and climate scientists are very limited. Some of the well-known examples of hydrological-ecosystem models are DSSAT (Jones et al., 2003), APSIM (Keating et al. 2003), and AgMIP (Rosenzweig et al. 2013). However, despite detailed biophysical modelling of the ecosystem, many climate models are missing a complete economic link. On the other hand, despite many economic models can analyze the economic systems very well, they are often lacking a linkage to detailed biophysical aspects. To fill this gap, some economic IAM models try to consider the heterogeneity of land, water, and climate inputs. Some important economic models are IMPACT-WATER (Rosegrant et al., 2002), WATERSIM (de Fraiture, 2007), IGSM-WRS (Strzepek et al., 2010), GTAP-BIO-W (Taheripour et al., 2013; Taheripour et al., 2016), and ENVISAGE-W (Haqiqi et al., 2016).

Economic models are also different in terms of agricultural commodity groups and water-land details. Studies with the GTAP-BIO-W model include 19 regions, 6 major crop groups, and 126 river basins around the world. With 18 agro-ecological zones (AEZs) within each river basin, it forms around 1000 land units. On the other hand, published studies with the ENVISAGE-W model show no details on land use and may include only two aggregate crop groups.

To make the comparison, we need a common database with detailed water and land use information. The current GTAP-Water Database includes only 19 aggregate regions at river basin AEZ level. One contribution of our study is introducing a GTAP-Water Data Base for 140 regions and by river basin AEZ. We follow Haqiqi et al. (2016) to construct the data base. Main modifications are 1) starting from gridded information; 2) and using production values instead of production quantities in splitting value added. We are aware that models are different in terms of modeling bioenergy. A complete analysis requires bioenergy information also to be included.

We construct the database using the information from Global Map of Irrigation Areas (GMIA) provided by Siebert et al. (2010), Global Crop Water Model (GCWM) by Siebert and Döll (2010), AQUASTAT and FAOSTAT by Food and Agriculture Organization (FAO, 2016), and economic information of GTAP-WATER by Haqiqi et al. (2016). After construction of the base year data, water shocks are taken from estimations of IWSRs (Irrigation Water Supply Reliability) from the IMPACT-WATER model (Rosegrant et al., 2012).

Results

We use the database and modified models to explore adaptation pathways in each model. According to Haqiqi and Hertel (2016), fundamental adaptation pathways to a water shock are irrigated-rainfed substitution, within border relocation, crop switching, change in food share, and international trade.

We find that both models are losing some adjustment margins to water shocks. The international trade margin in a 19-region version of GTAP-BIO-W might be less effective as the model assumes easy relocation within aggregated regions. It not only implies easy labor and capital movement, it also implies easy relocation of water and land. In reality, relocation of production from one country to another country is represented in trade. On the other hand, the crop switching margin of ENVISAGE-W may be less effective as it includes only two crop groups.

It also ignores the relocation adaptation pathway. Although we usually assume that these issues are negligible, this study tries to investigate how important are them.

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