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Analysis

The Distributional and Multi-Sectoral Impacts of Rainfall Shocks: Evidence From Computable General Equilibrium Modelling for the Awash Basin, Ethiopia

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ABSTRACT

This paper presents an analysis of the multi-sectoral and distributional economic impacts of rainfall shocks in the Awash river basin in Ethiopia. Using novel disaggregated data on crop production, we estimate the direct impacts of rainfall shocks on agriculture and then use a Computable General Equilibrium model to simulate how these rainfall shocks propagate through the wider economy of the basin under three different climate change scenarios. The basin's economy and expanding agricultural sector are highly vulnerable to the impacts of rainfall shocks. A rainfall decrease scenario could lead to a 5% decline in the basin's GDP, with agricultural GDP standing to drop by as much as 10%. All sectors benefit from greater rainfall amounts. Distributional impacts depend on income group, with poor households accruing greater benefits relative to non-poor households under a scenario of additional rainfall and suffering proportionally lower income losses under a scenario of rainfall decrease.

1. Introduction

Understanding the impact of hydro-climatic factors on the economy informs the design of agricultural and water polices. It has important implications for the economic appraisal of investments in the water sector vis-à-vis investments in other sectors, quantifying if and how unmanaged hydro-climatic variables lead to unfavorable economic outcomes. In the face of climate change and increasing water demands, this understanding also informs adaptation decisions and is increasingly being integrated into investment decision-making.

For over a decade, scholars have highlighted the regional and global economic impacts of hydro-climatic variables on economies, recognizing for instance that factors such as rainfall variability and drought affect economic outcomes at multiple scales ranging from national economic production (Barrios et al., 2010; Grey and Sadoff, 2007; Sadoff et al., 2015; Hall et al., 2014; Garrick and Hall, 2014) to household wealth and income dynamics (Dercon, 2004; Coulter et al., 2010; Barrett and Santos, 2014). Despite recognition of the importance of hydro-climatic variables in influencing economies and perpetuating poverty traps, there still remains much to be studied in terms of the mechanisms by which these variables influence different economic sectors and how the impacts are distributed through society and different income groups.

This paper follows this line of work and aims to quantify the multi-sectoral and distributional impacts of rainfall shocks in the Awash River basin, Ethiopia. This analysis has implications for informing adaptation strategies in the Awash basin and, more broadly, for understanding current and future vulnerabilities to climatic factors in areas such as Sub-Saharan Africa where rainfed agriculture is dominant.

The paper is structured as follows. Section 2 reviews the motivating evidence for this study and articulates the main contributions. Section 3 presents the background to the study area and Section 4 presents the data and the analytical framework used to investigate the linkages between economic activities and rainfall and extremes at the river basin scale. In Section 5 the results are presented and in Section 6 the limitations are discussed. Section 7 presents conclusions from the study and suggests areas for future research.

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2. Motivating Evidence and Contribution

The question of climate's role (both rainfall and temperature) in influencing the economy has challenged thinkers for several decades and is of increasing relevance to assessments of the economic impacts of climate change (Hsiang, 2016; Carlton and Hsiang, 2016). In the case of rainfall, studies examining its role in influencing economic outcomes have ranged from econometric analyses at the global scale (Brown and Lall, 2006; Brown et al., 2013) to household level surveys (Dercon and Christiaensen, 2007; Coulter et al., 2010). Overall, studies have found that rainfall variability and extremes have a significant effect on both household welfare and national economic output, especially in agricultural-based economies (Shiferaw et al., 2014).

Given the natural relationship between agricultural production and rainfall, it is not surprising that in agricultural-dependent economies where most agriculture is rainfed, variations in rainfall can cause significant economic impacts. However, this intuition may be difficult to test in practice, because high resolution data on agricultural production and rainfall are often lacking and because it is difficult to estimate how direct impacts, especially on the agricultural sector, are transmitted through other sectors of the economy.

Early work in the economics literature used production function approaches to establish a relationship between hydro-climatic variables and agricultural output and then simulate the impacts of changing climate conditions (Adams, 1989; Dell et al., 2014). More recently, studies have used panel methods to estimate the impact of climatic factors on agricultural production. Most of these studies have focused on the role of temperature, such as Deressa and Hassan (2009) who showed how increasing temperatures would reduce crop revenue in Ethiopia or Schlenker and Lobell (2010) who demonstrated that higher temperatures lead to lower agricultural yields in Sub-Saharan Africa. Other studies have examined the role of climate variability and extreme weather events in influencing crop production at local (Rowhani et al., 2011) and global scales (Lesk et al., 2016), quantifying the extent to which crop yields are sensitive to both intra- and inter-seasonal changes in temperature, precipitation, and drought occurrence. Panel data analysis has also been used to examine farmer responses to changes in rainfall variables, for instance by examining how rainfall variability in Ethiopia impacts fertilizer use (Alem et al., 2010) or food crop choices (Bezabih and Di Falco, 2012), or the impacts of rainfall shocks on agroecosystem productivity (Di Falco and Chavas, 2008).

Beyond analysis of the agricultural sector, econometric analyses using panel data have been employed to investigate the impacts of long-term hydro-climatic fluctuations and extremes on national economies. Examples include Barrios et al. (2010) who showed that higher rainfall is associated with faster economic growth in Sub-Saharan Africa, Brown and Lall (2006) who established a statistically significant relationship between greater rainfall variability and lower per capita GDP, Brown et al. (2011) who demonstrated negative impacts of droughts on GDP per capita growth and Brown et al. (2013) who found that rainfall extremes (i.e., droughts and floods) have a negative influence on GDP growth. Recent work by Sadoff et al. (2015) has used for the first-time surface runoff to test its impact on national economies, finding that it has a negative impact on economic growth at the global level.

Building on empirical estimates of the direct effects of rainfall on economic outcomes, scholars have also investigated the economy-wide impact of water-related variables, especially rainfall variability and availability. These analyses have relied on Computable General Equilibrium (CGE) models to show the impact of rainfall on economies at various scales under historical climate variability and also under climate change. Pauw et al. (2011) combined a crop loss model with a CGE model to estimate the impacts of rainfall extremes on Malawi's economy. Strzepek et al. (2008) used a CGE model to look at variability in water supply and model the economic value of reduced variability following the construction of the High Aswan dam in Egypt. Other applications of CGE models to assess the indirect impacts of water-related variables include Berritella et al. (2007), who investigated the role of water resources and scarcity in international trade, Roson and Damania (2016), who explored the macroeconomic impact of future water scarcity and alternative water allocation strategies, Brouwer et al. (2008), who modelled the direct and indirect impacts of water quality improvements on the economy of the Netherlands, and Carrera et al. (2015), who assessed the impacts of extreme events (flood shocks) in Northern Italy.

In the context of Ethiopia, analysts have emphasized the vulnerability of the agricultural sector to climate change (Deressa et al., 2008) and found evidence of the linkages between economic outcomes and rainfall variability (Grey and Sadoff, 2007). Revisiting the Grey and Sadoff (2007) analysis with a longer data series, Conway and Schipper (2011) found a weaker relationship between rainfall and GDP, but still emphasized the sensitivity of Ethiopia's economy to major droughts and argued that evidence of the relationship between wet and dry extremes and the economy is essential to assess the significance of future climate change. Following a similar line of work, Deressa (2007) investigated the economic impact of climate on Ethiopia's agriculture and found that increasing temperature and decreasing rainfall have negative impacts on farmers' net revenues. Bewket (2009) identified strong correlations between cereal production and rainfall in the Amhara region and similar conclusions were reached by Alemayehu and Bewket (2016) for the central highlands.

Despite this growing body of work, there remain some unanswered questions of scholarly and policy relevance. First, most studies have typically focused on country-level assessments, without diagnosing the distributional and multi-sectoral impacts of rainfall shocks at the river basin scale. Although country-level assessments provide valuable information to focus policy-makers' attention on the issue, the most interesting variations in economic variables of relevance for decision-making are often observed at regional rather than national scales (Henderson et al., 2012), and for different sectors and income groups. Second, as noted by Brown et al. (2013), most analyses to date have relied on spatially averaged rainfall data, which introduces systematic biases in the results by smoothing out variability and extremes.

To address these gaps and contribute to the existing literature on the impacts of hydro-climatic variability and climate change at different scales, this study analyses the multi-sectoral and distributional impacts of rainfall shocks in the Awash basin, Ethiopia. First, the direct impacts of rainfall shocks on crop production are quantified. To avoid bias due to rainfall averaging, spatially disaggregated rainfall data are used to estimate the effects of positive and negative rainfall anomalies on agricultural production at the administrative zone level. Second, a CGE model is used to quantify how these shocks are transmitted through the economy under three different climate scenarios. This allows us to quantify the potential economic impacts of climate change-induced variations in rainfall. Using a CGE model also allows us to compute the indirect impacts of rainfall shocks for different income groups, providing an understanding of the distributional implications of rainfall shocks.

3. Background

The Awash River basin, spanning 23 administrative zones, covers 10% of Ethiopia's area and hosts about 17% of its population. In aggregate, the water available for use (including surface water and groundwater) of the Awash river basin meets existing demand, with 4.9 billion m^3 available per year on average compared to an average annual demand of 2.8 billion m^3 (Tiruneh et al., 2013). However, this availability is highly variable both temporally and spatially. Most rainfall occurs between July and September and water availability during the dry season is on average 28% lower than in the rainy season (Bekele et al., 2016). The lower reaches of the Awash receive on average 27% to 45% of the rain that falls in the upstream basin