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Analysis of the relationship between rainfall and economic growth in Indian states☆

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ABSTRACT

The relationship between rainfall variability and economic growth is complex, and tends to be significant in economies like India where agriculture plays a major role in economic output and food security. This paper seeks to provide insight into this relationship using Indian state-level economic and rainfall data from 1961 to 2012. We examine all 15 Indian states with populations exceeding 20m as of 2000, totalling 920m people, about 12% of the global population. Physical and human geography vary greatly between, and even within, these states, reflecting the global range of water security challenges and providing an analogue for a range of global economic development and environmental conditions. We identify three patterns of interdependence between rainfall variability and economic growth: i) Continuous Correlation of rainfall and economic growth rates, ii) Decayed Correlation from a significant to an insignificant relationship, and iii) Never Correlated i.e. no significant observable correlation between rainfall and growth. Sensitivity to rainfall variability is somewhat less in wetter states. Investment in irrigation infrastructure has helped states to reduce their economic sensitivity to rainfall variability, with three of the four states that have Decayed Correlation of growth with rainfall having the highest percentage expansion in irrigated areas of the 15 states. Greater use of groundwater supplies (rather than surface water) does not, however, appear to influence the sensitivity of economic growth to rainfall variability. The relationship between rainfall-growth correlation and long term income is complex; states which are correlated generally appear to be growing faster than states which are not correlated, but that growth is occurring from a lower per capita income level. Finally, confirming national trends for India, the paper does not find that economic diversification away from agriculture has reduced economic sensitivity to rainfall variability. The observation that growth in economically-diversified states can still be dependent on rainfall invites further research into the ways in which rainfall either directly, or through other hydro-climatic variables, influences the general economy.

1. Introduction

Throughout modern history, India's economy has been thought to be strongly influenced by variations in water resources on a seasonal and annual basis, estimated by some to account for 45% of fluctuations in inter-annual Gross Domestic Product (GDP) (Virmani, 2004). Significant work has been carried out examining the link between water resources and growth at the national level (Gadgil and Gadgil, 2006; Mooley et al., 1981), with attempts to explain the propagation through the economy of the impacts of rainfall variation. The challenges of ascribing causal mechanisms are highlighted by the literature, including the paradox that the economy has continued to be sensitive to rainfall even while the national economy has diversified away from agriculture, and while the irrigated agricultural area has expanded. At the state level, India exhibits significant geographic and climatic diversity, in addition to economic, cultural and political variation. Nonetheless, Indian states are governed by the Constitution of India, a common national framework that makes state-level data more amenable to comparison than country-level data used in previous studies of the relationship between hydroclimatic variability and economic growth (Hall et al., 2014). This paper examines the relationship between rainfall and economic growth across Indian states, revealing statically verifiable differences in behaviour, and deepening understanding of how water management may affect economic impact of changes in rainfall. In so doing, this paper extends the methodology and justification for examining rainfall-growth relationships. Section 1 of the

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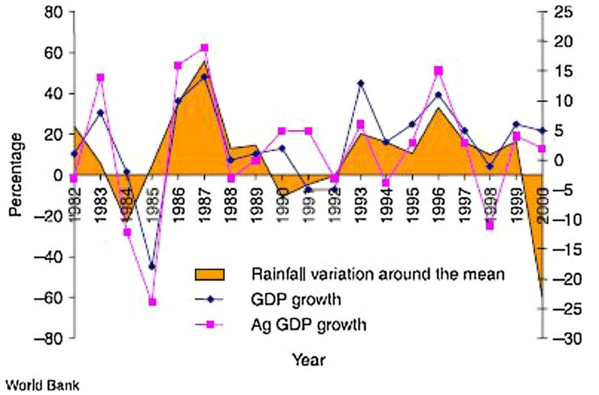

Fig. 1. Rainfall variation and Economic Growth for Ethiopia 1982–2000. From Grey and Sadoff (2007), Fig. 5, developed from World Bank, 2006, Fig. ES2.

paper reviews past empirical and conceptual work on rainfall-growth relationships, Section 2 reviews the economic and water resource development and rainfall-growth relationships in India. Section 3 highlights research gaps and frames research hypotheses in light of the literature review. Section 4 discusses the data used in the analysis, with results and analysis presented in Section 5, followed by conclusions in Section 6.

Previous work has examined relationships between rainfall and growth (and/or agricultural output) at global or national scales, using a range of methodologies both to examine trends and investigate possible causal influences. The fundamental assumption behind this work is based on the premise that economies' growth can be influenced by rainfall and water availability (e.g. Brown et al., 2013), whereby droughts and floods impede agricultural, power and industrial production, and floods also impact physical infrastructure. At a country level, this relationship is illustrated by Grey and Sadoff (2007) to be evident for Ethiopia over an 18 year period (Fig. 1). Their work proposes that, for the period to 2000, Ethiopia's total and agricultural growth is influenced by annual rainfall. The years since 2000, not included in Grey and Sadoff's analysis, have been relatively stable in terms of rainfall, and also experienced significant economic growth, potentially removing the correlation with rainfall that was observed up to the year 2000 (Conway and Schipper, 2011). However, drought was still seen as a major risk (IMF, 2016), which has been realised in 2016 (IMF, 2016).

Building on work by Brown and Lall (2006) which comprised a global analysis of rainfall-growth relationships, Sadoff et al. (2015) further highlights the strong relationship between trends in growth and water availability, in this case runoff, and suggest mechanisms by which growth has been buffered from the effects of inter-annual water resource availability. They conclude that the economic impact of rainfall variability (i.e. a form of water insecurity) poses a significant drag on long-term economic growth and development potential. It has been further argued that investment in infrastructure and institutions is associated with reduction in the negative impacts of variability on economic growth (Grey and Sadoff, 2006). Sadoff et al. (2015) presented three cases to illustrate different versions of the inter-relationship between hydrological variability (as indicated by runoff) and growth (Fig. 2): (i) Malawi is presented as a case of low investment and low water security, with a continuous sensitivity of growth to runoff variation; (ii) India is presented as a case of medium investment and reduced sensitivity of economic growth to runoff; and (iii) China, with high investment in water (both storage and flood control), is seen to have eliminated the sensitivity of growth to inter-annual runoff variability. The three countries fit on to an 'S' curve of investment and water insecurity presented by Grey and Sadoff (2007), whereby cumulative investment in water security measures enable countries to transition via a tipping point from water insecure to water secure states. Dadson et al. (2017) take the process further, conceptualising instances of investment as a promoter of growth and other cases where insufficient or poor investment further drags the economy, resulting in a low-level equilibrium trap. In this low-level trap, economies suffer recurrent losses and are not able to accumulate enough wealth to invest in water security.

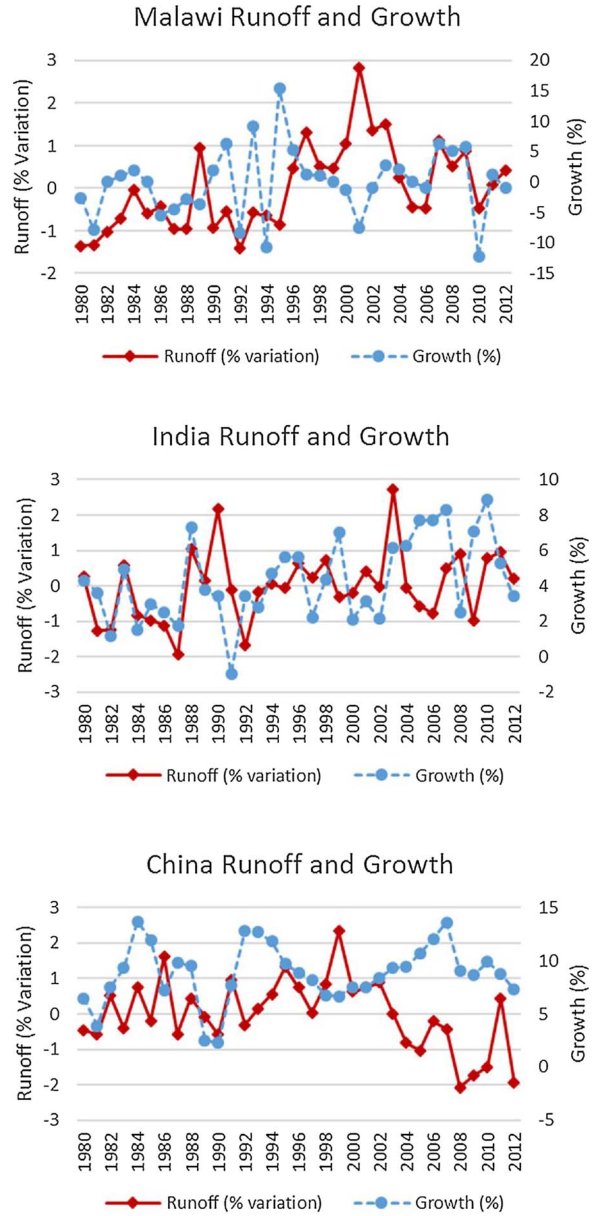

Fig. 2. Runoff variation (%) and annual growth (%) for Malawi (low investment, low water security), India (medium investment, medium water security) and China (high investment, high water security, growth no longer correlated with runoff variability). Adapted from Sadoff et al., 2015, box 2, data pers. comm.

This growing body of literature has established hypotheses about the relationship between hydroclimatic variability, water security and economic growth (changes in income) at national level, which is conceptualised in Fig. 3. The model captures the ideas from Dadson et al. (2017), that low rainfall (drought) will restrict agricultural and other production, and result in reduced income. Slightly below average rainfall can be tolerated, and can produce positive income, while moderately above average rainfall produces enhanced production and income. Extreme rainfall can produce floods that negatively impact income through lost crops, disrupted communication and trade, and also result in damage to assets, captured in the model by a decline in income with large rainfall events. Water-related investments can help