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Analysis

Estimating the causal effect of water scarcity on the groundwater use efficiency of rice farming in South India

Shalet Korattukudy Varghese *, Prakashan Chellattan Veettil [1], Stijn Speelman [1], Jeroen Buysse [1], Guido Van Huylenbroeck [1]

Department of Agricultural Economics, Gent University, Coupure Links 653, 9000 Gent, Belgium

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ABSTRACT

There is no consensus among researchers on the influence of scarcity on common pool resource use: some suggest that scarcity leads to prudent use, whereas others suggest that it will cause over-extraction of resources. This issue is particularly of interest for developing countries, where natural resources are becoming scarce at an alarming rate. This paper investigates the causal association between water scarcity and groundwater use efficiency in a rice based cropping system in south India, where groundwater is increasingly becoming a scarce resource. Contextualization of the work is done under the premise of reported contradictions concerning the scarcity — efficiency nexus. Using a two stage approach the causality is estimated: first, farm level groundwater use efficiency (GWUE) scores are calculated using non-parametric efficiency analysis, and then these inefficiencies are linked to farm level scarcity indicators using the Inverse Probability Weighting method. Our results showed a negative causal association between farm level water scarcity and GWUE, indicating the existence of competitive appropriation behavior in the face of scarcity. Hence, policy measures to conserve groundwater should include supply enhancement to remove the threat of immediate scarcity on farm to avoid inefficient pumping in addition to demand management measures and improved governance.

1. Introduction

In the context of the escalating global water supply-demand mismatch, stakeholders and policy makers are increasingly interested in improving the efficiency with which every drop of groundwater is extracted and used. Considering the consumptive nature of agricultural water use and the sheer volume of groundwater used for agriculture, it is imperative that groundwater use efficiencies (GWUE) be assessed and causal nodes of inefficiencies are identified. With agriculture being the largest consumer of water withdrawals from developed water resources in many countries (Rogers et al., 2002) and groundwater being the major water supplier for irrigation, policy designers in most countries are forced to search for new policy mechanisms to improve the GWUE. Key to designing effective policies to improve GWUE at the farm level is the understanding of the nexus between water scarcity/availability and efficient use. Economic literature widely differs in its views concerning the effects of resource scarcity on efficiency (Osés-Eraso and Viladrich-Grau, 2007). While it is often believed that in abundance, resource use will be inefficient and that scarcity of a resource will cause more prudent use (Arnold, 1998; Leite and Weidemann, 1999; Molden et al., 2010; Molle et al., 2010; Osés-Eraso and Viladrich-Grau, 2007; Ostrom et al., 1994, 1999), several authors (Grossman and Mendoza, 2003; Herr et al., 1997; Maldonado and Moreno-Sanchez, 2008) report the occurrence of appropriative competition under resource scarcity, implying less efficient use under scarcity.

In the light of the inconclusive evidence in the literature, the current paper attempts to estimate, using causal inference theories, the nexus between water scarcity and efficiency of groundwater use in the intensive rice farming system in the central dry zone of Karnataka, India, where groundwater is a critical and a fast depleting resource. We specifically try to address following questions: (i) does water scarcity causally influence the groundwater resource use in the production activities of farms, and (ii) how does intensive rice farming influence GWUE in this water scarce region? In contrast with extant empirical analyses of the nexus between water scarcity at individual level and water pumping in the case of groundwater, which have largely been based on experimental settings (Gardner et al., 1997; Herr et al., 1997; Maldonado and Moreno-Sanchez, 2008), this paper uses farm data. An accurate causal estimation of the effect of water scarcity on GWUE at individual farm level, could also lay the foundation to predict the impact on GWUE of policies aiming at modulating the water availability. The central contribution of this paper is to clarify the inconclusive discussions on scarcity efficiency nexus in a developing country context by

* Corresponding author at: Coupure Links 653, 9000 Gent, Belgium. Tel.: +32 9 264 93 75, +32 9 264 59 28; fax: +32 9 264 62 46.
E-mail address: Shalet.KorattukudyVarghese@UGent.be (S.K. Varghese).
[1] Tel.: +32 9 264 59 28; fax: +32 9 264 62 46.

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using a promising and accurate method and to propose policy guidelines with regard to the common groundwater stock uses in rice farming in the presence of acute water scarcity.

This is highly relevant for Karnataka and in general for India, where escalating irrigation water demand along with the private ownership and control of groundwater wells , the policy of electricity subsidies for pumping and the improvements in pumping technology tremendously increased the number of bore-wells supporting irrigated farming (Shah et al., 2003). When the groundwater resources were thought to be abundant, high appropriation happened in many Indian states as shown by the construction of a high number of wells in the last decades (Anantha and Raju, 2010; Shah, 2009; Shah et al., 2003). This behavior led to eventual over-extraction and scarcity, which could have been affecting farmer abstraction behavior (Fig. 1) and thereby groundwater use efficiencies. Because of the widespread use of flood irrigation systems which requires more water to be applied and the double cropping of rice, stress is put on the groundwater reservoirs. Currently it is already reported that over-pumping due to the expansion of rice farming under well irrigation has resulted in dramatic reductions in water storage of wells and to drops in water table levels in many regions of Karnataka (Maréchal, 2009). Clearly this scarcity might have an effect on the farmers' abstraction behavior and on the groundwater use efficiencies.

The remainder of the paper is organized as follows. The next section talks about the theoretical background of the research by discussing scarcity-efficiency relations. Next, we describe the methodology used for the analysis of causal effects of water scarcity on GWUE. After contextualizing the important concepts, we proceed with exploring the nexus between water scarcity and efficiency through causal inference theory. Thereafter, the methods used to estimate the causal link are briefly discussed. The methodology section also describes details about the case study setting with details about the study area, the sample and the collected data. The article then proceeds with highlighting the relevant results. Finally in the conclusion, we briefly discuss the policy implications and the relevance for groundwater resource use.

2. Scarcity-Efficiency Nexus

The nexus between resource scarcity and efficiency of use of common pool resources is debated. Generally it is believed that scarcity gives users incentives to use a resource more efficient. Under Neoclassical economics which assumes total rationality to its subjects, the scarcity would force markets to bring in a price which is indicative of the scarcity. The institutional economics, however assumes bounded rationality, where its subjects are rational beings who behave under the institutions, rules and norms existing in the society. However, some authors in their case studies have noted that scarcity creates further inefficient use to further causing exhaustion. Leite and Weidemann (1999) for example found that in the absence of scarcity resource use was inefficient and warned that this could possibly cause exhaustion. Such behavior is not expected under perfect rationality assumption of neoclassical economics. Arnold (1998) reports that users act to reduce their appropriation of a common pool resource when shortages are perceived. Likewise, Ostrom et al. (1999) points out that after users observe substantial scarcity self-organization in the commons is likely to occur and lead to more efficient use. This indicates that under some circumstances, institutions evolve to regulate the exhaustion behavior which imposes bounded rationality on the subjects. However, other studies including those under behavioral economics suggest that resource scarcity may promote appropriative competition and thus lead to a faster rate of exhaustion (Grossman and Mendoza, 2003; Herr et al., 1997; Maldonado and Moreno-Sanchez, 2008). Herr et al. (1997) for example considered the effect of increasing extraction costs, which indicate scarcity, on appropriation decisions. They concluded that players behave myopically by neglecting that current extraction decreases the future value of the resource. Such myopic behavior intensifies the chase for the resource in a time-dependent setting. Maldonado and Moreno-Sanchez (2008) observed for fish stocks that under scarcity the tragedy of the commons may be exacerbated, as individuals tend to over-extract a resource in a "race to the bottom", that is not only inefficient privately but also inefficient socially and dangerous for the sustainability of a common pool resource. Giordana et al. (2010) distinguish between two types of externalities when common-pool resources become relatively scarce: static externalities and dynamic externalities. In a given period, a static externality arises whenever current withdrawals reduce current exploitation profits, because users compete with each other for the available units. A dynamic externality arises if such static competition among users also affects the available units of the resource in future periods. Both affect the behavior of resource users (Giordana et al., 2010). They found that even when both static and dynamic externalities occur people tend to behave myopically.

For the case of water resources, the evidence of the scarcity-efficiency relationship is also mixed. While Molden et al. (2010) note that water scarcity is a key driver behind gains in water productivity and Venot et al. (2010) show that during drought farmers optimize their scarce production factor (water) by obtaining a higher water productivity, authors like Bekkar et al. (2009) and Molle et al. (2010) indicate that improving water productivity is just one possible strategy for farmers. They observe that farmers sometimes also adopt offensive strategies towards water access, trying to get continuous access by increasing investments or exploiting alternative resources. This last option was reported by García-Vila et al. (2008) and by Palanisami et al. (2008).

The nature of the resource, the institutional setting and the policy framework largely determine which strategy farmers adopt. The influence of an extrinsic motivation to continue to exhaust (for example, in the current case a price support mechanism for rice cropping) or lack of restrictive institutions compounds the extraction rate. However, Van Oel et al. (2010) report that response to scarcity can even differ between the wet and the dry season. They found that in the wet season high (low) water availability results in low (high) water use, while during the dry season high (low) water availability results in high (low) water use. Several authors (Bekkar et al., 2009; Moench, 2007; Schlager, 2007) also indicate that in particular groundwater is prone to over-extraction because of diffuse individual access, weak property rights, absence of community control, invisible nature of the resource and difficulty faced by farmers to perceive the impact of their own use on the dynamics of groundwater. Another issue is that groundwater rights are often only legal rights to use water meaning that the volume

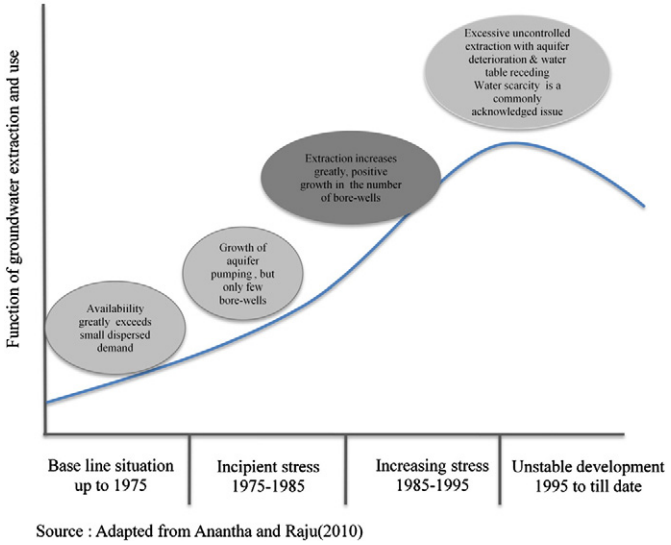

Fig. 1. Groundwater extraction and use in India.