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Strategic entry and externalities in groundwater resources: Evidence from the lab☆

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ABSTRACT

This study uses economics experiments to extend the literature on common-pool resources by focusing on entry investment behavior in a stylized, spatially explicit aquifer. The model consists of a two-stage game, where participants make an entry decision in the first stage and, if they choose to enter, decide how much resource to extract in the second stage. Results show that entry behavior and groundwater pumping decisions are significantly affected by the underlying spatial externalities of the resource. In instances where the impacts of groundwater use are spread across all resource users, we observe both a greater number of users choosing to use the resource and a higher intensity of use. The results support expectations from the model that groundwater management policies should focus on entry in addition to decisions related to the volume of pumping. The results also discern the interplay of entry with both hydrogeologic characteristics of the resource and the option to exit and reveal that the option to exit increases the intensity of extraction as well as initial entry rates.

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1. Introduction

Inefficient exploitation of groundwater resources to meet irrigation and other demands occurs because users seldom face private extraction costs that match social costs. In 2009, more than 65% of groundwater withdrawals in the US were used for irrigation and 407,923 irrigation wells served 97,690 farms (National Ground Water Association, 2011). In parts of Texas, water levels have dropped 45 m over the past 60 years (Madramootoo, 2012). In India, between 1951 and 2006, a surge in demand for irrigated crops and inefficiencies of agricultural production using surface water increased the number of wells from 3.9 to 12 million (Sakthivadivel, 2007; Mukherji, 2009). Satellite-based estimates in the Indian States of Rajasthan, Punjab, and Haryana suggest an average rate of groundwater depletion of 18 km^3/yr (Rodell et al., 2009).

Economists have long recognized that appropriations of common-pool resources (CPRs) may lead to market failure. Groundwater research beginning with Gisser and Sánchez (1980), however, shows that when the storage capacity of an aquifer is relatively large, welfare losses will be small and therefore optimal use leads to only small efficiency gains relative to myopic use. The conditions under which the Gisser-Sánchez effect may apply have been extensively examined by research that has focused primarily on heterogeneous economic, hydrologic, and agronomic conditions. These include capital investments (Burness and Brill, 2001), cost, demand and return functions (Worthington et al., 1985; Allen and Gisser, 1984; Brill and Burness, 1994), the hydrologic substitution effect between surface water and groundwater (Burness and Martin, 1988; Knapp and Olson, 1995), occurrences of an irreversible effect (Tsur and Zemel, 1995, 2004), and crop and technology adaptation (Kim et al., 1989; Reinelt, 2005; Koundouri and Christou, 2006). Overall, these studies primarily focus on extraction decisions and ignore decisions related to entry and investment.

This paper is unique as it examines both entry and pumping behavior in a spatially explicit groundwater resource using laboratory economics experiments. The specific treatments provide information on the effect of spatial aquifer features on the propensity of firms to both enter and exit a groundwater resource. To provide a concrete setting for the experiments, the firms are modeled as agricultural producers accessing groundwater for irrigation. The objective of our study is to identify how entry investment behavior changes in response to variations in groundwater resource properties. The results show that hydrogeologic characteristics significantly affect both entry and observed pumping decisions, and thus must be accounted for when designing an optimal policy to prevent over-exploitation. Although we do not investigate specific policy interventions, the research highlights the importance of considering the influence of hydrogeologic characteristics of common pool groundwater resources on incentives at both the extensive (entry) and intensive (pumping) margins.

Section 2 summarizes the relevant literature. Section 3 describes the theoretical model. Section 4 outlines the experimental design and protocols, and Section 5 presents and analyzes the results from the experiments. Finally, Section 6 discusses the policy implications, limitations, and areas for future study.

2. Relevant literature

Many previous studies have examined rent dissipation with respect to common pool resources using laboratory economics experiments. The framework for experimental studies on CPRs was pioneered by Walker et al. (1990), Gardner et al. (1990), and Ostrom et al. (1992). However, most previous experimental research provides limited specific guidance for aquifer management because the underlying resource models are static, too general to inform policy decisions for a particular resource, and do not allow participants to make both entry and extraction decisions. In this section, we review a select set of previous research that provides insight for the specific features of groundwater resource use that we attempt to capture in our experiments.

Several recent experimental studies utilized a dynamic rather than a static framework to explore CPR use. Mason and Phillips (1997) evaluated welfare differences between games with static and dynamic externalities in markets with various group sizes. In the dynamic cost externalities setting, welfare gains were reduced when the number of firms was greater than three, while in the static setting welfare was enhanced as the number of firms increased. In the dynamic setting, the authors found that