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Analysis

Land subsidence, production efficiency, and the decision of aquacultural firms in Taiwan to discontinue production

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ABSTRACT

For some time the over-pumping of groundwater by aquacultural producers has contributed to severe problems with land subsidence in many areas of Taiwan. This has led to policy initiatives that impose extra costs on groundwater users. By investigating the effects of the conditions of aquifers, production efficiency and other factors on decisions of Taiwanese aquacultural producers to exit the industry, this paper lays an important foundation for an understanding of the effects of these policy initiatives. Using data from a nationwide survey, this exit decision is examined using an innovative empirical strategy that combines Data Envelopment Analysis with a discrete choice econometric model. Results indicate that less efficient firms and those located in areas where land subsidence is severe are more likely to exit. These relationships may in part reflect the effectiveness of the recent policy changes to reduce land subsidence attributable to aquaculture production.

1. Introduction

Over the past couple of decades, the aquacultural sector in Taiwan has undergone dramatic changes. Production costs in Taiwan are relatively high compared with those in other countries. Since Taiwan joined the World Trade Organization in 2002, domestic products must now compete with these lower-cost imported products. Due at least in part to this increased competition, the number of aquacultural firms in Taiwan has declined in recent years. Between 2000 and 2006, for example, the number of aquacultural firms fell by about 12%, from nearly 42 thousand to just under 37 thousand (Council of Agriculture, 2007). For these reasons, there is increased interest in Taiwan toward re-orientating policy to facilitate production adjustments by aquacultural fisheries. Because efficiency of resource use is one of the drivers of aquacultural development, policies have been proposed that would encourage some of the less efficient firms to leave the business (Fisheries Agency, 2007).

In spite of its considerable economic benefits to the Taiwanese agricultural sector, aquacultural production has also had some negative environmental effects. Since water quality as well as quantity is essential for aquacultural production, the demand for fresh water by aquacultural producers has contributed to the growing demand for groundwater in recent years. In some areas in Taiwan, this increased use of groundwater for aquacultural production has also led to severe problems with land subsidence (e.g., Chen et al., 2006; Liao and Chen, 2008). According to the official reports, the annual rate of land subsidence in the major aquacultural production regions increased from 7 to 11.7 cm between 1985 and 2005 (Water Bureau in Taiwan 2008). To alleviate this problem, legislation to control land subsidence was launched in 1995 by the Taiwanese Legislative Yuan (Pense et al., 2008; Yang and Yu, 2006).[2] Under this legislation, there are serious monetary penalties for pumping groundwater in areas where land subsidence is severe. These penalties are expected to affect the succession plans of firms that are located in the land subsidence areas.

To develop effective policies to achieve a structural adjustment in the aquacultural sector, it is crucial to have a better understanding of the producers' behavior and the factors that are related to their decisions to exit the industry. For this reason, the research reported in this paper focuses on the extent to which production efficiency and land subsidence, as well as other factors, may be associated with the decisions of firms to exit the sector. The analysis is based on data from a nationally representative random survey of the aquacultural firms in

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[2] Taiwan's government (Ministry of Economic Affairs, MOEA and the Council of Agriculture, COA) initiated a five-year Land Subsidence Prevention and Reclamation Plan (LSPRP) in 1995 to remediate the land subsidence problem. The Plan's main objectives are: (1) to alleviate land subsidence problems from groundwater overdraft and (2) to develop improved land-use and water resources plans in subsidence affected areas to minimize further economic and social losses. The Fisheries Agency, COA, is mainly responsible for aquaculture production control and water conservation.

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Taiwan (Fisheries Agency, 2006). In the survey, detailed information on production and input use was collected. In addition, data on some social and demographic characteristics of the firm and its operator are also documented. The survey is unique in that operators were also asked if they planned to continue production or if they planned to stop production within the subsequent three years.

By using these data, we are able to specify and estimate a discrete choice model to investigate how the differences in production practices, the characteristics of the operators (e.g. age, education, and production experience), local environmental and geographic conditions affect the likelihood that firms will exit the industry. Special attention is given to quantifying the effects of the technical efficiency of production on the firms' decisions to exit the industry. To control for the effects of production efficiency, we include an estimate of technical efficiency as an explanatory variable in the discrete choice model. Differences in the technical efficiencies of production among firms are estimated using a nonparametric Data Envelopment Analysis (DEA) method; care is taken to adjust initial estimates for estimation bias using bootstrap methods.

Furthermore, some producers may view both the development of land-use and water resources plans and the potential imposition of fines on firms that use groundwater in excess of allowable quantities as serious deterrents to continuing production. Since our data do not include information on the imposition of fines or the nature of any land-use and water resource plans, we address this issue indirectly. That is, using data that characterize the conditions of the local aquifers, we also control for the severity of land subsidence in the choice model. In so doing, any quantifiable relationship between the severity of land subsidence locally and the decisions of firms to discontinue production may be a leading indicator of the effectiveness of future policies in Taiwan to reduce land subsidence associated with aquaculture.

Considerable literature has focused on the production performance of aquaculture at the firm level. However, the primary emphasis of these studies is on the estimation of technical efficiencies based on either a parametric frontier model (e.g., Chiang et al., 2004; Dey et al., 2000; Sharma and Leung, 1998) or a mathematical programming frontier model (e.g., Cinemre et al., 2006; Sharma et al., 1999; Sharma and Leung, 1998). Studies designed to identify the factors that are likely to affect the decisions of the aquacultural firms to discontinue production are still limited. Some exceptions are found in Ward and Sutinen (1994), Ikiara and Odink (2000), Pradhan and Leung (2004), and Mente et al. (2007). In general, these studies have demonstrated how the socioeconomic characteristics of the producers affect the decision to discontinue production or to retire. For instance, using data for 532 fishermen, Mente et al. (2007) investigated the socioeconomic sustainability of fisheries and aquaculture in the South Evoikos Gulf in Greece. They found that high salaries and the education of the workers contribute to the sustainability of the aquacultural sector. Using a pooled annual cross-sectional and time-series survey between 1991 and 1998 of long line fishers in Hawaii, Pradhan and Leung (2004) examined the factors which are associated with the entry, stay, and exit decisions of the fishers. By estimating a multinomial logit model, they found that the potential earnings, crowding externalities, and some other management factors significantly determine the exit decisions of the firms.

In contrast to these earlier studies, our study exploits the methodologies from both these strands of literature. By first estimating technical efficiencies of production, we are able to incorporate them into a discrete choice model to highlight the importance of the technical efficiency of production on the decisions by firms to discontinue production. In conducting the analysis, we are careful to correct for the inherent upward bias of input oriented measures of technical efficiency that are derived by conventional DEA methods. To obtain consistent estimates of technical efficiency, we adjust the original estimates for this potential bias by using the bootstrap methods suggested by Simar and Wilson (2007). Furthermore, while the maximum likelihood estimation is the prevailing statistical method in the literature for estimating discrete choice models, there have also been some recent applications based on Bayesian methods. In this study, we estimate the binary choice model of the exit decision by aquaculture firms using both the conventional maximum likelihood and the Bayesian methods. By comparing the estimates based on these two methods, we are able to examine the robustness of our findings.

The remainder of the paper is organized as follows. We begin with a discussion of the two major components of the analytical framework. Next, the data used in the empirical analysis are described. After discussing the empirical results and policy simulation, we conclude with a summary and some policy implications.

2. Methodology

There are two primary components to our empirical analysis. In the first, we estimate the technical efficiency of producers using nonparametric DEA. In the second, we specify a binary probit model to examine the extent to which socioeconomic factors of the operator, firm characteristics, and geographic heterogeneity may be associated with the decision of the firms to discontinue production. In what follows, we introduce the details of the analysis.

2.1. Estimating technical efficiency

The estimates of the technical efficiencies for aquacultural firms are based on extensions of Farrell's (1957) piece-wise linear convex hull approach to frontier estimation. In 1978, Charnes et al. (1978) extended Farrell's measures of technical efficiency from a single-input, single-output process to a multiple-input, multiple-output process. Since then, this method has been referred to as Data Envelopment Analysis (DEA), and it has been used to estimate the efficiencies for many different types of firms, ranging from firms in the public sector to those in natural resource sectors such as agriculture and the fisheries industry (see Sharma and Leung (1998) for a comprehensive review).

The basic idea underlying DEA is to use linear programming methods to construct a piece-wise surface (a frontier) over the production data for all firms. Measures of technical efficiency for each firm are then calculated relative to that surface (Coelli et al., 2005). This is accomplished by calculating a best performance measure for each firm, and comparing this measure to similarly calculated measures for all firms. In an input-orientated model, a best-practice frontier maps out the minimum level of inputs that could produce the given levels of outputs.

Following Fare et al. (1994), suppose there are $j = 1, \ldots, J$ firms. For simplicity, we assume the jth firm uses N inputs ($x_j = x_{1j}, x_{2j}, \ldots x_{nj}$) to produce one output (y_j). The input-orientated variable returns to scale DEA model of the jth firm is then formulated as (Coelli et al., 2005, pp 172):

$$\underset{\lambda,\theta_j}{Min}\,\theta_j \tag{1}$$

s.t:

$$-y_j + Y\lambda \geq 0, \tag{2}$$

$$\theta x_j - X\lambda \geq 0 \tag{3}$$

$$\lambda \geq 0 \tag{4}$$

$$I1'\lambda = 1, \tag{5}$$