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RESEARCH ARTICLE

Technical and environmental efficiency of hog production in China —A stochastic frontier production function analysis

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Abstract

This article analyses the technical and environmental efficiency of hog production in China using data from the *China Agricultural Product Cost-Benefit Compilation* (NDRC 2005–2013) and the *First National Census of Pollution: Manual of Discharge Coefficient of Livestock and Poultry Industry* (IEDA and NIES 2009). The empirical results show a great variation in environmental efficiency, ranging from 0.344 to 0.973 with a mean value of 0.672 that declines over time. Southwest China is found to be the most environmentally efficient region, while the Northeast and the Northwest are the least efficient. Another finding is that technical and environmental efficiencies are highly correlated in hog production; the most environmentally efficient regions are usually found to have high technical efficiency, and vice versa. In addition, we computed the output elasticities with respect to each factor input. The results show that feed is the most efficient input, with an output elasticity of approximately 0.551, which is much higher than the elasticity of the nitrogen surplus, other capital or labour. The output elasticity with respect to the nitrogen surplus is 0.287 on average. Finally, the scale elasticity in hog production is slightly higher than 1.

Keywords: environmental efficiency, technical efficiency, hog production, China, stochastic frontier production function

1. Introduction

China is the world's largest hog producer. Since the Reform and Opening-Up in 1978, hog production has maintained at least 290 million head and reached 470 million head in 2011, accounting for 48.9% of global total production (FAO 2014). At the same time, with the rapid growth of per capita income and changes in food consumption structure, there has been an increase in pork consumption as the primary source of protein intake. The quantity of per capita available has increased nearly 4.2 times from 7.6 to 39.9 kg between 1975 and 2013[1]; therefore, it not only greatly outnumbers the world level on average but also narrows the gap with the EU countries. In response to the rapid growth of domestic demand for pork, China's livestock production systems have developed from a traditional backyard model

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[1] We found that the data for per capita consumption of pork published by the United States Department of Agriculture (USDA) are higher than those published by the National Bureau of Statistics in China. The data published by the USDA are per capita available and take account of the conditions of domestic production, international trade and wastage.

to a specialized household or enterprise model (Ma *et al*. 2011; Xiao *et al*. 2012). Data show that scale farms with more than 500 slaughtered fattened hogs produced 34% of China's total hog production in 2011[2]. Scale farming has been playing an important role in improving comprehensive hog production capability and ensuring an effective supply of animal products. However, highly intensive farming not only increases the risk of infectious diseases but also boosts the cost and difficulty of faeces treatment (Kautsky *et al*. 2000; Weiss and McMichael 2004). Hog faeces, rich in nitrogen, phosphorus and other organic matter, have been regarded as the primary source of agricultural non-point source pollution. As estimated by the Ministry of Agriculture of China, the faeces excreted by one fattening 70-kg pig in North China contain a total of 33.23 grams nitrogen per day or 10.22 g if some pollutant reduction measures are taken. Leaching the organic nitrogen compounds contained in hog faeces not only leads to water eutrophication (Schofield *et al*. 1990; Baker 2002), but also leads to air pollution, soil contamination, and ecosystem destruction and thus affects human health (Hantschel and Beese 1997; McCulloch *et al*. 1998). In 2001, the Chinese government formulated policies and regulations regarding pollutant emission standards and processing techniques for scale livestock faeces. The No. 1 Central Document in 2013 explicitly proposed conducting control efforts to prevent agricultural non-point source pollution and livestock farming pollution. In this context, hog farmers must utilize input factors in appropriate proportions to improve production efficiency and produce environmentally friendly products by accounting for faeces processing technology and its cost. What is the status quo for technical and environmental efficiency in China's hog production industry? Is there any difference between regions in terms of technical and environmental efficiency? To answer these two questions, we quantitatively calculate the technical and environmental efficiency of the hog production industry.

Heated discussions have been conducted on how to estimate technical efficiency. Sharma *et al*. (1997) estimated the technical efficiency of hog production in Hawaii by using a data envelopment analysis (DEA) model of constant returns to scale and variable returns to scale, but they did not account for undesirable output. The effects of undesirable output were also neglected when Galanopoulos *et al*. (2006) analysed the technical efficiency of commercial hog farming enterprises in Greece and when Rae *et al*. (2006) analysed hog production efficiency and its progress in China. Therefore, when analysing producers' behavior, we should take all outputs into consideration (Shephard and Färe 1974), including undesirable outputs such as wastewater, gas, slag generated by modern factories and waste discharges generated by animal farms. Pittman (1983) was perhaps the first to treat environmentally detrimental factors as undesirable output variables, and he thus constructed the multi-output productivity index of Tornqvist to assess environmental performance. Meanwhile, it is necessary to price undesirable outputs in applications; Pittman (1983) solved this pricing problem by computing the shadow price of the undesirable output. However, his methods could not distinguish differences in shadow prices among individuals. Färe *et al*. (1989) constructed the enhanced hyperbolic productive efficiency model to estimate environmental efficiency based on a multi-output technical efficiency model developed by Farrell (1957). By treating the undesirable output as an output variable, the enhanced hyperbolic productive efficiency model could vary flexibly in accordance with the disposal cost of the undesirable output. Thus, the shadow price can be avoided when using a nonparametric mathematical programming technique known as DEA, but the technique might still calculate the same environmental performance for the majority of the producers. Subsequently, Färe *et al*. (1993), having considered undesirable outputs, developed a parametric mathematical programming technique similar to goal programming to calculate the parameters of a deterministic translog output distance function and estimated the environmental performance of paper and pulp mills in Michigan and Wisconsin. Yang *et al*. (2008) and Yang (2009) further noted that the model assumption developed by Färe *et al*. (1989), using weak disposability to model undesirable outputs, was likely to suffer from certain problems (Yang *et al*. 2008). They utilized undesirable output removal as a proxy for output in pollution and analysed the environmental efficiency and its determinants in the hog production industry in Taiwan of China.

To increase environmental efficiency, measures are taken to decrease undesirable output. The two approaches above, including adjusting the conventional indexes of productivity change and adjusting conventional measures of technical efficiency, have both taken the form of incorporating undesirable output or undesirable output removal into the output vector. A number of studies modelled undesirable output as input to the production function because the relationship between an environmentally detrimental variable and output resembles the relationship between conventional input and output (Pittman 1981; Cropper and Oates 1992; Haynes *et al*. 1993, 1994; Boggs 1997). Reinhard *et al*.

[2] A speech from the vice minister of Ministry of Agriculture of China Gao Hongbin in 2011 National Conference of Standardization of Livestock Breeding. http://www.moa.gov.cn/govpublic/XMYS/201110/t20111025_2387430.htm