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ANALYSIS

Shadow prices and pollution costs in U.S. agriculture

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Abstract

We use the directional output distance function to derive estimates of production inefficiency, shadow prices for polluting outputs, and the associated pollution costs. Using a quadratic functional form for the directional output distance function and data for the U.S. agricultural sector during 1960–1996, we find that the pollution costs (the shadow values) from the runoff and leaching of pesticides are 6% of crop and animal revenues and are highest in the Midwest and lowest in the Western states. If states were to reduce technical inefficiency and operate on the production frontier, pollution costs could be reduced by 7%.

JEL classification: C61; D24; Q10

1. Introduction

A key to the implementation of welfare enhancing agricultural-environmental policies is the measurement of the cost of pollution caused by the production of agricultural products. While the application of pesticides enhances crop yields, a by-product of the application is the contamination of surface and groundwater. Pesticides cause public health impacts, reduce the natural enemies of some insects, cause honeybee and pollination losses, and kill fish and birds. A 1994 report by the U.S. Geological Survey found that 71% of crop land in the U.S. lies in watersheds where at least one agricultural pollutant violates criteria for recreation or ecological health (Smith et al., 1994; Hayward et al., 2000). Pimentel et al. (1992) document that $8 billion of environmental and social costs are associated with pesticide use in agriculture.

The purpose of this paper is to provide a framework for measuring the shadow prices of non-market undesirable or bad outputs that are by-products of some agricultural production process. By exploiting the duality between the directional output distance function and the revenue function, we are able to derive shadow prices for bad outputs and the total

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negative value (cost) of the bad outputs. We apply our theoretical model to the U.S. agricultural sector where land, labor, capital, and material inputs are used to produce crops and animals along with by-products from the runoff and leaching of pesticides into surface and groundwater. In particular, we formalize and estimate a quadratic form of the directional output distance function for a panel of U.S. states during 1960–1996.

Weber and Domazlicky (2001) use directional output distance functions to measure productivity growth in the U.S. manufacturing sector accounting for toxic releases in manufacturing. Similarly, Ball et al. (2000) estimate productivity growth in U.S. agriculture accounting for polluting outputs. When the process of technological change or efficiency change causes an increase in good output production and a decrease in bad output production or vice versa, one can correctly infer either an increase or decrease in economic welfare. However, when technological change or efficiency change causes both good and bad outputs to simultaneously increase or decrease, there is no way to ascertain whether the change has been welfare improving without knowledge of the economic value placed on the good and bad outputs. Thus, estimation of shadow prices for undesirable outputs will enhance our ability to evaluate changes in the production of good and bad outputs. Färe and Grosskopf (1998) show how shadow prices for non-traded desirable and undesirable outputs are derived from the output distance function. Under their method, the ratio of the derivatives of the output distance function with respect to the desirable (good) and undesirable (bad) outputs equals the marginal rate of transformation, which in first-best equilibrium equals the marginal rate of substitution for the consumer.

Coggins and Swinton (1996) and Swinton (1998) employ a translog output distance function to compute shadow prices for sulfur dioxide emissions by electric utilities. Their estimates of the shadow price of sulfur dioxide are in line with the actual prices paid for sulfur dioxide permits by electric utilities. Similarly, Färe et al. (1993) employ a translog output distance function to estimate the shadow prices of undesirable outputs that are by-products of pulp and paper mills. Our approach is similar to these empirical studies, but uses the directional output distance function. This function allows for a simultaneous expansion of good outputs and contraction of bad outputs, unlike the Shephard output distance function, which expands both good and bad outputs to the production frontier. Given policymakers' general interest in reducing polluting outputs, the directional output distance function is a natural way of modeling the production process. Färe et al. (2001) use a quadratic directional output distance function to value the characteristics of Missouri Conservation lands, a non-traded good output.

In the next section we define the output possibility set and derive shadow prices for bad outputs by exploiting the duality between the directional output distance function and the revenue function. Then, we describe the quadratic functional form and estimation technique for implementing a shadow-pricing model. Our choice of the quadratic functional form allows restrictions implied by the translation property (discussed below) to be imposed. We discuss the data and the empirical estimates we obtain for the shadow prices and pollution costs in the U.S. agricultural sector in Section 4. In Section 5 we summarize our method and findings.

2. The theoretical underpinning

In this section we introduce the theoretical framework upon which we base our shadow-pricing model. We start by introducing the underlying production model, here output possibility sets, and impose conditions that allow us to model the joint production of good (desirable) outputs and bad (undesirable) outputs. To make the model tractable we introduce the directional output distance function as a representation of the production model. This distance function inherits its properties from the output set. These properties are derived and they are imposed on our parametric model. We choose the quadratic form as our parametric approximation of the true underlying technology. Once we estimate the model, the shadow prices of the bad outputs are derived using the envelope theorem.

Denote inputs by $x=(x_1, \ldots, x_N)\in R_+^N$, good outputs by $y=(y_1, \ldots, y_M)\in R_+^M$, and bad or undesirable outputs by $b=(b_1, \ldots, b_J)\in R_+^J$. The technology is represented by the output sets $P(x)$, $x\in R_+^N$ where

$$P(x) = \{(y,b) : x \text{ can produce } (y,b)\}. \tag{1}$$