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ANALYSIS

Shadow prices of environmental outputs and production efficiency of household-level paper recycling units in Vietnam

Nguyen Van Ha[a,1], *Shashi Kant*[b,*], *Virginia Maclaren*[c,2]

[a]*Forestry University of Vietnam, Xuan Mai — Chuong My — Ha Tay, Vietnam*
[b]*Faculty of Forestry, University of Toronto, 33 Willcocks St., Toronto, Ontario, Canada M5S 3B3*
[c]*Department of Geography, University of Toronto, 100 St. George St., Toronto, Ontario, Canada M5S 3G3*

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ABSTRACT

The production efficiency and shadow prices of three environmental outputs (BOD, COD, and SS) of 63 household-level paper-recycling units, from a recycling craft village in Vietnam, are assessed A two-stage procedure, linear programming and stochastic estimation, is used to estimate output distance function. Social capital as a production factor and environmental outputs are included in the output distance function. Results indicate that production efficiencies could potentially be improved by 28%. There is a substantial variation in the shadow prices of environmental outputs among the production units of different types of paper products. Furthermore, the average shadow prices of the three environmental outputs are all positive. This indicates a potential for improving environmental quality though introducing pollution-prevention methods to paper-recycling production processes in Vietnam (e.g., recirculation of wastewater), and suggests that it may be inappropriate to restrict the shadow prices of environmental outputs to be non-positive for the analysis of some production processes.

1. Introduction

The growing concerns about environmental problems and the burden placed by industrial activities on environmental quality have prompted scientists to accommodate joint production of good and bad outputs into models of productivity and efficiency analysis. The methods employed include index number approaches, distance functions, and data envelopment analysis. Pittman (1983) was the first to extend the multilateral productivity measurement technique of Caves, Christensen, and Diewert (1982a,b) to include the possibility of undesirable outputs in multilateral productivity and efficiency measurement. Since Pittman's study, many studies (e.g., Färe et al., 1989, 1993, 1996; Yaisawarng and Klein, 1994) have incorporated undesirable outputs into efficiency analysis. More recently, there has been growing interest in using a distance function approach to incorporate environmental outputs into efficiency measurement and to derive shadow prices of undesirable outputs (e.g., Färe et al., 1993; Ball et al., 1994; Yaisawarng and Klein, 1994; Coggin and Swinton, 1996; Hetemäki, 1996; Hailu and Veeman, 2000).

The main advantage of the distance function approach is that it allows production modeling of a multi-input and multi-

* *Corresponding author*. Tel.: +1 416 978 6196.
E-mail addresses: ngvanha@yahoo.com (N. Van Ha), shashi.kant@utoronto.ca (S. Kant), maclaren@geog.utoronto.ca (V. Maclaren).
[1] Tel.: +84 91 511 2686.
[2] Tel.: 1 416 978 1594.

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output technology when the prices of some outputs or inputs are not available or, alternatively, when the prices are available but cost, profit or revenue representations are precluded because of the possibility of violations of the required behavioral assumptions of cost minimization or profit maximization (Färe and Primont, 1995). However, due to a lack of micro level data, most previous studies, except Färe et al. (1989) and Yaisawarng and Klein (1994),[3] have generally concentrated on measuring the effects of undesired outputs using industry or country level aggregate data (Hetemäki, 1996). In addition, these studies have been limited to the large-scale production processes of capital-intensive technologies from developed countries.

The concerns about environmental problems, including the contribution of industrial production processes to environmental pollution, in developing countries are as serious as in developed countries, and should not be neglected. However, many production activities in developing countries are quite different from those in developed countries; the main differences are in the terms of scale of operations, factors, and factor intensity (capital intensive versus labor intensive). In terms of scale, household-level production units are more common in developing countries than in developed countries. Similarly, in terms of factors, there is growing empirical evidence, at least from the rural sector of developing countries, that social capital can help households or small-scale household-level production units to overcome the deficiency of other capitals (Fafchamp and Minten, 2002; Annen, 2001). Many recent empirical studies, at the household-level, such as Narayan and Pritchett (1999), Grootaert (1999), Maluccio et al. (2000), Ruben and Strien (2001), and Ha et al. (2006) have used social capital as a production factor in the household production function and discovered that the contributions of social capital to household output (income) can even be greater than that of human capital and labor. Hence, the incorporation of social capital as one of the factors of the production process is as essential as the incorporation of environmental outputs. In terms of factor intensity, the production units in developing countries use more labor-intensive techniques; whereas firms in industrialized countries use more capital-intensive ones.[4]

Furthermore, most of the distance function studies, except Hetemäki (1996) and Reinhard (1999), constrain the shadow price of undesirable outputs to be negative (weak disposability), which may be a realistic approach for some technologies and countries where environmental regulations are strongly enforced and monitored. However, the possibility of positive shadow prices of undesirable outputs,[5] due to either "technological (biological) restrictions" (Reinhard, 1999, p.61) and/or strong or free disposability due to absence and/or lack of enforcement of environmental regulations (i.e., free disposal of waste or lack of monitoring and enforcement of regulations) cannot be excluded, specifically in developing countries.

In this paper, we extend and strengthen the production and efficiency analysis, in the presence of environmental outputs, to the household-level production processes in developing countries. Our specific case is of household-level paper recycling units[6] in Vietnam. We address all four of the issues (in some sense limitations) mentioned above — scale, factor, factor-intensity, and the restriction on shadow prices. The scale of household-level paper recycling units is many times smaller than the scale in previous studies[7] and we use production unit level (micro-level) data; the production units are labor-intensive; social capital is included as one of the production factors,[8] and we do not impose any restrictions on shadow prices. In addition, the technologies used by these recycling units are local and primitive compared to the mature technologies of pulp and paper production units in developed countries, which have been the focus of previous studies. The Vietnamese household-level paper-recycling units also produce different types of paper — Kraft, votive, tissue, wrapping, and mixed paper. Hence, our analysis also provides a comparative view of shadow prices of environmental outputs for the production processes of different types of paper.

We use output distance function to examine the technical efficiency (output efficiency) of household-level paper-recycling units and to derive the shadow prices of three environmental outputs: biological oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (SS). In contrast to previous studies, except Hetemäki (1996), we use a two-stage estimation procedure in estimating the distance function. The results are used to provide a comparative view of technical efficiency and shadow prices of environmental outputs for pulp and paper production for three cases: (i) household-level units in developing countries versus industrial units in developed countries, (ii) different sizes of household-level production units; and (iii) production units for different types of paper.

[3] These studies used micro data for calculations of technical efficiency; however, they were based on a non-parametric linear programming approach.

[4] For example Färe et al. (1993) studied 30 pulp mills operating in Michigan and Wisconsin, USA. The average value of physical capital used for one ton of paper in these paper mills was 30.36 times greater than that of paper-recycling units in Vietnam (U.S. $2352.42 per ton vs. U.S. $77.49 per ton at 2003 price); whereas the average worker-hour used for one ton of paper in the study by Färe et al. (1993) was 6.13 times less than that of paper recycling units in Vietnam (10.25 worker-hours per ton vs. 62.80 worker-hours per ton).

[5] Hetemäki (1996) also observed that there are no axioms behind the theoretical model that requires the imposition of a restriction of non-positive shadow prices of undesirable outputs. In his study, the bad output (FLOW) was non-regulated and its shadow price was also positive.

[6] Household-level paper recycling units, studied in this paper, are different than the household recycling units, refereed in recycling literature, that source-separate their garbage into recyclable and non-recyclable components. In our study, household-level recycling units produce paper using waste paper, and their operations are organized at household-level. Hence, these units are small-scale paper manufacturing units based on waste paper, but in local language these units are refereed as household-level paper recycling units, and therefore we have used the similar terminology in this paper. Further details about these units are discussed in Section 3.

[7] For example, in the study by Färe et al. (1993) the average production output of the pulp mills was almost 100 times more than the production output of the paper-recycling units in our study (108,055.7 tons vs. 1,084.67 tons).

[8] In this paper, the focus is on shadow prices of environmental outputs and production efficiency. Hence, social capital is included as a factor of production with the objective of avoiding misspecification, non-inclusion of known independent variables, and biased estimation results of the production process. However, due to space limitations, this paper does not include a discussion of the relative shadow prices of social capital with respect to other factors. For a full analysis of social capital as a factor of production for paper-recycling units, please refer Ha et al. (2006).