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Interfaces with Other Disciplines

Technical change and pollution abatement costs[☆]

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ABSTRACT

There is continuing interest in the trend of costs associated with pollution abatement activities. We specify an environmental production technology to model the joint production of good and bad outputs. The joint production model calculates pollution abatement costs and identifies changes in these costs associated with: (1) technical change, (2) input changes, and (3) changes in bad output production. Estimates of the relative importance of each factor are estimated using data from 1995 to 2005 for a sample of coal-fired power plants in the United States. Finally, we discuss the potential usefulness of the decomposition model for identifying discrepancies between ex ante and ex post pollution abatement costs that are linked to the underlying joint production model.

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1. Introduction

In recent decades the United States has enjoyed considerable success in reducing emissions of pollutants – the undesirable byproducts of production and consumption activities. One industry that has attracted considerable interest is the electric power industry. Table 1 lists the net generation of electricity from coal combustion, SO_2 emissions from coal combustion, and SO_2 emissions (in thousands of short tons) per billion kilowatthours (kWh). By 1995, SO_2 emissions per kWh were only 72 percent of the 1989 ratio. With the advent of Phase I of the SO_2 tradable permit program in 1995, the generation of electricity by coal increased by 18 percent between 1995 and 2005, while SO_2 emissions declined by 14 percent. As a result, SO_2 emissions per kWh declined by an additional 27 percent between 1995 and 2005.

If increasing marginal abatement costs characterize pollution abatement, the substantial decline in the SO_2 emission-intensity of electricity production should yield a corresponding increase in pollution abatement costs (PAC).[1] Once a society decides to implement policies to reduce its undesirable byproducts, there are four strategies available to reduce its production of bad outputs: (1) reduce good output production (moving down a given Leontief production ray which results in a proportional decline in good and bad output production), (2) input quality changes (i.e., the most commonly observed is fuel switching), (3) end of pipe (EOP) abatement technologies, and (4) change in process (CIP) abatement technologies. One strategy for measuring the cost of reducing bad outputs is surveying producers about the costs of inputs assigned to pollution abatement. Despite their widespread popularity, these surveys have a major weakness associated with efforts of producers to estimate the abatement costs associated with change-in-process abatement techniques. In this paper, we employ an alternative strategy to address the cost and productivity consequences of reducing the undesirable byproducts of production – modeling the joint production of good and bad output production.

The definition of PAC specified in this paper is not a narrower definition than the cost of inputs approach. Instead, it represents an alternative perspective to assigned input models that require information on the cost of inputs assigned to pollution abatement. In fact, when CGE models are used to assess the cost of regulations to reduce CO_2 emissions, they employ a special case of the joint production model.

This paper will calculate changes in opportunity costs – the foregone production of electricity – of reducing SO_2 emissions and the

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1 This is expected because for a given technology and input vector, a reduction in bad output per unit of good output (i.e., increased emission-intensity) will yield increased pollution abatement costs (i.e., increased levels of foregone good output production).

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Table 1
Trends in SO_2 emissions from coal consumption at electric power plants.

Year	Net generation from coal (billion kWh)	SO_2 emissions from coal (thousand short tons)	SO_2 (1000 short tons)/billion kWh	SO_2/kWh relative to SO_2/kWh in 1989
1989	1554	13,815	8.9	1.00
1990	1560	13,576	8.7	0.98
1991	1552	13,590	8.8	0.99
1992	1577	13,375	8.5	0.95
1993	1642	13,133	8.0	0.90
1994	1640	12,695	7.7	0.87
1995	1658	10,573	6.4	0.72
1996	1743	11,129	6.4	0.72
1997	1793	11,515	6.4	0.72
1998	1823	11,373	6.2	0.70
1999	1832	10,843	5.9	0.67
2000	1911	10,140	5.3	0.60
2001	1852	9281	5.0	0.56
2002	1881	9106	4.8	0.54
2003	1916	9255	4.8	0.54
2004	1921	8991	4.7	0.53
2005	1956	9071	4.6	0.52

Source: U.S. Department of Energy (2011, pp. 238 and 330).

relative importance of the factors associated with changes in PAC. After specifying unregulated and regulated production technologies in which good (net electricity generation) and bad (e.g., SO_2 emissions) outputs are jointly produced, we will demonstrate that changes in PAC between period t and period $t+1$ are associated with three factors: (1) changes in inputs, (2) changes in bad output production, and (3) technical change.[2]

A decrease (increase) in bad output production is associated with an increase (decrease) in PAC, while an increase (decrease) in inputs is associated with an increase (decrease) in PAC. In addition to the direct effect of reduced bad output production, the increased PAC associated with reduced bad output production can also indirectly affect PAC. For example, an increase in the intensity of abatement activities can affect the quantity of inputs employed by a plant as inputs are shifted among plants within an industry and among other industries. Hence, increased abatement activities can be associated with a decline in PAC as a result of a decrease in the quantity of inputs employed by a plant or industry. While it is possible to expand the specification of our model to include factor mobility among plants in an industry, we do not incorporate these indirect effects on PAC into our paper.

Whether technical change is associated with an increase or decrease in PAC, depends on the relative technical change associated with the unregulated and regulated technologies. If unregulated technical change is higher (lower) than regulated technical change, PAC will increase (decrease). One explanation for declining PAC is that as a society imposes environmental regulations, R&D effort is expended on developing processes capable of producing fewer bad outputs per unit of good output (see DeBoo, 1993). As R&D expenditures associated with processes that produce relatively large quantities of bad outputs per unit of good output are reduced, there is a slowdown in technical progress associated with those processes. Eventually, this regulatory induced technical change results in the less bad output intensive processes being capable of producing as much of the good output as the original free disposability (or less-regulated) technology. When this occurs, the opportunity costs of pollution abatement (i.e., good output production reduced as a result of pollution abatement) cease to exist. In summation, while regulations provide incentives for the regulated technology to innovate, no comparable incentives exist for innovation in the unregulated technology. As a result, we anticipate the regulated technology will exhibit higher rates of technical progress than the unregulated technology.

Using data for the twenty two-digit SIC manufacturing industries in the United States for 1970 to 1990, Pasurka (2001) found evidence supporting DeBoo's (1993) hypothesis that the opportunity cost of meeting a hypothetical constraint on emissions declined as a result of the technical change induced by environmental regulations. However, technical change is only one of several factors associated with changes in PAC. This study extends Pasurka (2001) by specifying a formal model that accounts for the association between three factors and changes in PAC.

In this paper we specify a production technology where good and bad outputs are produced jointly. From the original work of Färe and Grosskopf (1983) and Färe, Grosskopf, Lovell, and Pasurka (1989) that focused on the opportunity cost of pollution abatement, applications of the joint production framework – and discussions about the validity of its assumptions – have increased dramatically in recent years. Liu, Meng, Li, and Zhang (2010) and Sahoo, Luptacik, and Mahlberg (2011) discussed different approaches developed by researchers for modeling good and bad outputs when the bad output is regulated. For example, Seiford and Zhu (2002, 2005) and Färe and Grosskopf (2004) discussed different strategies for modeling bad outputs. While Färe and Grosskopf specified a production technology that imposes weak disposability and null jointness,[3] Seiford and Zhu maintained the standard DEA model for good outputs by transforming the values of bad outputs. The transformation was accomplished by multiplying bad output values by "−1" and then adding a translation vector value to each observation to ensure that all transformed bad output values are non-negative. Because the strategy adopted by Sieford and Zhu is not translation invariant, this model may generate different efficiency values than the Färe and Grosskopf models. Leleu (2013) proposed a linearization of the Färe, Grosskopf, and Pasurka (1986) non-linear specification of the joint production model with variable returns to scale. Leleu also proposed a solution to the problem of joint production models generating counter-intuitive signs for the shadow prices of bad outputs. An alternate solution to this problem was recently proposed by Färe, Grosskopf, and Pasurka (2014).

[2] The regulated technology depicts the case when a producer is interested in reducing bad output production. From the perspective of the joint production model, the motivation of the producer is irrelevant. Whether the reduction in the bad output is due to a voluntary action (i.e., a response to consumers wishing to purchase "green" electricity) or involuntary action (i.e., a government imposed regulation), the regulated technology is the relevant technology. The unregulated technology is the relevant technology when the producer is allowed to ignore the bad outputs it produces.

[3] Another variation can be found in Ball, Färe, Grosskopf, and Zaim (2005) which specified a non-parametric cost function with good outputs and bad outputs that are weakly disposable and null-joint.