EMISSION CONTROL: EFFICIENCY IN THE TEXTBOOK MODEL*

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ABSTRACT
The authors of several leading undergraduate textbooks on environmental economics use an MD-MAC model to graphically show and explain emission control. Their analysis, however, is site specific with an individual emission source using a least cost strategy to abate its emissions at a specific location. In this paper I expand the traditional textbook model with a graphical representation of the net gain to society when an emission source changes its venue. Specifically, I use my analysis to evaluate various emission control policies in terms of whether or not an individual policy will bring about the efficient move.

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JEL classifications: Q50, Q58

1. INTRODUCTION
The teaching of environmental economics to undergraduate students has been greatly enhanced by the publication of several textbooks dealing with environmental and natural resource economics and policy. Field and Field (2009), Kahn (2005), Keohane and Olmstead (2007), Kolstad (2010), Tietenberg and Lewis (2009), and Ward (2006) are examples of excellent texts in this area. These authors use a comparative statics analysis to show and explain the economically efficient level of emissions. In their analysis, an emission source reduces its emissions in a cost-effective manner by selecting the best control strategy from a broad array of abatement activities that

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includes output reduction, input changes, technological improvements, waste treatment, residuals recycling, and site abandonment.

Although framed in a broad context, emission abatement is shown at a specific location. In an older text, Downing (1984) discusses changing the location of the emitting source as a way to mitigate environmental damages. Downing expands the traditional textbook criterion of maximizing net benefits by including gains and losses at different locations, and he argues that it is efficient for an emission source to relocate when the net gain to society from a move is positive.

To facilitate discussion of the central issue posed in this paper, a graphical representation of Downing’s model is presented. Although my analysis draws from the conventional emission control model of most introductory environmental economics textbooks, the graphical analysis developed in this paper evaluates the effects of different emission control policies on the net gain to society from a change in the point of discharge. More specifically, this paper raises the question as to what type of emission control policy may bring about the efficient move for a polluting facility. By recognizing the net gain to society from a move, this paper also hopes to engender discussion among teachers and lecturers, especially those teaching courses in introductory environmental economics, about the concept of efficiency.

2. NET GAIN FROM THE MOVE
Downing’s analysis has an emission source located on a waterway which imposes damages on financially separate downstream economic entities. The source is assumed to be discharging an economically efficient amount of emissions at location \( A \) and imposing damages on firms and individuals located downstream at \( B \). If the source relocates to \( C \) and continues emitting at an efficient level, its emissions will result in downstream damages to those at \( D \). In Downing’s analysis, point \( C \) is below point \( B \) on a waterway. Figure 1 shows the flow of emissions as well as the points of discharge and damage. Downing questions whether it is efficient for society to have the emission source change its venue from \( A \) to \( C \). His net gain from the move \((NGM)\) may be expressed in terms of equation (1):

\[ \text{NGM} \]

1 Some authors discuss pollution havens and the location of industry; their analysis is very different from the model developed in this paper.
3. EMISSION CONTROL POLICIES AND THE EFFICIENT MOVE

Equation (1) is illustrated graphically in Figure 2. In my analysis, it is assumed that the emission source is initially located at discharge point A with either downwind or downstream damages occurring at point B. This is shown in panel (i). When the source relocates from A to C, the downwind or downstream damages are at location D. This is shown in panel (ii). Field & Field (2009, p. xvi) argue that the “strength of environmental economics lies in the fact that it is analytical and deals with concepts such as efficiency, trade-offs, costs, and benefits”. I, therefore, consider the effects on efficiency of the source relocation. The efficient levels of emissions and the gains and losses at each location depend on the slope and position of the marginal damage (MD) and marginal abatement cost (MAC) functions.

\[
NGM = TAC_A + TD_B - TRC_{AC} - TAC_C - TD_D
\]

where \( TAC_A \) is the total abatement cost saved when the source is no longer operating at A, \( TD_B \) is the reduction in total damage at B as the result of the move from A to C, \( TRC_{AC} \) is the total cost of relocating from A to C, \( TAC_C \) is the total abatement cost incurred by the source at C, and \( TD_D \) is the total damage at D when the source is discharging at C. If \( NGM \) is positive, the source should relocate downstream. In this case, the move from A to C is efficient and society is better off.\(^2\)

\(^2\) See Downing (1984), pp.82-83.

\(^3\) In my analysis the conventional \( MAC \) and \( MD \) curves are shown. For discussion of alternative shapes to the abatement and damage functions the reader is directed to Field and Field (2009), Kahn (2005) and Ward (2006).
in each panel. The amount of damage occurring at $B$ and $D$ may be affected by such factors as the size of the recipient population at each location and the assimilative capacity of the ambient environment,\(^4\) while the total abatement costs at $A$ and $C$ are likely to be influenced by the age of the emitter’s production facilities and the type of control technology it uses.

\(^4\) This would only occur in the case of a degradable waste.
In keeping with Downing’s analysis, the source generates the efficient amount of emissions at either discharge point.\textsuperscript{5} When the emission source is located at discharge point A in panel (i), $E_{A*}$ is the efficient level of emissions and $E_{AU}$ is the unregulated level. Total abatement cost is equal to area $g$ when the source reduces its emissions from $E_{AU}$ to $E_{A*}$, and total damage at location $B$ is shown by area $r$. When the emission source changes its location, it will discharge at point C. In panel (ii), $E_{C*}$ and $E_{CU}$ are respectively the efficient and unregulated levels of emission with total abatement cost now given by area $m$ and total damage by area $k$. The cost of relocating from site A to C is not shown in my diagram. In this case equation (1) is rewritten as:

$$NGM = \text{Area } g + \text{Area } r - \text{TRCA}_{AC} - \text{Area } m - \text{Area } k$$

When the $NGM$ is positive, the move from A to C is efficient.\textsuperscript{6}

A command and control (CAC) policy, which sets an emission standard at the efficient level, legally requires the source to reduce its emissions from either $E_{AU}$ to $E_{A*}$ or from $E_{CU}$ to $E_{C*}$. In panel (i), area $g$ is the total abatement cost saved when the source ceases to operate at location A and area $m$ is the abatement cost incurred when it relocates to site C. Since a CAC emission standard approach gives the source the right to discharge a specific amount of emissions, the damages given by area $r$ and area $k$ will always be external to the source’s decision to pollute at each location and to its decision to change its venue. In other words, the source does not consider $TD_B$ and $TD_{D}$ in equation (1) when deciding whether it should move from A to C. Although this CAC policy requires the emission source to discharge the efficient emissions at each location, under this policy the source may or may not make the efficient move. The source will move from discharge point A to discharge point C when (area $g$ – area $m$) > $\text{TRCA}_{AC}$, and this move is also socially efficient if $NGM > 0$. As a consequence, a pollution control authority will have to evaluate

\textsuperscript{5} The efficient levels of emission at discharge points A and C are \textit{locally} efficient.

\textsuperscript{6} The traditional textbook model is a single time period analysis with all costs and benefits occurring in the current period. In a more complex model, the move from A to C would still generate a one-time cost but the $MAC$ and $MD$ functions would occur in both the current and subsequent time periods. In this situation one would compare the discounted stream of costs and gains to the one-time cost of moving.
equation (1) to determine whether the move from location \( A \) to location \( C \) is efficient for society.

In contrast, an emission tax per unit of waste discharged may force the emission source to incur a cost that exceeds its downwind or downstream damage. With a tax of \( t^* \) per unit of emissions, the source, depending on its location, makes a cost minimizing decision to reduce its emissions to either \( E_A^* \) or \( E_C^* \). At location \( A \), the source’s pollution related cost consists of its abatement cost given by area \( g \) and its tax bill represented by area \( f+r \). This tax payment is greater than the damage at \( B \) by an amount equal to area \( f \). In similar respect, area \( h \) represents the excess tax payment relative to the damages at \( D \). With respect to equation (1), the emission source experiences a tax savings greater than \( TD_B \) and it incurs a tax expense larger than \( TD_C \). The source in Figure 2, which pays for the right to pollute and at each discharge point operates efficiently, may make a decision that brings about the efficient move from point \( A \) to point \( C \). The source will move when \((\text{area } [f + r + g] - \text{area } [h + k + m]) > TRC_{AC}\), and this move is socially efficient if \( NGM > 0 \). However, the flatter the marginal damage functions, the closer the tax payments will approximate the damages at \( B \) and \( D \). When the marginal damage functions at the downwind or downstream locations are horizontal, tax payments equal damages and a move by the emission source from \( A \) to \( C \) is efficient.

With a system of transferable discharge permits (\( TDPs \)), pollution permits may be initially auctioned off or given away. My analysis begins with the assumption that \( TDPs \) are sold in a competitive market at a price of \( p^* \). As a result, panel (i) of Figure 2 shows that the emission source at location \( A \) will purchase \( Q_A^* \) permits and discharge \( E_A^* \) units of emissions, and that its pollution costs will equal to area \( g \) (abatement cost) and area \( f+r \) (permit cost). The polluter’s permit cost for the discharge of \( E_A^* \) unit of emissions exceeds the damage cost at \( B \) by the area \( f \). Panel (ii) shows the relocation of the emitter to point \( C \) with an abatement cost given by area \( m \) and a permit cost by area \( h+k \). The permit cost now exceeds the damages at location \( D \) by area \( h \). In this scenario, the emission source bears the same pollution related expense as it did with the emission tax and, as previously shown, its decision to move also may be socially efficient. However, when \( TDPs \) are freely allocated, the polluter’s right to discharge is akin to the right granted under the aforementioned \( CAC \) emission
standard approach, and, as discussed, this situation may or may not lead to the efficient move.

A liability rule, which requires an emission source to pay compensatory damages, may bring about the efficient move from upstream to downstream. When a liability rule holds an emission source exactly liable for its damages, the source will internalize a cost just equal to its emission damages. As a consequence, when moving from $A$ to $C$ the source will consider an amount just equal to damages given by $TD_B$ and $TD_D$ in equation (1). Under this scheme, at discharge point $A$ the source pays area $r$ in damages in panel (i) of Figure 2, while at point $C$ it pays area $k$ in panel (ii). Since the source exactly compensates victims for damages and pays the cost of relocating from $A$ to $C$, the move is always efficient.

4. CONCLUDING REMARKS

The model used to frame the discussion of emission control in undergraduate textbooks is site specific. Several years ago, Downing expanded the traditional analysis by considering the net gain to society when an emission source changes its point of discharge. In this paper, the conventional textbook MD-MAC model is used to develop a graphical analysis of the NGM.

My analysis provides additional insight with respect to alternative emission control policies and the socially efficient move. Specifically, it addresses the issue of whether a particular control policy will force an emission source to internalize a cost just equal to its pollution damage and, as a result, make the efficient move. Because downwind or downstream damages are always external to both its decision to pollute and its decision to change location, my analysis shows that with a CAC emission standard approach the emission source’s decision to move is efficient when the net gain from the move is positive.

My model also examines three incentive based policies – an emission tax, TDPs, and a liability rule. It shows that under certain circumstances each of these approaches will lead to an efficient move. In contrast to CAC, incentive based policies require the emission source to pay for the right to pollute. More specifically, my analysis shows that a liability rule and, when marginal damages are constant, either an emission tax or TDPs with initially auctioned permits forces the source to internalize a cost just equal to its damages. As a result,
these moves are socially efficient. There are, of course, other variations of these control strategies and alternative situations that could be evaluated in terms an efficient move. I leave that task to the interested reader.

REFERENCES