Chapter 2

ESSAY 2: ENVIRONMENTAL PERFORMANCE

In this essay we give a selective overview of theory and application of modern axiomatic production theory and optimization models to the analysis of environmental issues. The overview is selective in that we focus on our own work in this area, which was originally motivated by the need to modify the traditional production model to accommodate the analysis of production when there are undesirable byproducts. That is the first issue we take up here—modifying the traditional axioms of production.

Those axioms have implications for the specification of technology, of course, which is what we take up next. Here we start with basic production sets modified to accommodate byproducts, then turn to function representations of technology—namely, distance functions. Since these may also serve as performance measures, we show how these may be modified to account for the fact that increases in byproducts are generally viewed to be undesirable.

Next we show how to use these basic building blocks—the distance functions—to provide us with some simple, but elegant, index numbers which can serve as basic environmental indicators for an industry or economy, for example. This basic index number approach can be elaborated to yield a productivity index which accounts for (and debits) the production of undesirable byproducts. We include an empirical application of this index to identification of an environmental Kuznets curve at

the end of this essay.

Up to this point we have managed to model production with environmental effects and suggest measures of performance without appealing to prices. This is, of course, extremely useful when we are trying to analyze products which are typically not marketed. However, prices are extremely useful information as well. In fact, using our distance functions, and noting that they are dual to support functions such as profit, revenue or cost, we can retrieve underlying shadow prices of the undesirable, non marketed goods.

Finally, we would like to turn to what we refer to as network models. Here one may model externalities and spillovers within and across firms in a simple way, and simulate the effects of various property rights arrangements. We include an example of a network model applied to the case of an environmental externality, which we use to show the effect of various property rights arrangements on profitability.

1. Models with Good and Bad Outputs

In environmental economics one often wishes to distinguish between desirable ($y \in \Re^M_+$) and undesirable ($u \in \Re^J_+$) outputs. In the production context the former is typically a marketed good and the latter is often not marketed, but rather a byproduct which may have deleterious effects on the environment or human health, and therefore its disposal is often subject to regulation. Thus it may be useful to explicitly model the effects of producing both types of outputs, taking into account their characteristics and their interactions. Along these lines we introduce the ideas of **Null-Joint Outputs** and **Weak Disposability of Outputs**.

We begin with modeling the idea that desirable and undesirable outputs may be jointly produced, i.e., u is a byproduct of the production of y. Here we are thinking of, for example, electricity generated from a coal-fired utility. In this case the desirable, marketed output is Kwh of electricity, one undesirable byproduct is SO_2 (others may include particulates and NO_x). The basic environmental problem is that given technology, producing electricity means simultaneously producing SO_2, even though its production is undesirable. Specifically we say that the desirable output vector y is **Null-Joint** with the undesirable outputs u if

$$(y, u) \in P(x), \text{ and } u = 0 \text{ then } y = 0. \tag{2.1}$$