

**ESSAYS ON PRODUCTIVE
EFFICIENCY, SHADOW PRICES,
AND HUMAN CAPITAL**

by

Per-Olov Marklund

Abstract

This thesis consists of five papers, four of them basically concerning environmental issues, while the fifth paper addresses the issue of measuring output from the educational sector.

The first paper starts from the fact that industrial activity causes environmental damage. Therefore, public authorities are called upon to regulate the behavior of producers by, e.g., legislating maximally allowed emission levels, which give rise to abatement costs. In this paper, marginal abatement costs (MACs) are estimated and a procedure to empirically analyze why MACs may vary between producers is suggested. The main focus is on whether the MACs in the Swedish pulp industry reveal that differences between counties in, e.g., economical characteristics, were influential when the authority, during 1983-1990, restricted 12 geographically scattered plants regarding emissions. The result indicates that county differences were influential.

The second paper analyses and suggests a procedure for testing the Porter hypothesis. Part of this hypothesis is based on the argument that increased environmental stringency not only brings a cleaner environment, but also makes the polluting producers aware of the opportunity of using resources more efficiently. The particular test suggested considers whether there is a positive correlation between producers' technical output efficiency and environmental stringency, approximated by a regulatory intensity index. It is empirically applied on 12 Swedish pulp plants during 1983-1990. No support for the Porter hypothesis is found in this particular case.

The third paper deals with the climate policy issue. Under the Kyoto Protocol, the European Union agreed to reduce its emission of greenhouse gases by 8 percent in comparison with the level in 1990. The *Burden-Sharing Agreement* (BSA) further redistributes the 8 percent reduction target among the member states. This paper evaluates the BSA both from an economical and a political perspective, i.e., whether cost-efficiency and equity, respectively, were considered when the BSA was settled. The empirical result indicates that both efficiency and equity were considered as important to the BSA.

The fourth paper evaluates the Swedish *Producer Responsibility Ordinance* (PRO), fully implemented in 1994, which states that sorted out, domestically collected waste paper, must be recycled by the paper industry and, therefore, cannot be incinerated by the heating industry in purpose of recovering energy. The result indicates that this policy has contributed to inefficient waste paper allocation among some of the paper producers. The result further indicates that the priority made by the PRO, i.e., that waste paper recycling is preferable to incineration, should be reconsidered.

The fifth paper relates the empirical attempts of measuring output from the educational sector to theoretical results about the welfare significance of a comprehensive *Net National Product* (NNP) measure. It is shown that economic theory provides a more focused way of interpreting such output estimates. The paper also contains estimates of the output from the Swedish educational sector. Among the results, it is shown that the private gross output value produced by higher education is approximately 2 percent of GDP. Furthermore, the private rate of return on investments in higher education in Sweden is calculated to 8.6 percent.

Acknowledgement

During my work with this thesis, many people have contributed to a greater or lesser extent. I am especially grateful to my supervisor professor Thomas Aronsson, who has contributed with comments and suggestions that have been invaluable. His very fast and careful reading must indeed be emphasized, and his engagement is very much appreciated.

I would also like to thank professor Runar Brännlund for supervising during my work with the Ph Licentiate thesis, which has served as a preparation for part of this PhD thesis, and for lending his data.

Associate professor Mikael Bask, PhD Jonas Nordström, associate professor Magnus Wikström, and all participants at my preparatory seminar, provided me with helpful comments and suggestions that have significantly improved my work. In this context I would also like to thank professor Kurt Brännäs for various hints and for answering questions regarding econometrics.

I have had the privilege of co-authoring three of the included papers. One of them with professor Thomas Aronsson and professor Karl-Gustaf Löfgren, names highly esteemed within the subject of economics. Two papers have been co-authored with PhD Eva Samakovlis. Besides being a very good friend, she is a competent and inspiring colleague as well as very generous with her time. She is always open for questions and discussions that have facilitated my work on everyday basis, including reading my manuscripts.

Furthermore, I would like to thank PhD Linda Andersson for some computational assistance, associate professor Roger Axelsson for helpful comments regarding the introductory chapter, and PhD student Dick Svedin for contributing with some graphics. I am also very grateful to Marie Hammarstedt for helpful proof reading and help with practical matters involved with finishing this thesis.

To colleagues at the Department of Economics, not mentioned by name, all support has thankfully been received.

Finally, and most important, I emphasize my gratitude to my family, especially to Marlene for her love and support.

Umeå in January, 2004

PER-OLOV MARKLUND

List of papers

This thesis consists of an introductory part and five papers. In the introduction, the papers are referred to by the numbers in brackets.

[I] Marklund, P-O. (2003) "Analyzing Interplant Marginal Abatement Cost Differences: A Directional Output Distance Function Approach", *Umeå Economic Studies*, No 618, Umeå University.

[II] Marklund, P-O. (2003) "Environmental Regulation and Firm Efficiency: Studying the Porter Hypothesis using a Directional Output Distance Function", *Umeå Economic Studies*, No 619, Umeå University.

[III] Marklund, P-O. and E. Samakovlis (2003) "What is Driving the EU Burden-Sharing Agreement: Efficiency or Equity?", *Umeå Economic Studies*, No 620, Umeå University.

[IV] Marklund, P-O. and E. Samakovlis (2003) "Reuse or Burn? Evaluating the Producer Responsibility of Waste Paper", *Journal of Environmental Planning and Management*, **46**(3), 381-398. (Reprinted with permission from Sarah King, Permissions Manager. Journal web site: <http://www.tandf.co.uk>)

[V] Aronsson, T, K-G. Löfgren and P-O. Marklund (1999) "On Output of the Swedish Education Sector: Additional Remarks", *Review of Income and Wealth*, **45**(4), 535-542. (Reprinted with permission from Edward Wolff, Managing Editor)

1 INTRODUCTION

This thesis consists of five papers, which can be separated into two categories. Papers [I] – [IV] focus on different environmental issues, and paper [V] deals with the problem of estimating output from the educational sector.

The first category of papers, [I]-[IV], adopts an approach focusing on producer behavior in the sense that they are based on production theory. Specifically, they all rely on the concept of productive efficiency in the spirit of Farrell (1957). He showed that a measure of overall efficiency could be decomposed into technical and allocative (price) efficiency measures. In papers [I]–[III] the production technology is characterized by a directional output distance function, which measures technical output efficiency. Some fundamental issues addressed in these three papers are, e.g., why shadow prices of pollutants may vary across producers, and how to consider that shadow prices vary across countries when forming a global environmental policy. Another issue addressed is how environmental regulations affect technical efficiency, which is related to the Porter hypothesis. In paper [IV], the technology is characterized by a standard production function. In this case shadow prices of a particular input is computed and used to study the pursued environmental policy and its effects on allocative efficiency.

The second category of papers includes paper [V], which focuses on how to measure output from the educational sector in context of social accounting and welfare measurement. The basic idea is that education can be thought of as an investment in human capital that gives a return in term of higher lifetime income. Therefore, output from the educational sector is measured by the present value of future income that follows from additional education.

The remaining part of this introductory chapter is structured as follows. Section 2 presents the fundamentals behind the methodologies adopted in papers [I]-[V]. First, the Shephard output distance function and the directional output distance function are outlined and compared. The shadow-pricing models associated with these functions are also described. Second, I will address some issues referring to

social accounting and welfare measurement in the presence of human capital. Finally, Section 3 offers a summary and conclusions for each paper.

2 METHODOLOGIES

In this section the fundamentals behind the methodologies in papers [I]-[III], and [V] are shortly outlined.¹

2.1 Output distance functions

Papers [I]-[III] are based on production theory, where an output distance function characterizes the technology in each case. Formally, let $y = (y_1, \dots, y_M) \in \mathfrak{R}_+^M$ and $b = (b_1, \dots, b_J) \in \mathfrak{R}_+^J$ be vectors of good and bad outputs, respectively, and let $x = (x_1, \dots, x_N) \in \mathfrak{R}_+^N$ be a vector of inputs. The technology is theoretically described by the output possibilities set $P(x)$, which, for a given vector of inputs, denotes all technically feasible output vectors. Output distance functions can then be defined on $P(x)$ and, therefore, inherits the properties of the technology.

Färe et al. (1993) employ the output distance function introduced by Shephard (1970). This function is defined on $P(x)$ as

$$D^S(x, y, b) = \inf_{\beta} \left\{ \beta : \left(\frac{y}{\beta}, \frac{b}{\beta} \right) \in P(x) \right\} \quad (1)$$

where the solution, $\hat{\beta}$, gives the maximum expansion of both good and bad outputs. That is, a technically feasible output vector, (y, b) , is scaled until it reaches the boundary of $P(x)$, and $\hat{\beta}$ reveals the distance that (y, b) is scaled. In Figure 1, this is represented by a movement from (y, b) to point B. This means that the producer is interpreted as becoming more technically output efficient

¹ Paper [IV] is left out since it is based on a rather standard approach. A cost minimization problem is formulated, given relevant restrictions. Then the resulting first order conditions are used to define an input shadow-pricing model. Consequently, shadow prices of inputs are derived from a standard production function.

when simultaneously increasing both good and bad outputs proportionally. However, this particular feature can be questioned. An efficiency improvement, by expanding all outputs proportionally towards the technology frontier, will indeed bring the producer gains, but this will occur at the same time as creating additional environmental damage due to larger production of bad outputs. If reduced production of bad outputs is desirable, the directional output distance function constitutes an appealing alternative to measuring technical output efficiency.

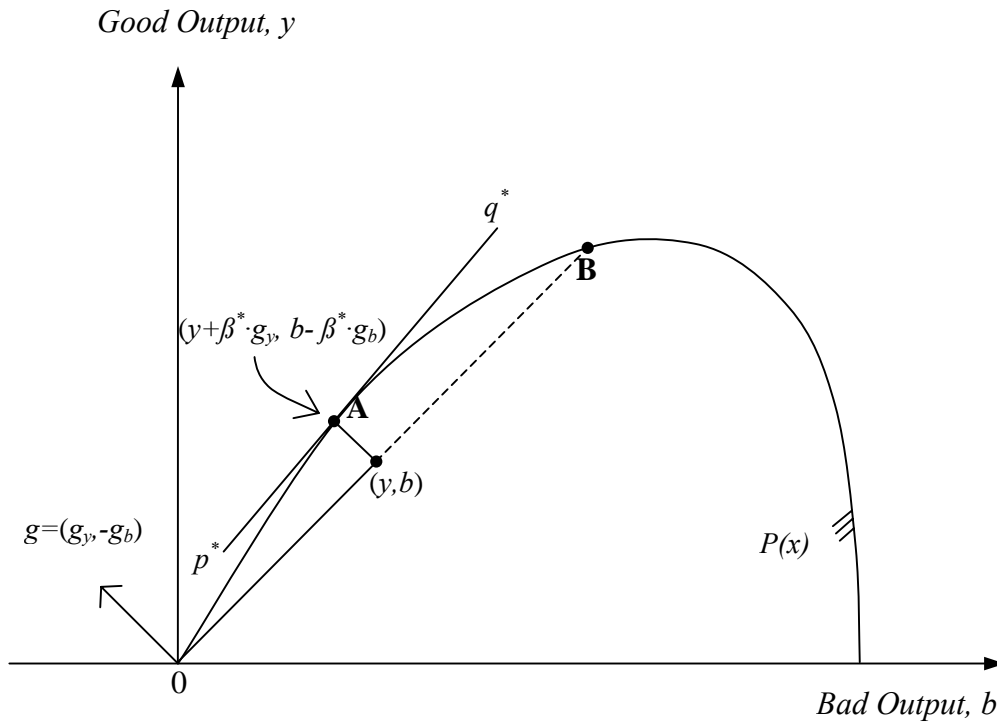


Figure 1 Output distance functions and shadow-pricing

Färe et al. (2002) employ the directional output distance function, which can be defined on $P(x)$ as

$$D(x, y, b; g) = \max_{\beta} \{ \beta : (y + \beta \cdot g_y, b - \beta \cdot g_b) \in P(x) \} \quad (2)$$

where the solution, β^* , gives the maximum expansion and contraction of good and bad outputs, respectively. In this particular case, the vector $g = (g_y = 1, -g_b = 1)$ specifies the direction of scaling. In Figure 1, the movement

from (y, b) to point A is consistent with the distance function in (2). Accordingly, the efficiency measure gives the extent to which the producer can increase the production of good outputs and decrease the production of bad outputs. The efficiency improvement in Figure 1 will in this case bring the producer private gains. It will also give rise to a cleaner environment due to less production of bad outputs. In papers [I]-[III] the production technology is characterized with the distance function in (2).

In paper [II], where the Porter hypothesis is tested, the choice of distance function may be of particular relevance. The hypothesis says that environmental regulations lead to more efficient producers. In this context, the usage of the Shephard output distance function in (1) to compute efficiency scores might be problematic, since it credits simultaneous expansion of both good and bad outputs.²

2.2 Shadow-pricing models

In earlier literature, shadow prices of environmental damaging substances have mainly been calculated to investigate whether the pollutant control requirements, imposed on producers, are allocating resources efficiently, i.e., promoting cost-efficiency. These calculated prices have also been used to construct productivity indices, see, e.g., Pittman (1983) and Reig-Martínez et al. (2001). One of the first attempts to estimate shadow prices of a pollutant was made by Pittman (1981), who specified a restricted profit maximization problem, which treats the pollutant in focus as a conventional input. Färe et al. (1993) present a shadow-pricing model, where the pollutants are treated as undesirable by-products, i.e., as bad outputs. Specifically, given that $p = (p_1, \dots, p_M) \in \mathfrak{R}_+^M$ and $q = (q_1, \dots, q_J) \in \mathfrak{R}_+^J$ represent absolute shadow prices of good and bad outputs, respectively, and that the shadow prices are derived from the Shephard output distance function in (1), the shadow-pricing formula can be written as

² Earlier studies that explicitly test the efficiency part of the Porter hypothesis are Hetemäki (1996b) and Marklund (1999). Other studies that investigate the impacts of environmental regulation on efficiency, but not in the purpose of explicitly testing the Porter hypothesis, are Boyd and McClelland (1999) and Hernández-Sancho et al. (2000).

$$\frac{q_j}{p_m} = - \left(\frac{\partial D^s(\cdot)}{\partial b_j} \bigg/ \frac{\partial D^s(\cdot)}{\partial y_m} \right) \quad (3)$$

which is the marginal rate of transformation between the j :th bad output and the m :th good output, MRT_{jm} . Therefore, the shadow price can be interpreted as the marginal abatement cost (MAC) in terms of decreased production of y_m that has to be met when reducing b_j marginally. In this case, the shadow price that counts for (y, b) in Figure 1 is calculated as the tangent at point B. Other studies using this shadow-pricing approach are, e.g., Coggins and Swinton (1996), Hetemäki (1996a), Marklund (1999), Swinton (1999), and Reig-Martínez et al. (2001). Färe et al. (2002) suggest a shadow-pricing model that is derived from the directional output distance function in (2), which allows for a different direction of scaling. In this case, the formula can be written as³

$$\frac{q_j}{p_m} = - \left(\frac{\partial D(\cdot)}{\partial b_j} \bigg/ \frac{\partial D(\cdot)}{\partial y_m} \right) \quad (4)$$

which reflects the shadow price relation, $q^* - p^*$, in Figure 1. This means that the shadow price counting for (y, b) is now calculated as the tangent at point A.

2.3 Welfare measurement in the presence of human capital

Paper [V] is based on the theoretical work of Aronsson and Löfgren (1996). They address social accounting and welfare measurement in an economy where human capital is present. To begin with, Weitzman (1976) made a scientific finding crucial to welfare measurement. He showed that in a perfect foresight intertemporal economy with a stationary technology and perfect competition, a comprehensive *net national product* (NNP) measure is proportional to the present value of future utility. This result implies that welfare can be measured from

³ A similar shadow-pricing model was introduced in Färe et al. (2001). However, on that occasion, bad outputs were not included.

Introduction

variables that are observable (or recoverable) at the time when the measurement is conducted.

Aronsson and Löfgren (1993, 1995) show that if technological change is disembodied the comprehensive NNP will still be incomplete as a welfare measure. In this case, technological change affects future consumption possibilities and welfare will, therefore, depend on time itself. Aronsson and Löfgren (1996) state that this incompleteness, to some extent, arises from labor augmenting effects of human capital not being accounted for. They also emphasize that the comprehensive NNP measure is still incomplete if not adding the value of the positive externalities that may originate from the stock of human capital. Within a Ramsey type growth model Aronsson and Löfgren (1996) take account of these two aspects of human capital and derive a complete comprehensive NNP measure in utility terms. They specify the production function such that the stock of human capital affects the marginal productivity of labor. This means that the consumer's incentive to invest in human capital follows from increasing marginal productivity, leading to an increase in the wage rate. Furthermore, the production function is specified such that the human capital stock is included as a separate argument. This means that human capital will have a direct effect on the production. Since the consumer is only paid for his/her input of labor, there are no reasons to believe that he/she will supply the socially optimal level of human capital. Therefore, there will be a positive external effect via the human capital stock in the production function. Furthermore, accumulation of human capital is, as conventionally, assumed to depend on time spent in education.

In practice, the return from investments in human capital is measured by the resulting increase in lifetime income. The positive external effect is overlooked due to measurement difficulties. Jorgenson and Fraumeni (1992a, 1992b) suggest a model to empirically measure the output from the educational sector, i.e., the value of additions to the human capital stock, as an increase in the present value of lifetime income following additional education. Exactly the same model is applied in Ahlroth et al. (1997). They present estimates of output from the educational sector in Sweden. While sympathizing with the general idea of

measuring output in the manner done in these papers, it is emphasized in paper [V] that economic theory brings a more focused way of presenting the results, which adds an important welfare dimension.

3 SUMMARIES OF PAPERS

Paper [I]: Analyzing Interplant Marginal Abatement Cost Differences: A Directional Output Distance Function Approach

The purpose of this paper is to compute and evaluate shadow prices of bad outputs. The background is that many types of human activities have negative side effects on the environment. These effects may be due to produced bad outputs, i.e., undesirable by-products from different production processes. Therefore, to limit the environmental damages, public authorities are called upon to regulate the performance of polluters. If environmental regulations force producers to increase the sharpness of their abatement efforts, they also face increased abatement costs that can be studied. For instance, computed shadow prices, i.e., marginal abatement costs (MACs), of bad outputs, can be used to find out which factors that influence the regulatory authority's stringency of environmental regulations to be imposed on polluters.

In this paper, the Swedish pulp and paper industry during 1983-1990 is being studied. To limit the emission into the water, the regulatory authority, which by law was prescribed to consider the polluters' technological possibilities of abating and the sensitivity to emissions in the affected surrounding environment, granted each producing plant permits that specify maximally allowed emission levels.⁴ However, during the handling of each such case, area residents and other parties concerned were allowed to express their views, which possibly introduced additional factors which may influence the amount of finally granted permits and, therefore, the MACs.⁵ This paper seeks the answer to whether also regional differences, in, e.g., economical characteristics, were important when the

⁴ The Swedish Environmental Protection Agency (2003).

⁵ The National Licensing Board for Environment Protection (2003).

Introduction

authority restricted 12 geographically scattered pulp plants with respect to emissions.

As a first step, shadow prices, reflecting MACs of oxygen-demanding substances and suspended solids, are computed for each pulp plant and compared to each other through non-parametric tests. These tests reveal that MACs vary significantly between plants. The approach adopted to compute the shadow prices originates from Färe et al. (2002). The model is founded on production theory, where technology is represented by the directional output distance function, from which the shadow prices are derived. The distance function is specified as a quadratic flexible functional form and estimated by a linear programming technique. In a second step, the computed MACs are regressed on a set of variables in an attempt to explain their variation across plants. Hypotheses concerning variables such as regional tax base and population density, and variables describing the situation on the regional labor market, are suggested. Also, fixed and time specific effects are modeled. The fixed effects are included to capture the effects from factors prescribed by environmental law, such as differences across plants regarding technological possibilities to abate, and the sensitivity to emissions in the affected surroundings, where each plant is located.

The result indicates that there are regional factors, not regulated by environmental law, which may influence the actually pursued environmental policy. For instance, the larger the relative size of the pulp and paper industry in the county, the lower the MAC of suspended solids for plants located in that county. This indicates that these plants were targets of laxer environmental regulation. Also, a higher county population density seems to have created opportunities for people to influence the actual policy pursued. This study shows that population density had different influences on the two types of emissions. In the case of oxygen-demanding substances, the density contributed negatively to the plants' MACs, indicating that plants located in counties with higher density were targets of laxer environmental regulation. On the other hand, in the case of suspended solids, the density contributed positively to the plants' MACs. That is, plants located in counties with higher population density were more stringently regulated.

Paper [II]: Environmental Regulation and Firm Efficiency: Studying the Porter Hypothesis using a Directional Output Distance Function

This paper is devoted to proposing a procedure to empirically test the Porter hypothesis, introduced in Porter (1991) and further developed in Porter and van der Linde (1995). The dominating argument of the hypothesis is that environmental regulation not only increases environmental quality, but also provides information, which makes the producers more aware of state of productivity and possibilities to improve competitiveness. The productivity change is divided into an efficiency change and a technological change.⁶

The procedure suggested is general in the sense that it can be applied to any production process at the firm, industry, or country level. It provides a tool to study the efficiency part of the Porter hypothesis, which argues that producers use resources inefficiently and that environmental regulation sends signals about these inefficiencies and induces producers to change their behavior. The hypothesis may be empirically analyzed by testing whether there is a positive significant correlation between producers' technical output efficiency and environmental regulation.⁷

Technical output efficiency is first estimated using a methodology that originates from Färe et al. (2002). The production technology is represented by the directional output distance function, which is defined to credit a simultaneous expansion of good outputs and contraction of bad outputs. The distance function is further specified using a quadratic flexible functional form and computed by a linear programming technique. Then, by regressing the obtained efficiency scores on environmental regulatory stringency, approximated by a regulatory intensity index that measures the difference between the unconstrained and the maximally allowed emission rate, the Porter hypothesis is explicitly tested.

⁶ The Porter hypothesis has been heavily criticized by economists who argue that the hypothesis lacks theoretical foundation, see, e.g., Palmer et al. (1995). However, there are also theoretical papers that partly find support for the hypothesis, see, e.g., Xepapadeas and de Zeeuw (1999), Mohr (2002), and Ambec and Barla (2002).

⁷ The empirical relationship between environmental policy and technological change is left aside. However, Jaffe et al. (2002) provide a thorough guide to the literature on this topic. See also Jaffe et al. (1995).

The suggested test procedure is applied on 12 Swedish pulp plants during 1983-1990. The result shows no support for the Porter hypothesis. That is, the test provides no evidence that environmental regulation made the pulp plants more resource efficient during the period under study. However, the opposite cannot be concluded either, i.e., that regulation made the plants less resource efficient.

Paper [III]: What is Driving the EU Burden-Sharing Agreement: Efficiency or Equity?

This paper provides an analysis of the European Union (EU) greenhouse gases (GHGs) policy. The Climate Convention was signed in 1992 with the objective to stabilize concentrations of GHGs. Explicit objectives and measures to be taken were settled in Kyoto, resulting in the adoption of the Kyoto Protocol in December 1997. Under the Protocol, EU committed itself to reduce the emission of 6 GHGs by 8 percent during 2008-2012, in comparison with the 1990 level. It was further agreed that EU could redistribute the assigned GHGs reduction target among the member states. The Climate Convention gave no clear guidelines on how to accomplish the redistribution, but emphasized the importance of equity and cost-efficiency. Which national circumstances that should be considered were much discussed. However, the Triptych study (Phylipsen et al., 1998) served as an advisory document and possibly influenced the final outcome. The Triptych study suggests that emissions are ‘equitably’ redistributed among countries if national circumstances such as population size and growth, standard of living, economic structure, energy efficiency in power generation, and climate are taken into account. However, how to actually redistribute GHG emission changes was agreed politically among the EU member states in 1998, and is referred to as the *Burden-Sharing Agreement* (BSA).⁸ It resulted in a differentiation of the EU GHGs emission reduction target, where half of the member states reduce their emissions and the rest stabilize, or even are allowed to increase, emissions. The BSA was reaffirmed by joint ratification of the Kyoto Protocol in 2002, where it became binding international law.

⁸ The Commission of the European Communities (2000).

Introduction

Many economic analyses, following the adoption of the Kyoto Protocol, have focused on analyzing the market for GHGs emission trading. The main conclusion of these studies is that trading improves cost-efficiency, lowering the cost of implementing the Protocol. Overviews of such studies are provided in Metz et al. (eds.) (2001), and in Weyant and Hill (eds.) (1999). Jointly for these studies is that they do not question the BSA, but take it for granted. However, Eyckmans et al. (2002) question the BSA, and they conclude that even if richer member states have been assigned relatively high abatement efforts and poorer ones are allowed to emit more, this differentiation does not go far enough. A disadvantage of their analysis is, however, that it covers only CO₂ emissions from state energy use. In paper [III] the analysis covers total state emissions of GHGs in accordance with the BSA, and the main purpose is to evaluate the BSA from both an economical and a political perspective. This means performing hypothesis tests of whether cost-efficiency and equity, respectively, were considered in the BSA settlements.

Variables used to perform the equity tests are chosen on the basis of the Triptych study and are readily available. However, the marginal abatement cost (MAC) variable, used to test the cost-efficiency hypothesis, must be computed. Therefore, as a first step, aggregate production data are used to compute MACs for each of the 15 EU Member States in each year of the period 1990-2000. A shadow-pricing model approach, suggested by Färe et al. (2002), which includes estimation of the directional output distance function, is adopted for that purpose. Furthermore, the distance function is estimated by using both a Corrected Ordinary Least Squares (COLS) technique and a Linear Programming (LP) technique, the latter suggested by Färe et al. (2002).⁹ Finally, in a second step, the hypothesis tests are made possible by regressing the BSA emission change figures on the MAC and equity variables, together with other variables that potentially had an influence on the BSA.

A general conclusion drawn in paper [III] is that efficiency did not rule out equity, and vice versa, when settling the BSA. For instance, the results indicate that

⁹ The COLS approach is used in Lovell et al. (1994), where a Shephard output distance function is estimated. Also, regarding the COLS estimator, see, e.g., Greene (1993).

efficiency arguments may have had an influence on burden-sharing, i.e., indicate that EU Member States with higher MACs of GHGs were assigned easier emission change requirements, and vice versa. Furthermore, the results also indicate that equity arguments may have been important, i.e., indicate that countries with lower standard of living, in terms of consumption, were assigned easier emission change requirements.

Paper [IV]: Reuse or Burn? Evaluating the Producer Responsibility of Waste Paper

The purpose of this paper is to evaluate the Swedish *Producer Responsibility Ordinance* (PRO), which prioritizes material recycling and, e.g., explicitly states that sorted out, domestically collected waste paper must be recycled by the paper industry and, therefore, cannot be incinerated by the heating industry. The history on the policy and the handling of waste paper in Sweden goes back to the mid-seventies, and is described in detail in Samakovlis (2001). However, the Packaging Committee presented new guidelines in 1991 for handling the waste, with the purpose of harmonizing with the EU Commission on packaging waste. These guidelines gave material recycling the highest priority. The resulting PRO in Sweden was gradually introduced in 1992, and fully implemented in 1994.¹⁰ For the PRO to work, Swedish producers established package waste corporations, responsible for ensuring that collections are organized and goals reached.¹¹ In every municipality, these corporations select responsible contractors, which collect, sort, and bundle the waste paper, and then sell it to the paper industry.¹² To finance the activities invoked by the PRO, a weight-based fee is levied on packaging for producers to pay, which, according to Fölster (2000), is transferred to the consumer through higher product prices.¹³ On the other hand, the

¹⁰ Regulated by government provisions SFS 1994:1235 (packaging) and SFS 1994:1205 (newspapers, etc.).

¹¹ For paper, the companies are Svensk Kartongåtervinning AB (paper and cardboard packages), RWA Returwell AB (corrugated cardboard packages), Pressretur AB (waste paper, i.e., newsprint, etc.).

¹² IL Recycling and Stena Returpapper are respectively contracted in 194 and 70 of 289 municipalities (Förpackningsinsamlingen, 2000).

¹³ The cost for one household due to higher product prices is evaluated to being around 140 SEK/year.

Introduction

corporation responsible for newsprint, Pressretur AB, claims that the producers carry the whole cost (Palm, 2000).

If successful, the PRO forces the Swedish paper plants to reuse all the domestically collected waste paper. However, the other option of incinerating waste paper to recover energy could be appealing, especially to sparsely populated areas, far from waste paper using plants.¹⁴ Heating plants also argue that increased waste paper recycling implies a lower energy supply. They consider waste paper to be a relatively energy-rich fuel.¹⁵

The economic literature on the PRO is scarce. However, Radetzki (1999) found that the PRO is very cost-inefficient and that a considerable net burden is put on society for small environmental improvements. From other literature such as life-cycle studies, that investigate environmental impacts throughout a product's life from raw material acquisition, through production, use, and disposal, e.g., Virtanen and Nilsson (1993), IIED (1996), and Finnveden and Ekvall (1998), it cannot be determined whether recycling or incineration is better from an environmental perspective.

Paper [IV] questions the PRO and suggests that recovering energy by incinerating waste paper must be considered as an attractive alternative when forming environmental policy. The point of departure is straightforward; as long as there exists no unambiguous scientific conclusion regarding whether recycling or incineration is better from an environmental perspective,¹⁶ it is reasonable to assume that the environmental net effects from the two alternatives are equal. Therefore, the environmental effects can be disregarded and a PRO evaluation can be limited to analyzing its effects on waste paper allocation. First, to determine whether the PRO has affected waste paper allocation in the Swedish paper

¹⁴ Kiruna, e.g., in northern Sweden, transports waste paper to paper plants in southern Sweden at the same time as it imports waste paper to supplement the energy needs of the local heating plant (Rutegård, 1999).

¹⁵ Generally, as the waste paper content increases, the quality of municipal solid waste as a fuel improves (Svedberg, 1992). Energy from incinerating waste paper would be a clean source of energy, if some of the chemicals and heavy metals used in the pulp, paper and board, and printing process were replaced with more benign materials (Virtanen and Nilsson, 1993).

¹⁶ See, e.g., Finnveden and Ekvall (1998).

Introduction

industry, waste paper shadow prices, reflecting marginal user values, are calculated for a period before the PRO implementation and for a period after. The shadow prices can then be compared with the actual prices paid in each period, which is done by using bootstrapped confidence intervals for the shadow prices. The results indicate that the shadow prices for plants using small quantities of waste paper were lower than the observed market prices during 1992-1996.¹⁷ The difference is interpreted such that the PRO policy forced these particular plants to use more waste paper than they otherwise would have done, being a source of inefficient waste paper allocation. Second, to evaluate the hierarchy of waste paper recycling being preferable to incineration, waste paper shadow prices are calculated for both the Swedish paper and heating industries.¹⁸ The results show that there was no significant difference between the two industries' marginal valuation of waste paper before the implementation. Therefore, the priority of recycling all the collected waste paper, instead of letting part of it be used to recovering energy, should be reconsidered.

Paper [V]: On Output of the Swedish Education Sector: Additional Remarks

The main purpose of this paper is to relate the empirical attempts of measuring output from the educational sector to theoretical results about the welfare significance of a comprehensive *Net National Product* (NNP) measure. Basically, referring to Aronsson and Löfgren (1996), the comprehensive NNP is derived for a perfect foresight intertemporal economy, where human capital is present and gives raise to a positive externality. Within this framework, the welfare contribution from the educational sector is valued as the private return of an increase in the stock of human capital, plus the external effects arising from an addition to the stock of human capital. The private return is the increase in lifetime income due to additional education. The fundamental idea is then that part of the output from the educational sector can be estimated as the present value of the future income it generates.

¹⁷ Paper plants were divided into small waste paper users (using 5000-69000 ton waste paper) and large waste paper users (using 70000-360000 ton waste paper).

¹⁸ Shadow prices are calculated only for the period before the PRO implementation, since after the implementation all domestically collected waste paper is recycled.

Introduction

For the purpose of estimating the increase in the present value of lifetime income from a small investment in human capital, an empirical approach originating from Jorgenson and Fraumeni (1992a, 1992b) is used.¹⁹ The estimating procedure is performed on data from the Swedish *Standard of Living Survey* (LNU), which is a household panel-data base containing data collected in 1968, 1974, 1981, and 1991. It contains individual data on, e.g., wages, number of hours worked, and the number of years of schooling. These data are used to estimate a wage equation, where the number of years of schooling approximates the human capital stock. This equation is combined with a ‘number of hours worked’ equation and a ‘probability to work’ equation in order to estimate the gain in terms of future income from an additional year in education.

The outcome of the estimating procedure shows that the private gross output value produced by higher education is approximately 2 percent of GDP.²⁰ Furthermore, by finding the interest rate which makes net output equal to zero, the private rate of return on investment in higher education is calculated to 8.6 percent, which corresponds reasonably well with earlier attempts to calculate the private rate of returns to higher educations in Sweden.²¹ It is worth emphasizing that the external effects from the educational sector are not measured by the adopted empirical method. It is possible that the contribution to welfare from the externalities associated with human capital is extensive.

¹⁹ Details regarding the model specification are available in Löfgren and Marklund (1996).

²⁰ High school and university/college are referred to as higher education.

²¹ See, e.g., Edin et al. (1993). They calculate the rate of return both before and after taxes and subsidies. However, they do not calculate output at the product wage (including the employer’s wage tax). This means that the figures are not directly comparable.

REFERENCES

- Ahlroth, S., A. Björklund and A. Forslund (1997) "The Output of the Swedish Education Sector", *Review of Income and Wealth*, **43**: 89-104.
- Ambec, S. and P. Barla (2002) "A Theoretical Foundation of the Porter Hypothesis", *Economic Letters*, **75**: 355-360.
- Aronsson, T. and K-G. Löfgren (1993) "Welfare Consequences of Technological and Environmental Externalities in the Ramsey Growth Model", *Natural Resource Modeling*, **7**(1): 1-14.
- Aronsson, T. and K-G. Löfgren (1995) "National Product Related Welfare Measures in the Presence of Technological Change, Externalities, and Uncertainty", *Environment and Resource Economics*, **5**: 321-332.
- Aronsson, T. and K-G. Löfgren (1996) "Social Accounting and Welfare Measurement in a Growth Model with Human Capital", *Scandinavian Journal of Economics*, **98**(2): 185-201.
- Boyd, G. A. and J. D. McClelland (1999) "The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plants", *Journal of Environmental Economics and Management*, **38**: 121-142.
- Coggins, J. S. and J. R. Swinton (1996) "The Price of Pollution: A Dual Approach to Valuing SO₂ Allowances", *Journal of Environmental Economics and Management*, **30**: 58-72.
- Commission of the European Communities (2000) *Green Paper on Greenhouse Gas Emissions Trading within the European Union*, COM(2000) 87 final (presented by the Commission).
- Dessai, S. (1999) A Critique of the EU Burden Sharing Agreement, website, august 2003, www.nop.nl/gb/nieuwsbrief/change47/n47p5.htm.
- Edin, P. A., P. Fredriksson and B. Holmlund (1993) Utbildningsnivå och utbildningsavkastning i Sverige, *Ekonomiska Rådets Årsbok*, 11-37 (in Swedish).
- Eyckmans, J., J. Cornillie and D. Van Regemorter (2002) "Efficiency and Equity in the EU Burden Sharing Agreement", *Working paper series no 2000-02*, Energy, Transport and Environment, Katholieke Universiteit Leuven.

Introduction

- Farrell, M. J. (1957) "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society, Series A (General)*, **120**(3): 253-281.
- Finnveden, G. and T. Ekvall (1998) "Life-Cycle Assessment as a Decision-Support Tool – the Case of Recycling versus Incineration of Paper", *Resources, Conservation and Recycling*, **24**: 235-256.
- Färe, R., S. Grosskopf, C. A. K. Lovell and S. Yaisawarng (1993) "Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach", *The Review of Economics and Statistics*, **75**: 374-380.
- Färe, R., S. Grosskopf and W. L. Weber (2001) "Shadow Prices of Missouri Public Conservation Land", *Public Finance Review*, **29**(6): 444-460.
- Färe, R., S. Grosskopf and W. L. Weber (2002) "Shadow Prices and Pollution Costs in U.S. Agriculture", paper presented at the Second World Congress of Environmental and Resource Economists 2002, Monterey, California.
- Fölster, S. (2000) "Vem bär kostnaden för förpackningsavgifter?", Report, Handelns Utredningsinstitut, web site <http://forpackningsinsamlingen.se> (in Swedish).
- Förpackningsinsamlingen (2000) web site <http://forpackningsinsamlingen.se> (in Swedish).
- Greene, W. (1993) "The Econometric Approach to Efficiency Analysis", in Fried, H. O., C. A. K. Lovell and S. S. Schmidt (eds.), *The Measurement of Productive Efficiency*, Oxford University Press.
- Hernández-Sancho, F., A. Picazo-Tadeo and E. Reig-Martínez (2000) "Efficiency and Environmental Regulation", *Environmental and Resource Economics*, **15**: 365-378.
- Hetemäki, L. (1996a) "Estimating Shadow Prices for Bads Using a Two-Stage Stochastic Distance Function Model", in *Essays on the Impact of Pollution Control on a Firm: A Distance Function Approach*, PhD thesis, Finnish Forest Research Institute, Helsinki.
- Hetemäki, L. (1996b) "Do Environmental Regulations Increase Production Efficiency? Evidence from the Pulp Industry", in *Essays on the Impact of Pollution Control on a Firm: A Distance Function Approach*, PhD thesis, Finnish Forest Research Institute, Helsinki.
- IIED (1996) *Towards a Sustainable Paper Cycle* (London, World Business Council for Sustainable Development).

Introduction

- Jaffe, A. B., R. G. Newell and R. N. Stavins (2002) "Environmental Policy and Technological Change", *Environmental and Resource Economics*, **22**: 41-69.
- Jaffe, A. B., S. R. Peterson, P. R. Portney and R. N. Stavins (1995) "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?", *Journal of Economic Literature*, **33**: 132-163.
- Jorgenson, D. W. and B. Fraumeni (1992a) "Investment in Education and U.S. Economic Growth", *Scandinavian Journal of Economics*, **94**: Supplement, 51-70.
- Jorgenson, D. W. and B. Fraumeni (1992b) "The Output of the Education Sector", in Griliches, Z. (ed.), *Output Measures in the Service Sectors*, The University of Chicago Press, Chicago.
- Lovell, C. A. K., S. Richardson, P. Travers and L. Wood (1994) "Resources and Functionings: A New View of Inequality in Australia", in Eichhorn, W. (ed.), *Models and Measurement of Welfare and Inequality*, Springer-Verlag.
- Löfgren, K-G. and P-O. Marklund (1996) "The Regional Output from Human Capital: Do Universities Matter?", *Umeå Economic Studies*, No 427, Umeå University.
- Marklund, P-O. (1999) "Environmental Regulation and Firm Efficiency", Ph Licentiate thesis, *Umeå Economic Studies*, No 504, Umeå University.
- Metz, B., O. Davidson, R. Swart and J. Pan (eds.) (2001) "Climate Change 2001: Mitigation", Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
- Mohr, R. D. (2002) "Technical Change, External Economies, and the Porter Hypothesis", *Journal of Environmental Economics and Management*, **43**: 158-168.
- National Licensing Board for Environment Protection (2003) web site, October 6, <http://hotel3.ausys.se/koncnmd/infoeng.html>.
- Palm, A. (2000) Speech given by Anders Palm, Pressretur AB, at the technical meeting of RVF in Stockholm, web site <http://www.ilreturpapper.se-arkiv/foredrag.html> (in Swedish).
- Palmer, K., W. E. Oates and P. R. Portney (1995) "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?", *Journal of Economic Perspectives*, **9**(4): 119-132.

Introduction

- Phylipsen, G. J. M., J. W. Bode, K. Blok, H. Merkus and B. Metz (1998), "A Triptych Sectoral Approach to Burden Differentiation; GHG Emissions in the European Bubble", *Energy Policy*, **26**(12), 929-943.
- Pittman, R. W. (1981) "Issue in Pollution Control: Interplant Cost Differences and Economies of Scale", *Land Economics*, **57**(1): 1-17.
- Pittman, R. W. (1983) "Multilateral Productivity Comparisons with Undesirable Outputs", *The Economic Journal*, **93**: 883-891.
- Porter, M. E. (1991) "America's Green Strategy", *Scientific American*, **264**: 168.
- Porter, M. E. and C. van der Linde (1995) "Toward a New Conception of the Environment-Competitiveness Relationship", *Journal of Economic Perspectives*, **9**(4): 97-118.
- Radetzki, M. (1999) "Återvinning utan vinning", *ESO-report Ds 1999:66*, Regeringskansliet (in Swedish with a summary in English).
- Reig-Martínez, E., A. Picazo-Tadeo and F. Hernández-Sancho (2001) "The Calculation of Shadow Prices for Industrial Wastes using Distance Functions: An Analysis for Spanish Ceramic Pavements Firms", *International Journal of Production Economics*, **69**: 277-285.
- Rutegård, G. (1999) "Konsekvensanalys i livscykelperspektiv av att använda insamlade tidningar och tidskrifter till materialåtervinning alternativt energiutvinning", *Report*, January, *Pressretur AB* (in Swedish).
- Samakovlis, E. (2001) "Economics of Paper Recycling: Efficiency, Policies, and Substitution Possibilities", PhD thesis, *Umeå Economic Studies*, No 563, Umeå University.
- Shephard, R. W. (1970) *Theory of Cost and Production Functions*, Princeton University Press, Princeton.
- Svedberg, G. (1992) "Waste Incineration for Energy Recovery", *Report 1*, Stockholm: Royal Institute of Technology.
- Swedish Environmental Protection Agency (2003), by telephone, interview with Björn Winell, October 6.
- Swinton, J. R. (1999) "At What Cost do We Reduce Pollution? Shadow Prices of SO₂ Emissions", *The Energy Journal*, **19**(4): 63-83.
- Virtanen, Y. and S. Nilsson (1993) *Environmental Impacts of Waste Paper Recycling*, International Institute for Applied Systems Analysis (London, Earthscan).

Introduction

- Weitzman, M. L. (1976) “On the Welfare Significance of National Product in a Dynamic Economy”, *The Quarterly Journal of Economics*, **90**: 156-162.
- Weyant, J. P. and J. Hill (eds.) (1999), “The Costs of the Kyoto Protocol, a Multi-Model Evaluation”, *The Energy Journal* (special issue).
- Xepapadeas, A. and A. de Zeeuw (1999) “Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital”, *Journal of Environmental Economics and Management*, **37**: 165-182.