PRODUCTIVITY, ENERGY EFFICIENCY, AND ENVIRONMENTAL COMPLIANCE IN INTEGRATED PULP & PAPER AND STEEL PLANTS[1]

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INTRODUCTION

The research in this paper is motivated by recommendations that were made by industry in a number of different forums: the Industry Workshop of the White House Conference on Climate Change, and more recently, in industry consultations with the Department of Energy for the Energy Policy Act Section 131(c) and Section 1605(b). These recommendations were related to reconciling conflicts in environmental goals, productivity improvements, and increased energy efficiency in the industrial sector. The paper present preliminary results from two industry case studies, integrated pulp and paper production and integrated steel plants. These case studies have been undertaken to obtain a clearer understanding of the process in industry that gives rise to (potential) conflicts in compliance with environmental goals and constraints, improving productivity, and improving energy efficiency. The project consists of two phases, the industry consultation phase and the analytic phase. One objective of the project is to gain a better understanding of the decision-making process used in two industries and the factors that contribute to the conflicts between environment, energy efficiency, and productivity. What is known about the decision-making practices used by these industries for energy efficiency and environmental compliance investments is summarized, as is anecdotal evidence of the conflict between energy, environment, and productivity. Another objective is to quantify, to the extent possible, the impact of environmental compliance on productivity and energy efficiency. This study is still ongoing and interested persons can contact the authors for a more compete report of the study findings.

Energy intensive industries are also pollution intensive industries. This occurs for two reasons. The first is that energy combustion is a source of air pollutants. The second reason is that conversion of raw materials, like metal ore, wood, petrochemical feedstocks, requires large amounts of energy and also can release hazardous byproducts into the water and air. This analytic phase of this study contributes to the discussion of environmental goals, productivity improvements, and increased energy efficiency in the industrial sector in two ways. The first is to integrate pollution into productivity estimates thereby providing estimates to the impact of pollution (controls) on production and costs. The second is to examine energy efficiency within the context of overall production efficiency. In this context energy is one of many inputs in a production process and our analysis estimates the (in)efficiency use of all inputs.

Background

The U.S. paper and steel industries operate in the face of two potentially conflicting forces: increasing needs for compliance with environmental regulations and heightened pressure to improve productivity at home and abroad. This situation has often lead to investment problems in these industries, particularly as a result of environmental

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regulations that are too narrowly defined and a limited appreciation in government for the trade-offs that need to be made between various productivity or regulatory compliance goals. For instance, 1) sometimes protecting one environmental medium has resulted in damage to another; 2) in other cases, controlling environmental emissions has had negative impacts on productivity. This conflict between worthy goals is exacerbated when energy efficiency is added to the equation; 3) sometimes protecting the environment can cause industry to increase energy consumption; and 4) productivity considerations prohibit investments in energy efficient technologies.

Several aspects of the conflict between productivity improvement, environmental compliance and energy efficiency in industry are summarized below.

Regulatory Compliance
The emissions, discharges and management of residual wastes in the paper and steel industries have become increasingly regulated in recent years. Both of these industries are subject to extensive regulatory requirements under the Clean Air Act (CAA), the Clean Water Act (CWA) the Solid Waste Disposal Act (SWDA), the Toxic Substances Control Act (TSCA) and other state and local laws. Yet, the impact of environmental regulations on these industries is only beginning to be understood. Several analysts have estimated expenditures for regulatory compliance and found the cost impacts to be significant (OTA 1994). For process industries like pulp and paper and primary metals, pollution control expenditures can be a large part of capital and other expenditures and a small but significant share of value added.

In the past, environmental goals were often seen to be in conflict with business goals of producing the most goods/services at the greatest profit. Environmental goals were characterized (by businesses and others) as constraints that place additional costs on the business/production process. To the extent that environmental constraints require businesses to divert resources to treat, contain, and manage 'bad' production byproducts that, with minimal regulations, were otherwise costlessly disposable into the environment, then these additional costs are those that society weighs in its decision to regulate environmentally 'bad' outputs of industry.

On the other hand, where inherent inefficiencies exist, regulation can sometimes produce positive competitive benefits for industries beyond improving the environment. Several concrete examples exist where environmental regulations improved productivity by allowing companies to identify and reduce inefficiencies. For instance, beneficial investments have occurred in pulp and paper where press drying increases paper strength and reduces energy use by 20%, thereby cutting several pollutants, and in steel-making where basic oxygen and electric arc furnaces have cut open hearth furnace pollutants and cokeless steel-making offers further pollutant reduction potential (OTA 1994). Generic improvements such as use of computerized process controls to restrict environmental releases have also lead to increased process throughput and reduced scrap and rework.

More recently, their have been positions typified by Porter (1991) and others that environmental goals are the route to improved competitiveness. Walley and Whitehead (1994) and others take the position that "talk.. is cheap; environmental initiatives are not." Clearly there is some question as to the degree of conflict between environmental coals and business goals of profitability. Walley and Whitehead illustrate this apparent conflict with an example of a chemical company that had 55% internal rate of return (IROI) on employee-generated environmental initiatives, however, the IROI on all corporate environmental projects (averaged together) was *negative 16%.* Clearly society does not wish the regulations to cost more than is required; positive IROI environmental projects should be encouraged. However the extent of the direct and indirect costs imposed by regulations needs to evaluated. The -16% IROI mentioned above may account for direct, short term costs. Other, indirect costs may be imposed by the regulations in terms of the impact on future growth and health, i.e. productivity, of businesses and in terms of other societal goals, like energy efficiency.

Energy Efficiency in Industry
In addition to environmental constraints, U.S. industry faces increasing pressure from federal initiatives to improve energy efficiency and reduce greenhouse gas emissions. These government initiatives place an emphasis on voluntary actions by industry to achieve energy efficiency and environmental goals. Several elements of EPACT, for instance, include voluntary industry efforts to improve energy efficiency and the Climate Change Action Plan relies almost entirely on voluntary actions to cut industrial greenhouse gas emissions.

Although environmental compliance is very important for many industries, energy efficiency by itself usually is not a high priority. Because of competitive pressures both in the U.S. and abroad, most plant managers and company officials focus on improving the overall economic productivity of all their inputs, not just energy efficiency per se. Generally, those industries with high energy intensity and related energy costs have had the most extensive efficiency programs.

The Need for Improvements

The need for government agencies to address this problem was highlighted by industry concerns over potential conflicts between three issues: industry's need to comply with federal environmental regulations, federal efforts to promote energy efficiency as only an energy-driven investment, and the need to address overall productivity and cost concerns in their plants. Conflicts arise because industry generally has limited funds to invest and cannot afford to address compliance requirements, energy concerns and overall quality and productivity needs at the same time. For instance, discussions with industry during production of the EPACT Section 131(c) Report to Congress highlighted a need to reconcile federal efforts at environmental protection, energy efficiency and industrial productivity improvement to ensure coordinated government action and more consistent technology investment opportunities for industry. This study is designed to address some of these concerns.

EVIDENCE OF PROBLEM

The major problem facing industry is its inability to optimize its investments in environmental abatement so that the negative impacts on energy efficiency and productivity are minimized. Industry is often not able to integrate its investments in environmental compliance, productivity and energy efficiency gains. This inability appears to be caused by the inflexibility of current regulations and the fragmented nature of current decision-making practices. Proof of these tensions is illustrated in examples demonstrating the unintended consequences of environmental regulations: on other environmental media, on energy efficiency, and on productivity.

Three types of contractions demonstrate the difficulties of looking at environmental protection, energy efficiency, and productivity in isolation: multimedia conflicts, conflicts between environmental regulations and energy efficiency, and conflicts between environmental protection and/or energy efficiency and productivity. Some examples of these types of conflicts as they pertain to the paper and steel industries are listed below.

Multimedia Conflicts

One problem with the current regulatory scheme is that it is possible to inadvertently harm one environmental medium as a result of trying to protect another. An example of a conflict between air and water pollution in the paper industry involves Total Reduced Sulfur (TRS). Low volume, high concentration of TRS are usually captured and burned in lime kilns. However, if there is an upset in a process and TRS needs to be vented into the atmosphere, there is a time limit after which the plant has to be shut down. This is because the emissions of TRS cause a bad odor (although they are not particularly harmful). But to shutdown the mill requires dumping liquors in the sewer. Between 5 and 10 thousand pounds of liquor has to be dumped as a result of the mill shut down. This taxes the waste treatment facilities. Therefore, preventing 50 lbs. of air pollution can result in 5-10 thousand lbs of water pollution as a result of single medium regulation.

There are other examples in the paper industry where actions taken to prevent environmental damage in one medium, created an environmental problem at another. At one paper mill in the Midwest, pulping effluents (black liquor) were discharged into a series of groundwater infiltration lagoons to protect local surface waters in the early 1950s. This action resulted in the inclusion of the mill on the Superfund National Priorities List for a groundwater pollution problem thirty years later.

The same sort of cross-media conflicts have occurred in the steel industry. RCRA regulations have provided the steel industry a disincentive to recycle and reuse materials. During the steel making process, intermediate materials, such as slag, dust, and sludge are generated, which have historically been reprocessed. EPA wants to regulate this reprocessing to prevent harm to the environment. EPA proposes to treat these non-hazardous wastes similarly to the way it treats hazardous waste. This would require additional reporting and permitting to reuse these materials. Also, it would limit the time these materials could be stored on-site. This would provide a disincentive to the steel industry to recycle and reuse these materials.

Regulation-Efficiency Paradoxes

Although it would seem that energy-related benefits would be derived from environmental projects, often the opposite is true. Investments in internal process changes to reduce environmental costs may increase energy costs. In the steel industry, environmental requirements, such as waste water treatment facilities and air pollution control systems add to the energy requirements needed. These systems require the use of pumps, fans, compressors, and the operation of other equipment that requires increased energy use. Indirectly, environmental requirements reduce energy efficiency by reducing the amount of capital available for investment in new technologies. It is usually new technologies that produce efficiency gains.

Other examples of conflicting environmental and energy efficiency goals exist. In the paper industry, regenerative thermal oxidation, a process used to control VOCs, exemplifies this conflict. Regenerative thermal oxidation is a process whereby gases are gathered together and pumped into a device that is heated with natural gas. The VOCs are burned off, and carbon dioxide and water remain. This technology comes from the paint drying industry, where concentrations of VOCs are much higher. In the paper industry, VOC concentrations are low and cannot sustain the flame necessary for burning. Therefore, air needs to be added to maintain combustion. This increases the amount of energy used by the mill. EPA has ordered this technology to be installed in several mills. If applied on a large scale, this technology would represent one tenth of one percent of the total U.S. electricity consumption.

Similarly, as a result of the proposed Cluster Rule, EPA is proposing steam stripping of high methanol sources as a Maximum Achievable Control Technology. Steam stripping is a process by which methanol that is dissolved in the effluent stream is collected and incinerated. This technology would require the use of a distillation tower, air to perform the incineration, and natural gas to supplement the stream. All of these factors would contribute to an increase in energy use. Because most mills do not have the capacity to generate the amount of steam needed to perform steam stripping, they will be forced to increase energy use to generate the additional steam capacity needed.

Another environmental issue that has important energy implications in the paper industry is paper recycling. It is a little known fact that increased recycling may increase energy consumption. Increased use of recycled paper products increases non-renewable energy consumption in the paper industry because much of the energy required to make paper is normally supplied by waste products generated in the process. These wastes are not present with recycled materials, therefore the energy they provide must instead be purchased in the form of conventional fuels from offsite.

Adverse Productivity Impacts Due to Regulations or Efficiency Improvements

In addition to the cross-media conflicts resulting from single medium regulation and the conflicts between environmental regulation and energy efficiency, there are also conflicts between environmental regulations and productivity. Any time a regulation requires that a plant be shut down when pollution abatement devices are not operational can hurt productivity. This situation occurs when pollution abatement devices need to be cleaned or are malfunctioning. To avoid this problem, plants would have to install an extra abatement device to operate when the main one is not on line. However, this would add considerable cost to abatement.

Other examples of the conflict between environment/energy and productivity exist. For example, there is a push to replace wood-fired steam generators with natural gas-fired generators in the paper industry. Although natural gas is cleaner burning than wood, it is a non-renewable resource. Additionally, gas-fired generators would decrease productivity in the paper industry because mills would have to purchase natural gas (as opposed to wood which they already have) and in some cases, they may have to build pipelines because many mills are located in rural areas where pipelines do not exist.

In general, requirements to purchase abatement equipment influence total factor productivity in two ways: directly by adding to total costs, and indirectly by changing the way conventional inputs are used to produce the manufactured good. While the direct effect reduces productivity by increasing costs with no commensurate increase in manufactured output, the indirect effect could be positive, negative, or zero. The indirect abatement effect varies substantially by industry. Some industries are capable of ameliorating part of the productivity costs of environmental regulation through changes in other inputs.

Consider the direct costs first. Taking the above chemical company referred to in Walley and Whitehead as an example, one sees that some of the costs incurred by the company are the costs of resources to manage the otherwise costlessly disposable 'bad' outputs of the industry. These cost arise from the constraints on the company not to release certain production residuals into the environment. These constraints arise from the current slate of pollution regulations.

However, not all of the regulatory approaches implemented by the company (or mandated by the regulatory body) for controlling these 'bad' outputs are efficient. In fact, there exist areas in this company where the production inefficiencies were so large that both environmental and business goals could be achieved. One important question is whether these areas are really extensive -- such that redesign of production processes (impelled by new regulations) forces attention on these classes of production inefficiency, with major business benefits.

Greeno (in HBR, 1994) points out that "achieving superior efficiency.. in environmental spending" is the real win-win situation by meeting social goals while "besting their competitors cost structures". Greeno's point is that relative efficiency can be a *competitive advantage*, given the imposed social goals of environmental improvement. Since Smart (in HBR, 1994) characterizes the "huge investments" required to meet environmental goals as a cost set by society of continuing to stay in business, this makes Greeno's recognition of efficiency an even more important business goal.

Direct investment (and operating) costs for environmental compliance are easier to identify and quantify than indirect costs. Indirect costs include two important categories, unmeasured costs of pollution abatement and 'lost opportunities'. Unmeasured costs are discussed at length in (Office of Technology Assessment 1994). The OTA report lists several reasons why Pollution Abatement and Control Expenditure (PACE) data collected by the Census may underreport abatement costs. The reasons identified by the OTA report include:

- Underreporting from Omitted Cost Items

  Productivity Losses
  Product Quality Impact
  Pollution Control Costs Embedded in Other Purchases
  Interest Expense
  Fees and Taxes
  Cost of Regulatory Delays
  Loss of Proprietary Information
  Research and Development Costs
  Penalties and Fines
  Other costs

- Underreporting from Lack of Full Knowledge of Costs

  Environmental costs embedded in capital equipment
  Administrative costs
  Management and engineering staff time
  Environmental Training
  Other costs

Studies which examine the impact of pollution abatement have traditionally focused on reported expenditure data. To the extent that expenditures underreport the "actual" cost, studies would tend to find the impact of pollution abatement to be greater than the direct reported costs. Two such studies are (Barbera and McConnell 1990)(Gray and Shadbegian 1993). They find that the indirect costs are as much as 3 to 4 times the direct effect in paper in steel (Gray and Shadbegian 1993) or as low as zero (Barbera and McConnell 1990) for paper. It is important to note that indirect effects need not be negative. Barbera and McConnell find some positive indirect effects for some industries in their study. For example, the product quality impact may be positive or accelerated retirement may induce a newer state-of-the-art vintage of equipment. However, these potential positive effects are driven by the existence of structural inefficiencies discussed above.

Other indirect costs may be characterized as 'lost opportunities'. These may be directly related to the inflexibility of the regulations, which mandate certain technological 'fixes' and do not encourage innovation. The second type of lost opportunities are those which are associated with investment constraints.

DECISION-MAKING REGARDING INVESTMENTS IN ENERGY EFFICIENCY*

There are five main conclusions that emerged from the discussions with industry representatives regarding energy efficiency investments. First, energy efficiency investments are primarily market-driven. Second, investments in energy efficiency are dictated by the availability of capital. Third, new facilities provide an opportunity for energy efficiency improvements to be made. Fourth, accounting practices influence energy efficiency investments. Fifth, the competing pressures on various corporate actors influence investments in energy efficiency. These conclusions are discussed in more detail below.

Energy Efficiency Investments are Market-Driven

Most improvements that are made in the energy efficiency arena (that are not mandated) are market driven. Objectives are usually customer or profit driven, not environment or energy driven per se. Therefore, energy efficiency needs to be viewed in context of total factor productivity. Energy consumed per ton of production is not as much a driving force for energy reduction as is overall production cost.

Some investments may not be counted as "energy projects" per se, but energy-related improvements frequently accompany process improvements. In the paper industry for example, boiler audits, which are usually billed as addressing safety and environmental concerns, also cover energy efficiency. Similarly, high efficiency motors, lighting, and insulation improvements are usually listed under capital improvement projects even though they impact energy efficiency.

Investments in Energy Efficiency are Dictated by the Availability of Capital

Voluntary energy projects are dictated by available capital and they compete with other customer-driven quality and productivity improvement projects, modernization programs and non-discretionary environmental expenditures. In addition to capital availability, some major economic criteria used in determining whether to make an investment are variations in fuel cost relative to other inputs and whether the payback period on any given investment is reasonable. In addition to voluntary investments, there are many "required" investments for environmental protection, that crowd out other projects. Required environmental investments exacerbates the problem of capital availability by eating away at the pool of accessible resources.

Because the steel industry has had a series of economic setbacks in recent years, it has a limited pool of capital from which it can invest in energy efficiency programs. The steel industry lost over $12 billion during 1982-1986. Modest profits in recent years have not offset those losses. To compete against international competitors in the future, the steel industry has been investing existing profits into modernizing facilities. There is very little discretionary capital available because all available capital for investment is being spent to improve product quality

* Most of these comments are from the Industry Consultation Workshop for Section 131 (c), Narrative Reports from Meetings Between DOE and Industry Trade Associations, and the Written Submissions in Response to the Federal Register Notice [Attachment to Appendix D, Section 2]. Although some of the comments were drawn directly from the steel and paper industries, others represent the views of industry in general, not paper or steel in particular. However, the Paper and Steel industry representatives participated in these forums, and these general comments seem to hold true for these industries.

so that market share can be maintained. As a consequence, potential energy conservation projects must have a high rate of return to compete for the dollars available for investment.

Pulp and paper is the most capital-intensive manufacturing industry, which causes several business implications regarding investments. Corporate decision-makers tend to be conservative in choosing investments; given a total operations budget of $1 to $10 billion, a single investment can be a large percent of the total; companies cannot afford to invest in unproven technologies or processes. The need to divert significant money toward capital investment may reduce the availability of money for research and development, which usually improves energy efficiency. Also, once the decision is made to invest money in new equipment, there is an intrinsic conservatism in subsequent business strategy; immediate changes cannot be made to the process without the generation of additional new money-- money which comes from the profitable operation of the existing process.

New Facilities Provide an Opportunity for Energy Efficiency

Decision-makers in these industries find that the best place to install new technologies, whether they be for improved energy efficiency or environmental gain, is at new plants. This is because retrofitting existing facilities is more costly than investing in new facilities and these investments have worse payback periods than installing new technology at new facilities. Therefore, the greatest gains may exist during times of production growth and installation of new production capacity. Production growth--which leads to investments in new facilities-- is driven by economic and market forces.

Investment in new facilities allows installation of state-of-the-art equipment and processes with minimal additional investment that is specifically attributable to environment or energy efficiency. Improvements at existing facilities can cost more due to inadequate support facilities and lost production while the facility undergoes improvement. Companies want to implement new technologies without affecting production. Additionally, there is a reluctance to do retrofits in cases where the remaining life of a plant is unclear, because companies don't want to invest in plant improvement when they don't know how long the facility will remain open.

There are several energy efficient technologies that may be appropriate in new plants, but that are not economically feasible at existing plants. In the steel industry for example, technologies such as auto-ignition of flared gas, top pressure recovery turbines, BOF off-gas recovery, programmed heating of coke ovens, fuel gas preheating, hot mill table covers, and evaporative skid cooling, have good paybacks in terms of purchased energy saved vs. capital invested. However, they do not have good paybacks when retrofitted to existing plants.

Accounting Practices Influence Energy Efficiency Investments

Current accounting practices, which are influenced by tax regulations and the Financial Accounting Standards Board (FASB), also influence whether or not projects are undertaken. Whether a new technology is treated as a capital expenditure or an operating cost can have important implications. Usually new facilities are capitalized and retrofits are expensed. Individual facilities have significant control over decisions that involve expense dollars, which weigh in against their productivity. Since expense dollars come out of the current year's budget, site managers want these expenses to pay for themselves in one year. Higher expenses reflect poorly on site managers since the cost of the project usually exceeds the energy costs saved during the first year.

A capital investment, on the other hand, can be amortized over the life of the project and can meet investment hurdle rates more easily. However, it is preferable to expense projects because tax laws allow you to take those expenses off your bottom line in that tax year. But again, people at the plant level are held accountable for short-term current year, expense budgets and are less likely to add unnecessary expenses. Headquarters is more likely to control capital budgets that are used for longer-term decisions. New equipment is usually capitalized, retrofits are often expensed.

The Competing Pressures on Various Corporate Actors Influence Investments in Energy Efficiency

Different cultures exist within companies between accountants, upper management, plant managers, etc. Knowledge of these differences is important in implementing change. For example, in some manufacturing industries, plant managers have had increased responsibility for energy and environmental compliance at facilities. In these cases, strategies for change should incorporate the plant manager's perspective because the CEO may not be making the decisions at the facility level. The headquarters of companies may play a more limited role than one would think. However, buy-in is necessary both from the top-down and the bottom-up of the corporate structure.

DECISION-MAKING REGARDING ENVIRONMENTAL COMPLIANCE

Like fluctuating prices of energy, availability of raw materials, or market demand cycles, evolving regulatory schemes cause direct and indirect economic impacts at production facilities. When new regulations are issued, decisions need to be made about how or whether to comply. With the severity of penalties for non-compliance, the only practical alternative to the "how to" aspect of compliance may be complete cessation of the regulated activity.

The regulations themselves offer some basis to support industry decisions, and anticipated costs and related economic impact analyses are considered prior to issuance of most federal environmental regulations. While the particular bases and methodologies for such estimates will vary considerably depending on the complexity and scope of the regulations, analyses offered by regulatory agencies typically include assessments of regulatory compliance costs, financial impacts, market impacts, employment impacts, or other measures of economic impacts with respect to prospective benefits for human health and the environment.

Industry does not have a great deal of flexibility in complying with environmental regulations. EPA has defined the major environmental regulations in technical terms and has developed guidelines for meeting regulatory requirements based on the available technology, the cost of achieving reductions, the engineering aspects on the control technologies, and other factors. For example, to assist in achieving the objectives of the Clean Water Act, EPA issued effluent guidelines such as: Best Practicable Control Technology Currently Available (BPT) for discharges of conventional pollutants from existing sources, Best Available Technology Economically Achievable (BAT) for toxic and nonconventional pollutants, and New Source Performance Standards (NSPS) for new plants. Similarly, the Clean Air Act requires that EPA set standards based on maximum achievable control technology (MACT) for hazardous air pollutants once minimum control levels are determined.

Because the regulations are prescriptive and technology driven, most companies choose to comply by installing the technologies identified by EPA and its contractors. To do otherwise would require additional investments to research alternatives and to conduct cost/benefit, engineering, and environmental analyses.

MEASURING PRODUCTIVITY

Productivity is a relative concept. Simple input productivity measures are expressed as the relative use of labor or energy to produce some unit of output, expressed either in physical units or monetary ones. These measures, like man-hours per ton of paper or kWh per ton of steel, are commonly used since they are simple to calculate and focus on specific inputs and issues that relate to those inputs. Since many inputs are used to produce goods like paper and steel, a measure of productivity that accounts for all inputs in the production process, i.e. growth accounting or Total Factor Productivity (TFP) is a better alternative. (Caves, Christensen, and Diewert 1982) introduce an easily computable form of a TFP index which is based on the Malmquist index. This approach allows a comparison of the relative growth (decline) in output relative to the amount of inputs required to produce the observed output level.

Productivity is frequently expressed not only as a measure of inputs relative to outputs, but also how that measure compares across entities (firms, countries, industries) or over time. Comparison of productivity between entities is an *efficiency* comparison. Comparison over time measures an entity's productivity *growth*. The studies using the PACE data, (Barbera and McConnell 1990) and (Gray and Shadbegian 1993) mentioned above, focus on productivity growth.

These distinctions between efficiency and productivity growth are important in the context of how environmental constraints impact on productivity. As Barbera and McConnell point out in their framework, the direct abatement effect will always lower TFP growth, *as long as there is growth* in abatement purchases. Environmentally driven investment constraints are also likely to impact on productivity growth, i.e. they impair the firms ability to add to their productive capital stock. However, if all entities start from the same competitive position, then environmental constraints may show up in the relative productivity, i.e. in their relative efficiency. It may also be the case that some entities are better, more efficient, at implementing environmental solutions or mitigating indirect impacts. These other studies do not account for the differences in absolute efficiency between entities, or how that distribution of efficiency may change over time.

Measurement of Technical Change, Efficiency, and Productivity

An extension of the Malmquist TFP index which accounts for changes in technology and changes in efficiency is constructed by Fare et al (1991). This decomposition is particularly important when examining issues productivity losses due to environmental regulation or energy (in)efficiencies. This index relies on linear programming techniques to define the 'Best Practice' production frontier. To incorporate undesirable outputs (pollution) we follow Fare et al (1989). Using this extended formulation the index of productivity, M, between two time periods, t and t+1, can be composed as:

$$M(u_{t+1}, x_{t+1}, u_t, x_t) = E \cdot T$$

where

$$E = F_{t,t} \;/\; F_{t+1,t+1}$$

is the efficiency change component of productivity change and

$$T = [\,(F_{t+1,t+1} \cdot F_{t+1,t}) / (F_{t,t+1} \cdot F_{t,t})]^{1/2}$$

is the 'pure' technical change component of productivity.

The modified Malquist index is based on the distance function, $F_{t,t+1}$. This is computed by solving the following LP problem for each observed value (each plant in the dataset):

$$F_{t,t+1} = \text{Min}\ \lambda$$

Subject to

$$Z \cdot V_t \geq v^{t+1}$$
$$Z \cdot W_t = w^{t+1}$$
$$Z \cdot X_t \leq \lambda x^{t+1}$$

$$Z\ \varepsilon\ R^k_t$$
$$\lambda\ \varepsilon\ R_t$$

where:

x^{t+1} = Observed inputs,
$u^{t+1} = (v^{t+1}, w^{t+1})$ = Observed outputs, both desirable outputs, and undesirable outputs,
X_t, V_t, and W_t = Matrices of inputs, desirable outputs, and undesirable outputs for the entire sample, and
Z = An activity vector.

The time subscript denote the relative comparison year. In this formulation the matrices X_t, V_t, and W_t comprise the data for the entire time period prior to year t. This assumes that technology does not reverse, i.e. T>1. This index, M, and its decomposition is computed twice. The first assumes that there is no undesirable outputs and the second where pollution is included as an undesirable output. By comparing the two different measure of productivity we gain insight into how environmental constraints effect the industry.

Data and Results

The data used in the analysis is confidential plant level data from the U.S. Bureau of the Census annual survey and census of manufacturing. This data is available for analysis through the Center for Economic Studies (CES) and the results are subject to disclosure screening to mask individual responses. More detailed data description is available from the authors. The results presented here are for a panel of 57 large integrated paper plants for the years 1985 and 1990. Integrated paper plants are those that convert wood to pulp and then to paper. Plants that use wastepaper as feedstock or that use groundwood processes are excluded from the analysis. These years were chosen because of the availability of air pollution estimates for those years. We use SO2 emissions as our measure of undesirable output. Kraft pulping process produces SO2 emissions, as can the energy combustion at a paper plant. These emissions are rather tightly regulated in the time period we consider. Air pollution is not the only environmental problem at paper plants. At the time of writing this paper the water pollution data had been received from EPA but was not combined with the census data. Toxic releases are also important and are being added to the analysis and will be present in the final report.

Figure 1 presents the distribution of plants with different level of productivity change. When one allows for the differences in pollution level between different pulp and paper plants we see a shift in the distribution of productivity, i.e. higher level of productivity change occur. This is not surprising, since it more accurately reflects the inputs required to control air pollution. The decomposition of the Malquist index tell us if the major difference between the productivity estimates is attributable to efficiency or to technical change. Figure 2 presents the distribution of plants with different level of technical change. It shows that technical change is much higher when one accounts for pollution as an output. This difference accounts for nearly all of the difference in the Malmquist index. In other words, we observe no change in efficiency component of productivity, but do observe a change in technology.

CONCLUSION

What is needed is further research to clarify how these contributions can be made in specific industries and to assess their potential value. A better understanding of the inter-relationships between environment, energy, and productivity on an industry-specific level is needed so industry can capitalize on existing inefficiencies and make investments that have positive impacts in more than one area. With more information and flexibility, industry can also choose options for compliance that have the greatest environmental impact at the lowest cost.

This paper present one approach to integrating analysis of environmental performance and efficiency. This approach treats all inputs, including energy, and subject to differing level of (in)efficiency. In the specific industry under examination, integrated pulp and paper plants, we do not find differences in efficiency level when one accounts for air pollution. These empirical results also need to be reconciled in light of consultations with industry representatives. These results are based on ongoing research. The analysis is being extended to the steel industry and to cover other pollutants in the paper industry as well. For more information or a copy of the final report contact the authors.

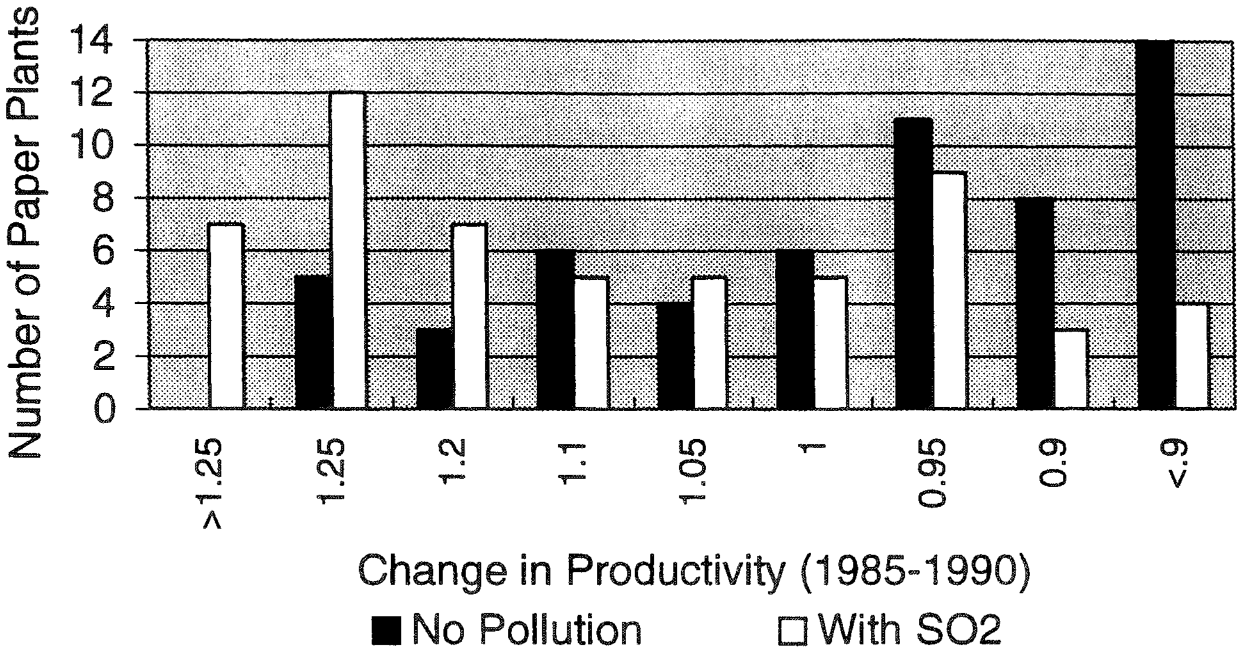

Figure 1 Productivity Estimates for Integrated Paper Plants, with and without SO2

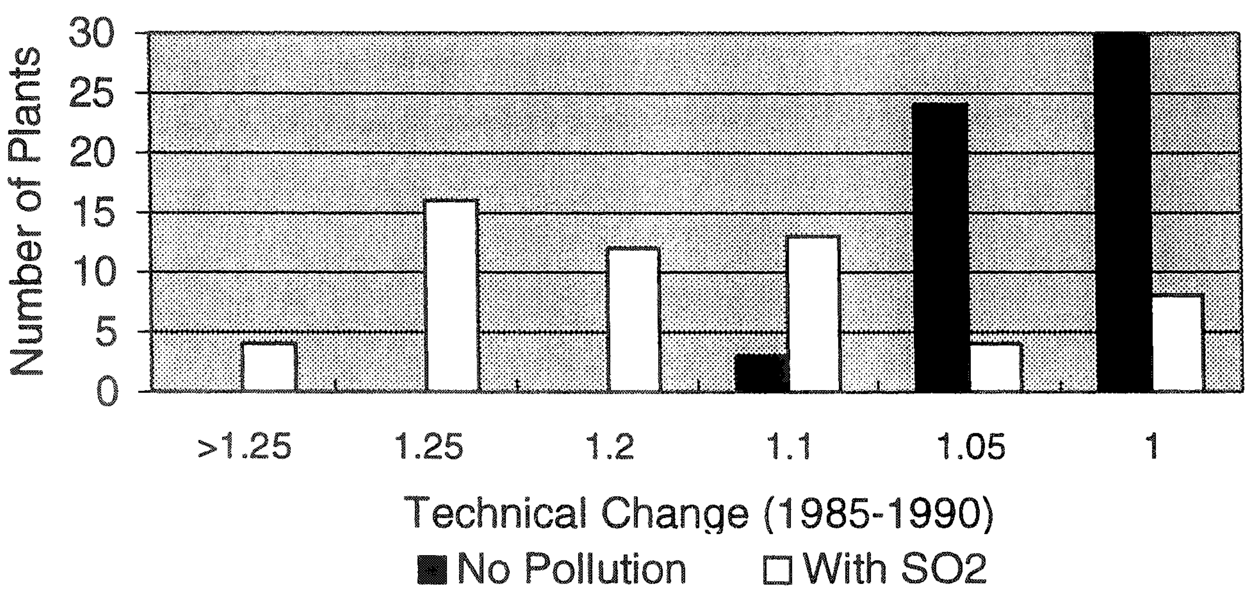

Figure 2 Technical Change Estimates for Integrated Paper Plants, with and without SO2

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