The 1990 Clean Air Act: a tougher regulatory challenge facing Midwest industry

Donald A. Hanson

Protecting the environment and human health is very important. Toward these goals, several new programs have been initiated under the 1990 Amendments to the Clean Air Act (CAA). This article provides an overview of these programs and their potentially extensive impacts and discusses the attendant challenges facing management and workers in U.S. industry.

According to preliminary U.S. Environmental Protection Agency (EPA) estimates, the annual cost of these regulatory programs will be around $20 billion [U.S. EPA (1990a)], but other estimates are considerably higher [Fumento (1992)]. The potential for a greater burden is due to a number of considerations which are difficult to quantify: 1) a greater need for compliance planning, including contingency planning; 2) administrative costs, potential delays, and a loss of operating flexibility for industrial facilities because of a complex, new permitting program; 3) direct compliance costs from more stringent regulations requiring higher pollutant removal rates and the potential for even tighter regulations in the future, as provided in the 1990 Amendments; 4) increased monitoring and reporting requirements; 5) new, stringent civil and criminal enforcement penalties; and 6) various rigidities which may aggravate economy-wide effects. The term "rigidities" refers to elements in labor markets or in markets for goods and services which may lead to deviations from full employment and efficient growth.

Increased protection of the environment and health will require significant changes in management, worker, and consumer attitudes and behavior. In attempting to lessen the costs of more stringent regulations, consumers and producers will act more judiciously in choosing among products purchased and the processes and materials used to manufacture them. But even with these adjustments, national and regional incomes as traditionally measured, which exclude many of the benefits of environmental improvements, may still be lowered by environmental regulations.

Because of its manufacturing orientation, the Midwest economy faces a greater challenge in striving for improvements in products and manufacturing to reduce environmental residuals. If the region can master these challenges, it may be possible not only to mitigate much of the potential cost of environmental legislation, but even to transform a regulatory burden into enhanced growth and welfare. By developing expertise in the design and manufacture of clean processes and environmental controls, some businesses could potentially cultivate a new source of income. The challenge will not be easily mastered, however, because many of the requirements (or alternative options) for CAA compliance are ambiguous or have yet to be determined. Businesses will have to work with multiple federal, state, and local govern-

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ment agencies in a heretofore untested partnership. Further, scientists do not fully understand the physical mechanisms leading to environmental effects. These uncertainties will require flexible business decision making and contingency planning.

In addition to providing an overview of the CAA, a second objective of this article is to present a simple economic model which illustrates more rigorously the nature of the costs associated with environmental regulations. In the model, environmental expenditures are placed in the context of the larger economy in order to investigate the macroeconomic, industrial, consumer, and regional impacts. The model identifies one of the potential reasons for macroeconomic cost impacts: workers may not be willing to accept the lower wages (reflecting clean air costs) which would be necessary to maintain full employment. Such so-called "sticky wages" can magnify the economic costs of the CAA program substantially; a numerical example shows costs under such a scenario to be higher by a factor of two compared with direct abatement expenditures. Addressing labor compensation issues in the face of increased real abatement costs and, in many cases, strong international competition, is a great challenge for industry and labor alike. From fairness and political points of view, it is probably undesirable for environmental regulatory costs to fall heavily on labor income; however, if the costs are borne by capital income, there may be less incentive for investment and future economic growth. This model addresses the cost side of environmental regulation but does not attempt to estimate the future benefits from a cleaner, more healthful, and productive environment.

The second section of this article provides an overview of the 1990 Amendments. The third section describes the acid rain regulations and highlights compliance within the Midwest region. The fourth section reviews the other major CAA areas: ambient air quality standards and nonattainment, prevention of significant deterioration, visibility and other air quality values, industrial air toxics, and stratospheric ozone depletion. Some of the burdens and challenges to the economy under the CAA programs are illustrated using a simple model presented in the fifth section. Conclusions are presented in the final section.

Origins and overview of the 1990 CAA Amendments

Following a rising tide of environmental awareness in the United States during the 1980s and a decade of research and congressional debate on acid deposition controls, the Bush Administration took a lead in the reauthorization of the Clean Air Act. Compromise legislation was finally crafted among the Administration's proposed bill, a House version, and a Senate version, which resulted in the 1990 CAA Amendments, signed by President Bush in November of 1990.

A system of tradable sulfur dioxide (SO_2) allowances was adopted as the central approach to reducing acid deposition. This approach was recommended in a December 1988 study sponsored by Senator Wirth, Colorado, and Senator Heinz, Pennsylvania, entitled *Project 88, Harnessing Market Forces to Protect Our Environment: Initiatives for the New President.* The study participants included not only academic economists but also business leaders and representatives of environmental groups, such as the Environmental Defense Fund. The adoption of this market based approach helped achieve the passage of the CAA legislation in Congress and hopefully may foreshadow considerably more reliance on market incentive approaches to other environmental regulations in the future. Recently, round two of *Project 88* has been published, further assessing the applicability of market incentives for environmental improvements.

Overview of the main titles

Three new innovative titles have been added: Title IV on acid rain control, Title V on comprehensive source permitting, and Title VI on stratospheric ozone protection. Many modifications and additions to existing titles were also made. For example, the hazardous air pollutant section of the 1970 CAA, Section 112, which had been an unworkable framework for controlling toxic air emissions, has been totally replaced with a new program; and the difficult urban ozone nonattainment problems have been tackled with new stringent requirements under Title I (see Box 1).[1]

A cleaner environment is no free lunch

Acid rain control was a contentious issue during the 1980s because of the sharp divergence of regional interests and the perceived high control costs, estimated to be about $4 billion per year [NAPAP (1991)]. The 1990 CAA Amendments authorize two significantly larger programs than acid rain control—urban ozone regulation and industrial air toxic pollution control—which are each likely to be two or three times as expensive to the nation and the Midwest economy as acid rain controls [see Portney (1990) and U.S. EPA (1990a)].

Other provisions of the CAA may also impose significant regulatory and compliance

BOX 1

The major titles under the new Clean Air Act and the relationship to the titles in the 1990 Amendments

Structure of new Clean Air Act		Comments and relation to 1990 Amendments
Title I	Air pollution standards and controls	Central title of the CAA
Part A Sec. 109	Provides for setting National Ambient Air Quality Standards (NAAQS) for common pollutants.	
110	Requires states to develop State Implementation Plans (SIPs) to attain NAAQS in nonattainment areas and to maintain air quality in attainment areas. SIPs require federal approval.	SIPs and NSPS continue to be required after the 1990 Amendments
111	New Source Performance Standards (NSPS) must be met as a minimum level of control for new sources or existing sources undergoing a major retrofit.	
112	Control of hazardous air pollutants	Sec. 112 of the 1970 CAA was replaced with a new program, Title III of the Amendments.
113	Federal enforcement	This section of the 1970 CAA was replaced with a much stronger provision in the Amendments Title VII.
Part C	Prevention of Significant Deterioration applies to maintaining air quality in areas already in attainment with NAAQS.	Part B of 1970 CAA was replaced with a more stringent ozone control program under Part D.
Part D	Nonattainment areas	Additional provisions were added for ozone nonattainment controls, carbon monoxide, particulate matter, sulfur dioxides, nitrogen oxides, and lead.
Title II	Mobile Source Emissions	
Title III	General Administrative/Misc.	
Title IV	Acid Deposition Control	New title
Title V	Permits	New complex permitting program
Title VI	Stratospheric Ozone Protection	New title

Additional Titles VIII - XI under the Amendments call for more research, a visibility impairment assessment, and other matters.

costs. The new Title V comprehensive permitting program could be a sleeping giant. If each significant piece of industrial equipment emitting at least one regulated pollutant, such as an industrial furnace, is defined by the EPA as requiring a permit, the paperwork and attendant delays could be overwhelming. Operating flexibility of industrial facilities will be reduced and continuous monitoring, record keeping, and periodic reporting will increase. Even though the 1990 CAA Amendments require that each state have its own permit program (with the federal government running the permit program, if a state refuses), each source permit may be reviewed by the EPA and the designated Federal Land Manager, such as the National Park Service. Further, after the federal review there still can be intervention by affected parties in the state or adjacent states. For example, sulfates affect the atmospheric process of light scattering and can cause visibility impairment. Because of the long range transport of sulfates, it is possible that sulfur dioxide (SO_2) reductions needed to obtain a permit will be much more stringent than would be necessary under the acid rain control program, Title IV of the 1990 CAA Amendments. Restrictive permits may also interfere with the effectiveness of the tradable SO_2 allowance program, which is described later in this article.

Advantages of market approaches to emission reduction

The CAA pioneers the heretofore underused market based approach to reducing emissions. The market based approach grants firms pollutant emissions allowances while ensuring that total pollution does not exceed national or regional limits. The overall limit ensures that society's goals for clean air are met. The market based approach allows firms to trade their emissions allowances so that pollution reductions are made by those firms that can make them most cheaply.

Market approaches, such as tradable emission allowances, can lower society's costs of pollution reduction by providing a level playing field for emission reductions among potential sources while, over time, stimulating the development of new abatement methods and technology. These characteristics of market approaches differ markedly from technology or regulatory standards. For example, if the law requires industry to install the "best available control technology," then there may be little or no incentive to innovate in ways that reduce pollution because the government would only proceed to make emission standards more stringent. Also, more stringent standards on new sources than on existing sources encourage the continued use of existing equipment beyond the point at which it would otherwise have been economical to modernize and replace the equipment. Hence, some critics argue that new source performance standards lower investment and reduce economic growth. In contrast, the level playing field under a market approach encourages new investments, reducing emissions and the need to purchase emission permits. In addition to the national market for SO_2 allowances, a tradable permit program is being proposed to address the regional smog in the southern California air basin around Los Angeles.

Interaction among the requirements

Urban ozone is one of the pollutants for which National Ambient Air Quality Standards (NAAQS) have been set to protect human health and other environmental values under Title I of the CAA. Those airsheds in which the pollutant concentration exceeds the NAAQS are classified by the EPA as nonattainment areas for that pollutant. The six common pollutants which are associated with NAAQS are shown in Box 2, along with a summary of the reductions in these pollutants since the mid-1970s achieved so far under the CAA.

The interaction and overlap between air programs can lead to uncertainty about compliance strategies. A single source may be regulated under more than one program. Many volatile organic compound (VOC) sources will be regulated under both urban ozone nonattainment and industrial air toxic provisions. Nitrogen oxides (NO_x) will be regulated under Title I in nonattainment areas and under Title IV on acid rain control. Sulfur dioxide is regulated under Title I, Title IV, and may be further controlled in the future to improve regional visibility. Any new source not only must go through New Source Review and meet New Source Performance Standards (NSPS), but also must meet possibly more stringent regulations due to being in nonattainment areas or being subject to prevention of significant deterioration applicable to cleaner air areas. Sources of hazardous air pollutants referred to as air toxics must also meet Maximum Achievable Control Technology (MACT).

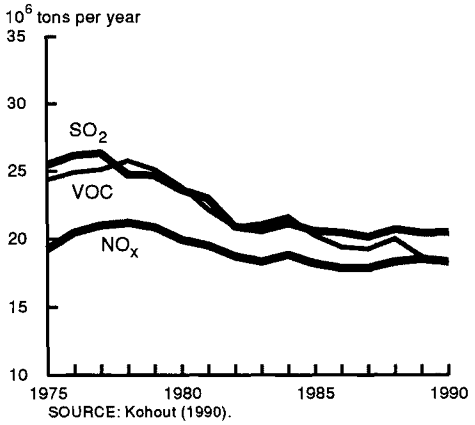
BOX 2

Trends since the mid-1970s following the original CAA

Regulations implementing the original CAA, such as State Implementation Plans (SIPs), have taken effect over various lengths of time. Meanwhile, the composition of economic activity has been shifting away from material intensive processing, a trend working in the direction of lowering the amount of pollution per dollar of GNP. For example, the share of manufacturing in GNP has decreased from 24 percent to 19 percent from 1977 to 1989. In spite of these complexities, it is interesting to compare the changes which have taken place over the 16 year period from 1975 to 1990. The time trends for the three precursors of acid deposition are shown in Figure 1.

FIGURE 1

U.S. emissions trends



SOURCE: Kohout (1990).

	1975 to 1990 % change
Pollutants affecting ambient air quality standards	
Sulfur dioxide (SO_2)	–19
Oxides of nitrogen (NO_x)	–5
Volatile organic compounds (VOC)	–26
Carbon monoxide (CO)	–28
Lead	–95
Particulate matter	–32
Energy use	
Electricity	46
Coal	59
Oil	4
Gas	–4
Economic activity	
Real GNP	58
Employment	40

Hence, emissions of major pollutants regulated under the CAA have decreased significantly while measures of economic value of output and employment have risen dramatically. Electricity and coal use have grown at about the same rate as GNP, whereas oil and gas use are nearly unchanged.

Existing sources are also subject to the New Source Review if operating changes increase emissions or if a major capital outlay is required to refurbish a unit. While the new state permit program is designed to consolidate overlapping requirements on a source, obtaining permits may involve lengthy delays and the permit might require even stronger controls to protect what the CAA refers to as "air quality related values."

With the attention focused on urban ozone nonattainment, any changes in operation of a facility will be scrutinized carefully, and permits for sources of VOCs or NO_x will be granted only with stringent controls. The cleanup of existing sources will need to be extended to the multitude of small sources and small businesses such as dry cleaners and auto repair garages using surface coatings, solvents, and cleaning fluids.

Emission sources in the U.S. and Midwest

The sources of three of the major pollutants regulated under Title I on nonattainment areas, Title IV on acid deposition control, and under other regulations are shown in Figure 1a for the U.S. and compared with the Midwest in Figure 1b. For the purpose of this Figure, the Midwest is defined as the East North Central Census Division which includes Illinois, Wisconsin, Indiana, Michigan, and Ohio, plus the states of Iowa, Minnesota, and Missouri.

Figure 1 shows that the major sources are different for each pollutant. Most of the SO_2, less than half of the NO_x, and essentially none of the VOCs are emitted by electric utilities.

Highway transportation emits NO_x and reactive hydrocarbons (VOCs) but not SO_2, although in the past, diesel ships on the Great Lakes have often used high sulfur oil. A significant amount of VOC emissions comes from wood burning, which is included in Figure 1 in the industrial and other category.

Table 1 presents the shares of these pollutants in the Midwest and compares these shares with the share of economic activity in the Midwest, that is, the 21.5 percent of gross state product that was generated in the Midwest in 1985. For example, 42.9 percent of SO_2 emissions from electric utilities are emitted in the Midwest. The share of emissions in the Midwest approximately mirrors its share of economic activities except for the higher amount of SO_2 emitted from electric utilities. This is due to the Midwest's heavy reliance on locally mined, high sulfur coal for electricity generation.

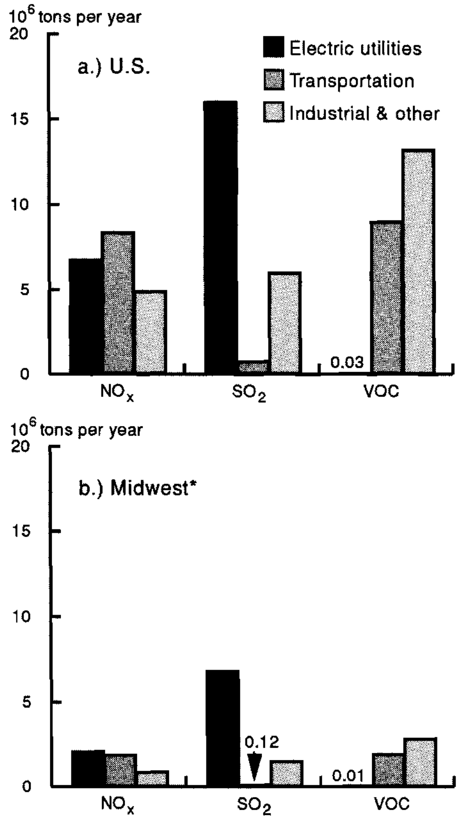
TABLE 1

Share of emissions and economic activity in the Midwest in 1985

Pollutant or economic activity	Share in Midwest by sector (%) All	Utility	Transportation	Industrial and other
SO_2	37.3	42.9	16.4	25.1
NO_x	24.2	30.9	22.6	17.6
VOC	21.6	22.2	21.6	21.6
Gross state product (GSP)	21.5			

FIGURE 1

Emissions sources



*Illinois, Wisconsin, Indiana, Michigan, Ohio, Iowa, Missouri, and Minnesota.
SOURCE: Kohout (1990).

Acid rain control of coal-fired electric utilities

The acid deposition title, Title IV, of the 1990 Clean Air Act Amendments is innovative in its approach to environmental protection policy; it creates a market incentive system based on SO_2 "emission allowances." An allowance must be obtained for each ton of SO_2 emitted, as described below. Once allocated by the EPA, allowances can be traded among companies or be reserved for future use or to hedge against higher emission allowance prices. Allowances are tradable between years, a concept called "emission banking." A two phase approach in Title IV is also innovative, as are the use of incentives to encourage flue gas desulfurization (FGD), also known as scrubbing, and the adoption of clean coal technology (CCT).

The acid rain title is scheduled to cut sulfur dioxide (SO_2) emissions from electric utility power plants from 16 million tons in 1985 (see Figure 1) to about 9 million tons in the year 2000. The ambient air quality standards for SO_2 had already reduced SO_2 emissions from their peak national level of 29 million tons for all sectors in 1977 to about 23 million tons in 1990 (see Figure 1 in Box 2).[2] However, the previous standards did not achieve the level of reduction that was sought for acid deposition control. If the high emitting power plants, many of which burn high sulfur midwestern coal, were to retire at age 30, then SO_2 emissions would rapidly decline in the 1990s and perhaps no Title IV would have been necessary, because the New Source Performance Standards (NSPS) regulations would have assured very low emission rates for replacement units. However, the general trend in the electric utility industry has been to refurbish, life extend, or even repower existing power plants with new clean coal technology (CCT) combustors [see U.S. Department of Energy (1989)]. The choice to maintain the existing higher emitting plants rather than retire and replace them was the result of a desire to avoid more stringent regulation of new sources as well as the difficulties which have beset the utility industry, such as lower than expected load growth, excess capacity, prudence reviews by state public utility commissions, the high cost of capital, rising construction costs, and high debt for those utilities that embarked on large nuclear energy programs. With no end in sight for the cleanup of the existing high SO_2 emitting plants, many of which are in the Midwest, those concerned with the acid rain issue wanted a newly focused approach to SO_2 controls.

Marketable emissions allowances

Emissions trading and banking provide cost savings over mandatory technologies in achieving long run environmental goals. These gains are achieved because, rather than mandatory control technology, firms gain the flexibility to reduce pollution by choosing among the cheapest technologies, alternative fuels, or alternative schedules in lowering emissions. Factors which will affect the least cost choice are: plant design suitability for retrofit, land availability, economies of scale in abatement technology, access to alternative fuels including differences in competition in transportation to power plants at different locations, and alternative local air quality requirements.

Gains from trade can be illustrated with a simple example. Suppose 100 tons of emission reduction are needed to meet the environmental objective. Suppose plant A has a marginal abatement cost (MAC) of $300 per ton and plant B has a MAC of $500 per ton. Under a uniform rollback policy each plant would reduce emissions 50 tons at a total cost of $40,000. However, suppose each plant is issued 50 tons of tradable emission allowances. Then plant A, which has a lower MAC, can sell its allowances to plant B for, say, $400 per ton. Plant A then reduces emissions 100 tons for $30,000, and gains $20,000 in revenue from the sale of allowances. Thus, the net cost to A of the reduction in emission is $10,000. Plant B's $20,000 cost of purchasing allowances is less than the $25,000 it would have had to pay to reduce emissions by 50 tons. The total cost of the 100 ton emission reduction is $30,000—$10,000 for A and $20,000 for B—rather than the $40,000 cost for the uniform rollback policy.

Under the new CAA, allowances are issued gratis to existing polluting utility units based on their "baseline" fuel use as measured by the annual average of 1985, 1986, and 1987 British thermal units (Btu) consumption. The basic Phase I allowances are calculated as 2.5 lb. SO_2 per 10^6Btu times the unit's baseline, and the basic Phase II allowances for the larger, dirtier units are calculated as 1.2 lb. per 10^6Btu times the unit's baseline, though allowance allocations are generally not larger than those required to meet historical emission rates.

Table 2 shows the utility generating units affected in Phase I. All but the smallest units are affected in Phase II. The Table illustrates that although the Midwest receives a disproportionate share of the emission allowances, it also is likely to have greater control costs because greater emission reductions are needed in the Midwest to meet the allocated allowances (alternatively, the Midwest can buy or sell allowances and reduce emissions less or more, respectively.) The estimates in Table 2 indicate that in Phase I, the Midwest receives 46 percent of the allowances but still must reduce emissions 43 percent (based on these allowances), compared with an average U.S. reduction requirement of 33 percent. In Phase II, the Midwest receives 28 percent of the allowances and must reduce emissions 65 percent from the 1989 level, compared with a 41 percent U.S. average Phase II required reduction.

Additional Phase I and II allowances are also distributed based on other considerations. In Phase I, a maximum of 3.5 million tons of SO_2 allowances are to be awarded to units installing scrubbers by 1997. These units can maintain their existing emissions for the first two years of Phase I and then after 1997, also receive '2-for-1' bonus allowances for emission reductions beyond those required by the 1.2 lb. per 10^6Btu limit.

As the CAA plays out over time, it is expected that utilities will in fact choose to bank Phase I allowances for use in Phase II. This is partially connected with the relative concentra-

TABLE 2

	Phase I affected units[1]			Phase II[2]		
	U.S.	Midwest[3]		U.S.	Midwest	
			% of U.S.			*% of U.S.*
Number of generating units	261	137	52	1107	443	40
Capacity *(thousand megawatts)*	81	39	48	294	97	33
SO_2 emissions *(million tons)*	8.3	4.5	55	15.1	7.1	47
SO_2 allowances *(million tons)*	5.6	2.6	46	8.9	2.5	28
Reduction needed to meet allowances *(percent)*[4]	33	43		41	65	

[1]Phase I affected units are listed by name in Table A of the 1990 Amendments; these are the larger, higher emitting units in the country.
[2]A few small units are not included.
[3]Illinois, Michigan, Wisconsin, Indiana, Ohio, Minnesota, Iowa, and Missouri.
[4]Required reduction based on no net trading of allowances outside the region.
SOURCE: Argonne Utility Simulation Model for 1989.

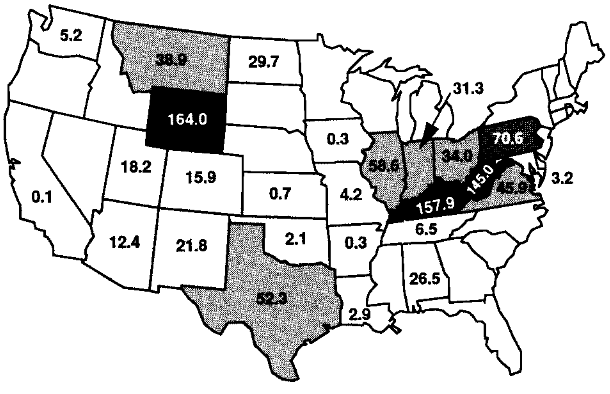
tion of coal production in the Midwest (see Figure 2). The incentives for installing FGD under the 1990 CAA Amendments along with pressure by mining interests in the Midwestern high sulfur coal producing states to scrub rather than switch to low sulfur coal, will result in banked allowances for use in Phase II. Another reason is that, assuming low sulfur coal prices are not bid up too high in Phase I, a unit may be able to switch fuels and achieve an emissions rate of less than 2.5 lb. per 10^6Btus. The banked emissions will lower the cost of complying with the more stringent rate effective in Phase II. For example, a utility could scrub those of its units that are the easiest to retrofit FGD and then burn low or medium sulfur coal in the remainder of its units, thereby banking allowances to cover any excess emissions in Phase II.

Bonus allowances of 0.53 million tons per year are also provided in Phase II to be awarded to units with low capacity factors in the baseline years and to units which would be otherwise penalized because they were already low emitting units as of 1985. Any excess allowances can be traded or used in conjunction with new growth in coal-fired generation. Utilities which contract for approved CCT may be awarded a four year Phase II extension.

Figure 3 shows qualitatively the anticipated paths for emissions and allowances. Allowance awards are the highest in 1995 and 1996

FIGURE 2

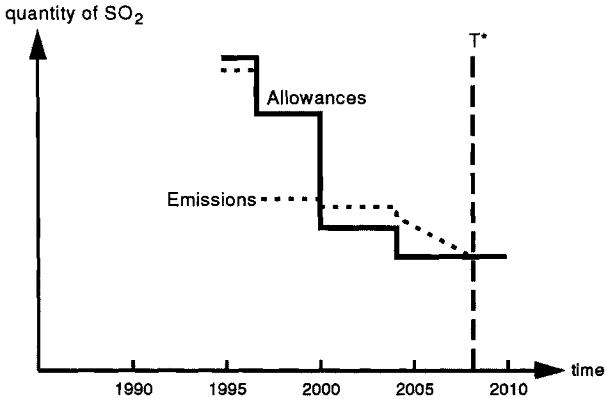
Total U.S. coal production by coal producing state
(Thousand short tons per year)



due to extensions for Phase I FGD. The allowances in 1997-1999 are based primarily on an allowed 2.5 lb. per 10^6Btu emission rate applied to the baseline fuel use for 110 affected plants in Phase I as defined in Table A of the 1990 CAA Amendments. The allowances in Phase II are based on 1.2 lb. per 10^6Btu or less, as applicable, with a four year extension for approved CCT. Hence, as illustrated in Figure 3, allowances are issued at a much higher rate early in the program. Although actual emissions will be decreasing over time, they will also decrease at a slower rate than allowances, which thereby implies an accumulation of banked allowances in Phase I and the using up or depletion of these banked allowances in Phase II (see Figure 4). The time at which banked allowances are eventually used up (that is, when the market regime switches to one of annual market clearing) is denoted by T* in Figures 3, 4, and 5.

FIGURE 3

Anticipated SO_2 emissions and allowances



NOTE: T*=year banked allowances are used up.

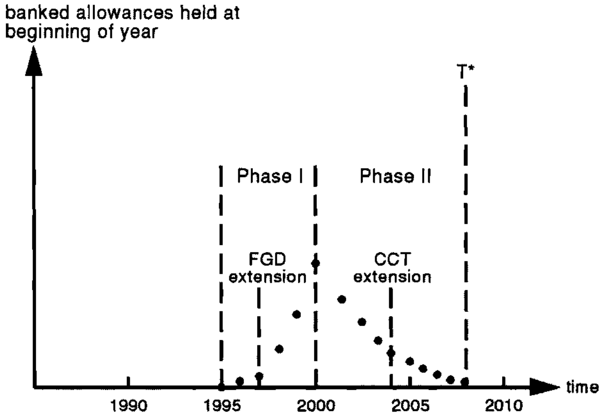
Hedging risks

The market price of allowances is expected to rise steadily over the course of Phase I and II through the middle of the next decade (see Figure 5). This is because (as illustrated in Figure 4), there is expected to be an excess stock of allowances held and the only advantages to holding allowances instead of acquiring them in the future as needed would be capital gains derived from an allowance price expected to rise or the holding of allowances for hedging against uncertainty in the escalation rate of allowance prices. The actual time path of prices will depend not only on technical economic factors such as fuel switching costs, but also on the motivations of market participants. Risk aversion provides a possible motive for electric utilities to bank allowances, thereby increasing the current price of allowances. But forward contracts and futures markets for SO_2 allowances, such as those proposed by the Chicago Board of Trade, may also influence allowance prices by facilitating the entry of speculators who are willing to bear some of the risks of risk averse utilities.

Major uncertainties affecting allowance prices include: future gas supply and deliverability, success of renewable energy, effectiveness of demand side management programs (DSM), recovery of the nuclear industry, CCT performance and future penetration, the extent of low sulfur coal reserves, future electricity demand growth, and regulatory risk. These uncertainties all affect required coal-fired generation during Phase I and Phase II and hence they effect the demand for allowances [see Hanson (1991a and 1991b)]. The holding of allowances can be used to hedge against these

FIGURE 4

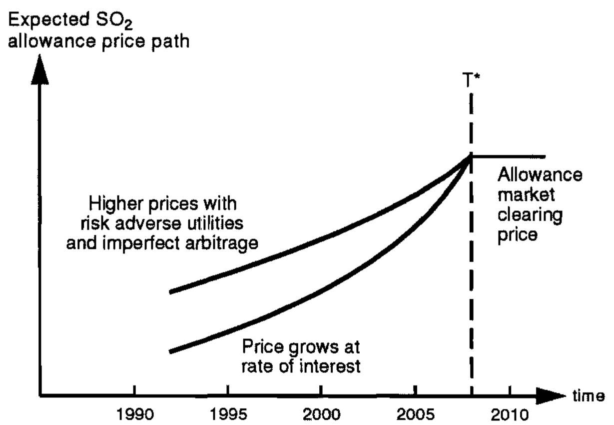
Accumulation and depletion of banked allowances



NOTE: T*=year banked allowances are used up.

FIGURE 5

Anticipated allowance price path with and without utility risk aversion



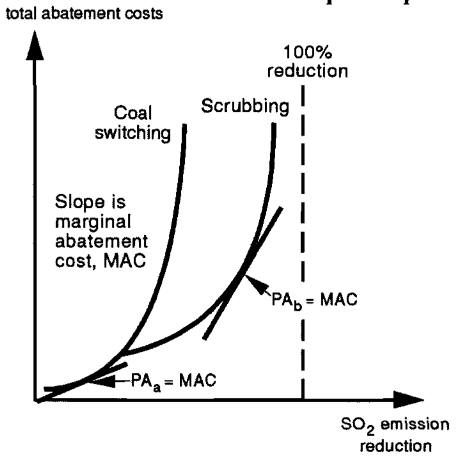
NOTE: T*=year banked allowances are used up.

uncertainties. By lowering costs and risks everyone can gain, including rate payers and utility shareholders.

Electric utilities may consider hoarding more allowances than is prudent or installing more scrubbers than is cost effective when this behavior is sanctioned by their regulatory bodies (public utility commissions). However, if a formal market exists for allowances, it may be more difficult for public utility commissions to make regulations that inhibit electric utilities from making least cost abatement choices, since the existence of market prices makes the alternatives clear to the public and to all involved.

FIGURE 6

Total abatement costs for a power plant



Abatement cost functions and emission reduction

The extent of emission reductions in Phase I and Phase II will be a function of the market price for allowances. A firm can either reduce emissions using fuel switching or scrubbing, or use its allowances. The rule of thumb in economics is that it is cost effective to reduce emissions up to the point where marginal abatement costs equal the price of allowances. For example, if the marginal abatement cost is greater than the price of allowances at the Phase II basic emission rate of 1.2 lb. per 10^6Btu, it would be cheaper for the firm to increase emissions and buy allowances. Figure 6 illustrates the total abatement costs for SO_2 reduction by switching to lower sulfur coal or retrofitting a scrubber for a typical Midwest coal-fired power plant. As Figure 6 illustrates, scrubbing is typically more economical at higher reduction percentages. The slope of the total abatement cost curve is the marginal abatement cost (MAC). The firm can observe current allowance prices, PA, but it must forecast future values for PA. The value of PA used by the firm for planning purposes is the slope of the tangent line (see Figure 6). As shown in the Figure, when the price of allowances is low (represented by the flatter line labeled PA_a), the solution for emission reduction is shown as point (a) and fuel switching is used. When the price of allowances is higher in Phase II (represented by the steeper line labeled PA_b), the solution is shown as point (b). In this case, the firm finds it economical to install a scrubber in Phase II.

Allowances and coal market price path interaction

Interestingly, marginal abatement costs (MAC) are, in theory, proportional to the low sulfur coal price premium, the additional amount paid for coal per unit reduction in sulfur content. Let *PC(S)* denote coal prices as a function of sulfur, where we define *S* in terms of the resulting lb. SO_2 per 10^6Btu emission rate. The *MAC* is just the extra price paid for lower sulfur coal from which it follows (adjusting for a change in units):

(1) $MAC = (-2{,}000 \text{ lb/ton})\ \Delta PC/\Delta S$.

Since the condition $PA = MAC$ provides the cost minimizing compliance strategy and emissions reduction as a function of the allowance price, PA, then

(2) $PA = -2{,}000\ \Delta PC/\Delta S$.

Therefore, market equilibrium low sulfur coal prices are closely connected with market equilibrium allowance prices. Bidding up allowance prices is equivalent to bidding up the price premium on low sulfur coal. Hence, observing the sulfur price premiums in the coal market is a proxy for emission allowance prices.

The other titles of the 1990 Amendments

The EPA has already issued many of the detailed regulations implementing the various titles of the 1990 CAA Amendments, but many more regulations are still scheduled to be promulgated in the future. Interested parties are encouraged to comment on notices of preliminary regulations. This section provides a little more background on some of the other important titles and issues in the new CAA.

Ozone nonattainment areas

Studies show that ozone damages materials and plants, contributes to urban smog, and is not healthy to breathe. Ozone is one of six common pollutants for which National Ambient Air Quality Standards (NAAQS) have been set under the authority of the earlier 1970 Clean Air Act. The other five common air pollutants are sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter, and lead. Under the CAA, the U.S. is divided into Air Quality Control Regions, or airsheds, which are monitored and are deemed to be either in attainment or in nonattainment of the NAAQS for each of the six air pollutants. Considerable progress has been made in the last twenty years in bringing nonattainment areas into compliance with NAAQS for all of the six air pollutants except ozone.

The 1990 CAA Amendments contain a tough new program designed to bring ozone nonattainment areas into attainment. In the 1990 Amendments, ozone nonattainment areas are to be classified as either extreme, severe, serious, moderate, or marginal. Los Angeles is the only extreme nonattainment area. The areas likely to be designated as severe in the Midwest are the Chicago and Milwaukee metropolitan statistical areas. The classification of an ozone nonattainment area determines the actions required under the 1990 CAA Amendments and the schedule.

Each of the states is required to submit a plan to bring nonattainment areas into compliance over a scheduled number of years. These are called State Implementation Plans (SIPs). Any new sources resulting from economic growth in a nonattainment area, or the replacement or modification of existing sources, requires New Source Review. The emission rates for new sources in nonattainment areas are even more stringent than the usual new source performance standards. Further, "offsets" must be obtained for new growth. An offset is a reduction in emissions, sometimes greater than 1-for-1, from another source. Various mobile source controls also apply in nonattainment areas.

Prevention of significant deterioration

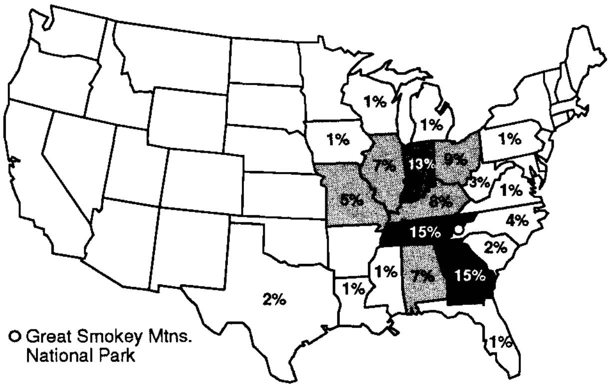
The areas already in attainment, that is the clean air regions, are classified as Class I, II, or III, with Class I areas being the most deserving of clean air. National parks are all classified as Class I areas because of their scenic beauty. Air quality may be allowed to worsen in existing clean air areas, but only by a very small increment, as set out by EPA regulations. This is called the PSD increment. The State Implementation Plans (SIPs) are also required to maintain existing air quality. New sources in the region of a Class I area may require lower emission rates than the usual NSPS.

Visibility and permitting

The Acid Deposition Title IV may not reduce SO_2 sufficiently to achieve goals of improved visibility in national parks, such as the Grand Canyon in Arizona, Shenandoah National Park in Virginia, and other scenic areas. Title VIII of the 1990 Amendments requires that the federal government undertake a study to identify and evaluate possible sources of regional haze. Unfortunately, it appears that, because sulfates are carried over long distances rather than deposited locally, only a small percentage of the contribution to visibility impairment comes from local sources. Based on Argonne National Laboratory's Advanced Statistical Trajectory Regional Air

FIGURE 7

Great Smokey Mountains - sulfate sources



SOURCE: Argonne National Laboratory ASTRAP model.

Pollution model (ASTRAP), relative contributions arriving at Great Smoky Mountain National Park by source state are illustrated in Figure 7. The role and frequency with which sulfates contribute to visibility impairment are now being studied statistically. If more controls are deemed to be needed, then considerably greater SO_2 reduction costs will be incurred beyond the compliance costs already under Title IV.

The reduction in visibility impairment cross cuts several of the regulatory controls in the CAA. The 1977 CAA Amendments set a national goal for no man-made visibility impairment, with reasonable progress to be made toward this goal over time. The PSD program can be used to enforce further controls on emission sources. Alternatively, air quality related values, such as visibility and sensitive ecological areas, can be protected through federal intervention in the state permitting process. Based on recent trends in rejecting new source permits and new regulations promulgated by the Department of the Interior, intervention by the Federal Land Manager to require more stringent emissions caps on existing sources is expected under the new permit program of the 1990 CAA Amendments.

Industrial emissions of hazardous air pollutants

The 1990 Amendments include a list of 189 potentially toxic industrial chemicals to be targeted for regulation. The EPA also has the authority to add to the list or modify it.

A best technological approach has been adopted to regulate air toxic releases under the 1990 CAA Amendments, in contrast to the risk assessment requirements under Section 112 of the original CAA, which proved to be unworkable. The technological approach is called Maximum Achievable Control Technology (MACT). However, a firm may postpone the stringency of the MACT controls if it opts for early compliance. Hence, planning is required to make the best decision because if a firm waits and a stringent MACT is required, the cost may be much greater. After this program is implemented, another wave of regulation is possible. Cost benefit studies will be commissioned by the EPA to see if future controls are warranted.

Stratospheric ozone depletion and global warming

Chlorofluorocarbons (CFCs) and similar bromine compounds are destroying ozone in the stratosphere and are also so-called "greenhouse" gases. Recent scientific studies indicate a more rapid thinning of the stratospheric ozone layer than previously thought, which will, for example, increase the ultraviolet radiation from the sun that reaches the earth's surface.[3] Hence, more skin cancer cases are projected. The Montreal Protocol on ozone depleting substances calls for remedial steps to be taken by industrial countries. Title VI of the 1990 Amendments complies with the Montreal Protocol which calls for controlling both the chemicals themselves and products containing the chemicals. The production and sale of a list of chemicals and yet to be determined substitutes is to be regulated by the EPA. Hence, manufacturers will need to develop substitute chemicals and products including chemicals for use in automobile air conditioners and for cleaning fluids for electronic and photographic equipment.

The Administration's position on controlling greenhouse gases is to reduce these emissions when it is beneficial to do so based on criteria other than the effect on global warning. As a result, cost effective energy conservation is also encouraged to reduce greenhouse gas emissions.

Burdens and challenges: a general equilibrium model

Many of the burdens to individual firms complying with the new Clean Air Act Amendments have been discussed here: increased expenditures for emission abatement or for related planning and administrative activities, loss of flexibility in industrial facility operations, the need to monitor emission releases, and the resulting burden of higher product prices or lower profits or wage payments. But the challenge facing industry is one that economists have trouble describing succinctly because it goes beyond the aforementioned burdens. Emission control is just one of many challenges facing management and labor, who must also be concerned about marketing, product quality, reliability, worker health and safety, labor productivity, cooperative management, worker morale, supplier relationships, new product development, and shareholder profits. Industry must reduce emissions to comply with new regulations and at the same time increase product quality and lower costs. How this can all be done is perhaps a topic in management and organization. From a public standpoint, analysis must focus on how product prices and wage increases are impacted by an environmental regulation. At least in the short run, this reflects the notion that society can enjoy and benefit from a cleaner environment only at the expense of reduced income.

In this section, it is suggested that the extent of these costs on the macroeconomy will depend heavily on the behavior of the real wage rate, that is, a wage adjusted for its power to purchase market goods. The economy may be aptly characterized by sticky wages if workers are reluctant to recognize that lower wages are the cost of a cleaner environment and, for example, continue to negotiate for constant purchasing power. A falling real wage can partly offset the abatement expenditures and full employment can be maintained. But if the real wage is sticky in the downward direction, then the economy will adjust to the new regulations at a greater total cost. Moreover, in a dynamic context, much of this magnified cost will fall on profits which could lower investment spending and new product development. Reasons to anticipate sticky nominal and/or real wages have recently been assessed by Robert Gordon (1990). Descriptions of economic behavior in terms of dynamic wage price spirals have been used in numerous analyses such as the DRI quarterly model of the U.S. economy. Recent empirical evidence has been presented by Mehra (1991).

A simple model has been constructed to illustrate these relationships based on microeconomic principles [see, for example, Varian (1984)]. For ease of exposition, the economy is divided into two industry sectors: Sector X, which creates pollution, and Sector Y which is assumed not to pollute. To obtain numerical results for illustration we assume that 1/3 of the labor force is employed in Sector X and 2/3 in Sector Y. The time horizon is short to medium term which means that technology and production facilities are fixed but that sectorial output can be raised or lowered by hiring more or fewer workers. A marginal product of labor is assumed in which an n percent increase (decrease) in labor gives rise to a 1/2 n percent increase (decrease) in sectoral output. This marginal product of labor assumption defines the production possibility frontier at full employment, as labor is shifted from one sector into the other.

Under the environmental regulation, some output is used for real abatement expenditures. Abatement expenditures are assumed to be divided between heavy manufacturing equipment and materials purchases from Sector X and service and light equipment purchases from Sector Y. These abatement purchases are represented as intermediate goods described by interindustry flows. Substituting between these two abatement factors is allowed (that is, to minimize costs of regulation to the firm) and the feasible substitutions are described by a Cobb-Douglas technology. Abatement costs are taken to rise more than proportionally with reductions in emissions per unit of output in Sector X. Total abatement costs (TAC) using the price in Sector Y as the numeraire, is given by:

$$(3)\quad TAC = (P_x/P_y)\, X_a + Y_a\,;$$

where P_x and P_y are the prices of goods X and Y respectively, and X_a and Y_a are the outputs of sector X and Y respectively, sold to sector X firms for pollution abatement. Hence, the subscript "a" refers to real resources used in emission control. It is often suggested that environmental regulations create income and jobs and hence presumably have positive impacts on the economy. I agree with this position only in part. It is true that abatement expenditures, modeled here as TAC, also represent income earned by some business and that the production of abatement goods, X_a and Y_a, will employ workers. (In fact any output from sectors X or Y will employ workers.) The reason, however, that abatement expenditures (TAC) are a cost to the economy is that the skilled workers and other resources producing X_a and Y_a have an opportunity cost; they could produce other valuable output for society.

In a numerical example, we consider a new regulatory program with TAC equal to 20, which corresponds to the preliminary cost estimate for the 1990 CAA Amendments cited earlier of $20 billion. This is 0.42 percent of national income, I, taken for illustration to be 4,800:

$$(4)\quad I/P_y = (P_x/P_y)X + Y;$$
$$= (.8)2{,}000 + 3{,}200 = 4{,}800;$$

where X and Y are the original equilibrium outputs assumed to be 2,000 and 3,200, respectively (see Figure 8). The numerical values shown for income, 4,800, and the relative price ratio, 0.8, correspond to the consumer equilibrium point described by the consumers' demand curve. The price elasticity of demand is assumed to be –0.5, so that a 10 percent increase in the relative price of X, that is, P_x/P_y, reduces the relative demand for X by 5 percent. The equilibrium point is illustrated in Figure 8.

Another behavioral assumption of the model is profit maximization. In addition, firms in each sector are assumed to be price takers. Firms hire labor and produce output up to the point where the value of the marginal product of labor (MPL) equals the wage rate, W. For Sector Y we express this formally as:

$$(5)\quad MP_L\,(L_y) = W/P_y\,.$$

In Sector X, expenditures for pollution abatement (TAC) per unit of output must be subtracted to obtain the net value marginal product of labor:

$$(6)\quad (P_x/P_y - TAC/X)MP_L\,(L_x) = W/P_y\,.$$

These three relationships: 1) the production function, 2) profit maximization, and 3) consumer equilibrium, define the model. It is a general equilibrium model in which sectoral prices, wages, outputs, and employment are all determined endogenously. The idea is to compare the initial equilibrium point of the model (that is, without the environmental regulations) to the new general equilibrium solution which is reached subsequent to the environmental regulation.[4]

The distribution of income between labor and capital at the initial equilibrium can be calculated from the above assumptions, yielding

$$(7)\quad (I/P_y) = WL/P_y + \pi/P_y\,.$$

We wish to examine changes in real income, real labor income and real capital income. The real values are the nominal values I, WL, and π deflated by a price deflator consistent with consumer preferences. The rate of change in the price deflator is given by:

$$(8)\quad dP/P = 1/3\ dP_x/P_x + 2/3\ dP_y/P_y\,,$$

where the appropriate weights 1/3, 2/3 have been derived from the model.

The "general equilibrium" results from the model are calculated for three policy scenarios which are based on differing assumptions about how flexibly the economy reacts to environmental regulation: 1) full employment, in which the wage rate, W/P_y, decreases in response to environmental controls, 2) a constant real wage based on the price deflator shown

FIGURE 8

Hypothetical starting equilibrium point before regulation

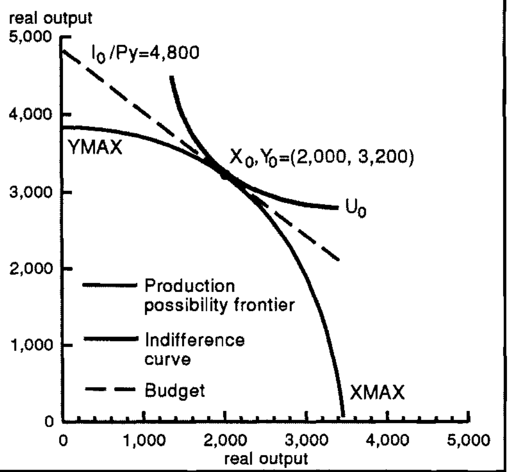


TABLE 3

Illustrated direct and total effects of environmental policy

	Direct abatement cost	Total change in real income*		Change in real labor income		Change in real profits		Addition to unemployment
	Dollars	Dollars	%	Dollars	%	Dollars	%	%
Full employment, lower wage	20	−20.0	−0.42	−14.0	−0.42	−6	−0.42	0.0
Constant W/P_y	20	−23.3	−0.49	−16.3	−0.49	−7	−0.48	0.14
Constant real wage	20	−40.1	−0.84	−14.0	−0.42	−26	−1.80	0.42

*Includes direct abatement cost.

above, and 3) an intermediate case in which W/P_y is constant. In this intermediate case output in Sector *Y* is unchanged but some unemployment will arise from reductions in output for Sector *X*. However, because the price of good *X* increases due to new abatement expenditures, the constant value W/P_y will actually represent a decreasing real wage based on the price deflator. In the case of a constant real wage, the result is even higher unemployment and a magnification of cost due to lost economic output.

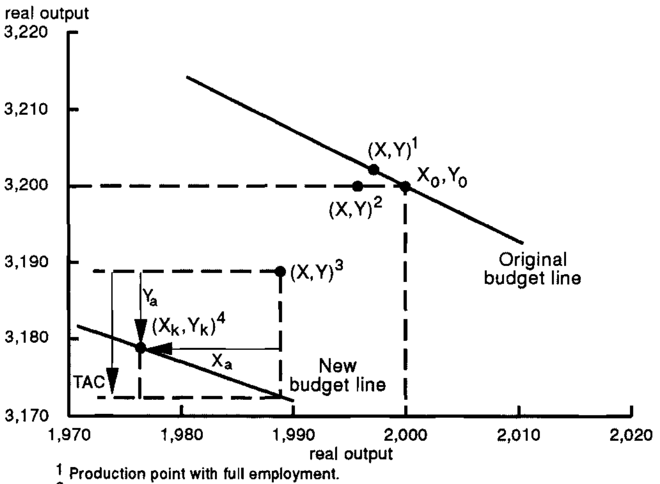
Using these assumptions and numerical values under the constant real wage case in which labor attempts to maintain its real income, the loss in national income is about double the loss in the full employment case. Under the full employment case the loss in national income just equals the direct abatement cost (see Table 3). Further, with a constant real wage, 0.4 percentage points are added to the unemployment rate and real profits decrease about 2 percent, which represents an amplification effect: a direct cost of $20 reduces real profits by $26 and wages by $14 so that the constant real wage shifts the burden more onto capital income (see Table 3 and Figure 9).

Of course, this framework accounts only for a "snapshot" estimate of costs to the economy. As a matter of conjecture, in a dynamic context, a more significant burden would be expected to develop if lower profits reduce investment spending and delay the adoption of new competitive technology, thereby dampening economic growth. In a world characterized by stiff competition in most products, it may not be possible for firms to simply raise prices to partly offset abatement costs.

Some observations can be made regarding regional impacts. It would appear that a region is better off if it produces more of good *Y*, such as services or light industrial products whose output under full employment expands, than a region which produces more of good *X*, which can be thought of as heavy manufacturing, chemicals, refining, coal-fired power plants, mining, and materials processing.

FIGURE 9

Illustration of the effects of regulation under a constant real wage



1 Production point with full employment.
2 Production point with constant Y output.
3 Production point with constant real wage.
4 Consumption point with constant real wage.

There are also regional implications regarding goods consumed versus goods produced. Final goods consumed decline to the extent that they are displaced by the production of abatement goods. And even if the national level of X does not decrease very much, there may be regional reallocations of production as some of the output from X goes into the abatement expenditure activity. A regional goal to preserve regional income in heavy manufacturing areas like the Midwest will be to capture a large part of the market share for pollution abatement sales rather than importing these goods from other regions or from other countries.

However, it should be noted that according to the model, even if a region maintains its share of abatement business in proportion to its original output from sector X, total national output from X is expected to decrease. A region would have to gain share in order to maintain its output. At the present time, the prospects for the U.S. or its industrial regions gaining share would be difficult in view of the strong market positions of other nations, particularly Germany and Japan, in the abatement equipment market.

Conclusions

It is unlikely that the announced costs of around $20 billion per year for the 1990 Clean Air Act Amendments will actually come to pass. Rather, costs are likely to be either higher or lower depending on how the economy adjusts; that is, either how it rises to the challenge, or on the other hand, how the burdens become magnified. In the best case scenario, industry successfully plans to meet the requirements and technology is developed or adopted to meet emissions requirements so that with continued increases in labor productivity and economic growth and adaptation of thinking on the need to control emissions, there may be little public attention regarding an emissions control burden. This optimistic scenario largely reflects previous experiences with environmental legislation; many environmental programs have proven to be less costly than originally feared.

The alternative, less positive scenario is one where planning is difficult because regulatory requirements remain uncertain, partly as a result of uncertainty as to environmental effects and partly due to the unpredictable outcomes of political wrangling over CAA implementations. The permitting process for industrial sources is long, detailed, inflexible, and uncertain. The goals of reducing urban ozone and cleaning up industrial waste and emissions remain as elusive as they have been over the first twenty years of the Clean Air Act's history. U.S. industry falls behind in developing and marketing new, more competitive, cleaner processes. Corporate funds available for investment in new or retrofitted facilities are low. In this negative scenario of lower economic growth, the distribution of income becomes more contentious. Labor, not meeting its expectations for real standard of living growth, attempts to increase its real wage at a time when real environmental control costs are rising. These macroeconomic effects have been observed historically in the 1970s and 1980s, following the oil price shocks of 1974 and 1979 and the rising environmental clean up expenditures during these decades [for example, see Wilcoxen and Jorgenson (1990) and Hickman, Huntington, and Sweeney (1987)]. This, as was shown in our simple economic model, magnifies the direct abatement costs and thereby gives rise to additional lost output and slightly more unemployment. The challenge is to promote communication and cooperation among business leaders, scientists, engineers, and labor so that the worst case scenario involving high costs of a cleaner environment can be mitigated.

FOOTNOTES

[1]The titles and sections under the original 1970 CAA and the 1977 Amendments are distinguished from the titles of the 1990 Amendments. For example, Title III of the 1970 CAA deals with administrative and miscellaneous matters, whereas Title III of the 1990 Amendments provides language to replace Section 112 of the original CAA dealing with hazardous air pollutants from industry (see Box 1 for a listing of the major titles).

[2]National Ambient Air Quality Standards have been set for the six common pollutants shown in Box 2 under the authority of Title I of the original 1970 CAA in order to protect health and environmental values.

[3]Silver (1990), see Chapter 9.

[4]A paper describing the model in more detail is available from the author.

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