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Do We Need the Federal Government to Protect Air Quality?

by Indur M. Goklany

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Abbreviations

Chemical Compounds:

CO	carbon monoxide
NO_x	nitrogen oxides
O_3	ozone
PM	particulate matter
PM-10	PM less than 10 micrometers in diameter
SO_2	sulfur dioxide
TSP	total suspended particles
VOC	volatile organic compounds

Other:

NAAQS	national ambient air quality standards
GNP	gross national product
E/GNP	emissions per unit of GNP
tBTU	trillion British Thermal Units
$\mu g/m^3$	micrograms per cubic meter of air
NIMBY	“not in my backyard”

Introduction

The 1994 Republican takeover of the U.S. Congress stoked the fires of a debate already raging over the federalization of environmental regulation, particularly air pollution regulation. Articles have appeared in law reviews and journals debating the virtues and failings of federalization and whether in its absence states would, as conventional wisdom asserts, inevitably engage in a so-called "race to the bottom."

Without federal regulations, would the environment be sacrificed in a relentless competition for jobs and economic growth? Would this race reduce social welfare and economic efficiency? Is the current framework of air pollution regulation justified by the fact that certain air pollutants cross state boundaries? Would devolution roll back the hard-won environmental gains of the last generation?[1]

Perhaps the most remarkable aspect of this debate is how long it has gone on based largely upon idealized (i.e., theoretical) economic models of firms' decisions to locate new facilities under environmental standards of varying stringencies. Virtually no reference is made to empirical data on air quality or emission trends *prior* to federalization of air pollution regulation.[2]

This report redresses this oversight by developing (where necessary) and analyzing long term national trends in air quality using data straddling the pre- and post-federalization eras for the five original "criteria" (major) air pollutants for which health- and welfare-related national ambient air quality standards were first promulgated in 1971. The pollutants examined are sulfur dioxide (SO_2), particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), and ozone (O_3) or one of its precursors, volatile organic compounds (VOCs). Specifically, I analyze long term "national" trends for the following: (1) residential combustion emissions per occupied household—crude proxies for indoor air pollution—from 1940 to 1990[3]; (2) ambient (outdoor) air concentrations from the 1950s onwards for PM, early 1960s for SO_2, and later for the other pollutants; and (3) emissions per dollar of gross national product from the year 1900 onward for SO_2, NO_x and VOC, and from 1940 on for PM and CO.

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To explain the social, economic, and technological factors driving pollution trends, the report begins with a review of the history of air pollution in the United States. Sections II and III examine national pollution trends—first indoors, then outdoors. Section IV synthesizes the information presented in the trends analyses. Section V provides a unified framework for understanding why and how the peaks occurred for each pollutant.

Section VI compares the evidence of the data with the conventional wisdom that prior to federalization effected by the Clean Air Act Amendments of 1970 there had been little or no progress in improving air quality.[4] It also addresses the concept of a race to the bottom.[5]

Section VII identifies positive effects of federalization, and the last section offers policy recommendations for future air pollution control.

I. A Historical Perspective of Air Pollution in the United States

Where There's Smoke, There's Air Pollution

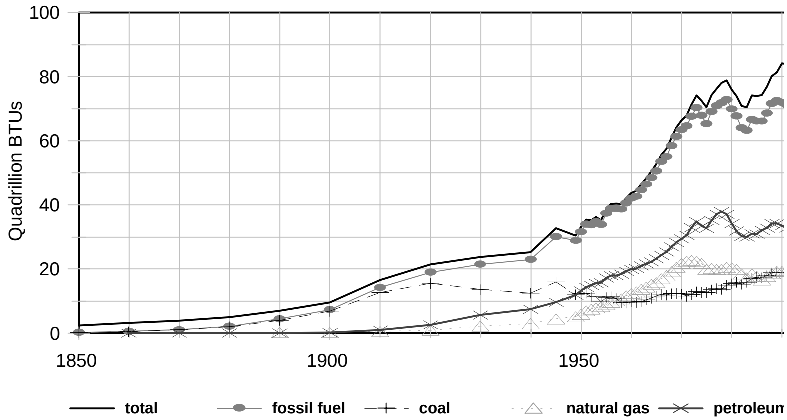
In the United States, smoke was first perceived to be a problem when urbanization and industrialization followed the frontier westward. Unlike the eastern seaboard, which was near the eastern Pennsylvanian sources of "smokeless" (anthracite) coal, Pittsburgh and areas west of it were close to large supplies of soft or high volatility bituminous coal, which was very smoky when burned. By 1860 U.S. fossil fuel combustion, which had been about three trillion British Thermal Units (tBTU) in 1800, had increased to more than 520 tBTU, almost equally divided between anthracite and bituminous coal.[6] (See Figure 1.) While this was still overshadowed by fuel wood combustion (at about 2,640 tBTU), Midwestern cities such as Pittsburgh, St. Louis, and Chicago were beginning to experience smoke problems.

However, there was little progress in dealing with the smoke problem until the late nineteenth century when the mutually reinforcing forces of economic growth and technological change created both the supply and the demand for new, cleaner technologies. As society became more prosperous, cleaner energy sources, namely, natural gas, oil, and electricity—high tech products of the day—began to displace coal and wood in homes, businesses, and industries.

Urbanization, while responsible for many environmental woes, accelerated this process of substitution because higher population densities reduced access to wood, and increased the cost effective-

Figure 1

U.S. Energy Consumption, 1850-1995



Source: *Historical Statistics of the United States* (1975), p. 588; *Annual Energy Review* (1995), Chapter 1.

ness and economics of distribution systems for natural gas and electricity. New technologies entered the marketplace, which increased the efficiency of all types of combustion equipment and reduced the amount of soot produced and fuel burned for a given amount of usable energy. These included more efficient and cleaner furnaces and boilers for homes, businesses, industries, and power plants.

In some places, underground and street railways powered by steam were electrified. In others cities, electrification replaced horse-powered street cars, reducing another, but no less real, form of pollution. The automobile—later viewed as an environmental archvillain—was still a relatively little-used luxury; in 1910 there were two automobile registrations per 100 households. In fact, motor vehicles served an environmental purpose (as did electrification of street railways) by reducing the horse population in urban areas.[7]

Following World War II, there was rapid improvement in the smoke situation. Technological changes begun previously penetrated further: railroads and river boats switched from coal to diesel; industries and large buildings installed smoke reduction devices; and private residences switched first to smokeless coals and then to natural gas. Between 1940 and 1950, the number of Pittsburgh's households using coal declined from 80 percent to 32 percent, while those using natural gas increased from 17 percent to 65 percent, with most of these changes occurring after 1945.[8] Because of a combination of such developments, by the 1960s the smoke problem was virtually solved in most urban areas.

But like heads of the Hydra, as one problem was being solved, new ones were cropping up. Coal pulverization and better air mixing had reduced smoke but had caused more ash to be emitted. More importantly, a series of air pollution episodes occurred in which "excess" deaths and sicknesses were noticed and widely reported on.

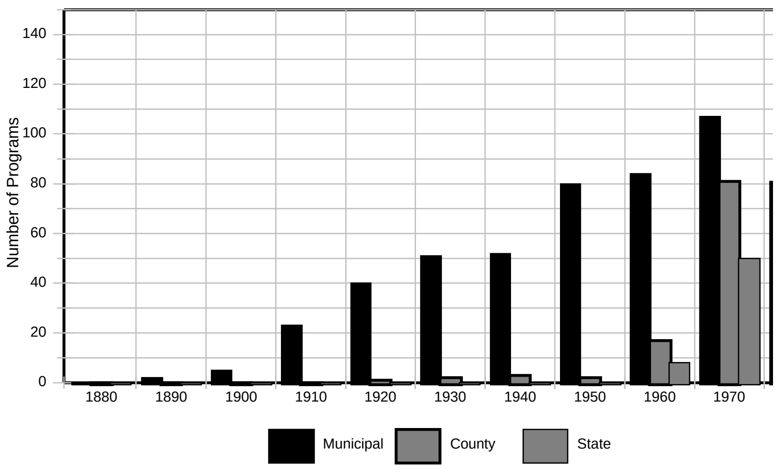
The first was the four-day episode in Donora, Pennsylvania, in October 1948 when a stagnant air mass resulted in 18 deaths in a population of 14,000. That is 15 percent of all deaths we would expect today from all causes in a full year in a population of equivalent size. Retrospective measurements indicated daily SO_2 and PM concentrations in Donora may have been at least 1,800 $\mu g/m^3$ (micrograms of SO_2 per cubic meter of air) and 5,320 $\mu g/m^3$, respectively.[9] By comparison, the 24-hour U.S. health-related NAAQS adopted in 1971 for SO_2 and PM were 365 $\mu g/m^3$ and 260 $\mu g/m^3$, respectively.[10] By 1996, the PM standard had been replaced by one that only measured "inhalable" PM, i.e., PM less than 10 micrometers in diameter (PM-10). The 24-hour PM-10 standard, set at 150 $\mu g/m^3$, approximates the original PM standard. The SO_2 NAAQS remains unchanged.

The second incident was the infamous five-day London episode of December 1952. One-day average SO_2 and smoke concentrations reached 3,830 $\mu g/m^3$ and 4,460 $\mu g/m^3$, respectively. Visibility was reduced to between one and five meters. Four thousand deaths in a population of 8.5 million were attributed to that episode. For a population equal to that of the United States today, this would translate to more than 100,000 deaths in less than a week, compared to an average of 37,000 weekly deaths — roughly a 200 percent increase![11]

Other episodes followed in the fifties and sixties in both London and New York. About 200 deaths were ascribed to the last big one, which occurred in New York around Thanksgiving of 1966. These episodes galvanized public support behind air pollution control and set the stage for sweeping regulations. In the United States the initiative was taken by numerous local and state agencies. (See Figure 2.) By 1956, there were 82 local air pollution control programs; the first state program began in Oregon in 1951, and by 1954, there were 14.[12]

The federal government helped out by providing research, training, and technical assistance under the Air Pollution Control Act (1955). Under the Clean Air Act of 1963, federal grants were made

Figure 2
Growth of Air Programs, 1880-1980



Source: *Stern (1982).*

available for developing, establishing, or improving state and local programs. The 1963 Act also established a "conference" procedure to allow federal authorities to address interstate or, at the request of state and local agencies, intrastate pollution.[13] By 1968, this procedure was invoked for at least nine interstate areas, cumulatively involving more than 10 percent of the nation's population. The general impression,[14] as one historian of the development of the Clean Air Act put it, was that "very little air pollution abatement was actually accomplished by these procedures, which were later abandoned."[15]

Recognizing Unseen Air Pollutants

While other areas of the country focused on PM and SO_2 from stationary sources, in the early 1940s Los Angeles began experiencing a new kind of air pollution quite unlike the traditional smoke problem experienced elsewhere in the industrialized world. This pollution phenomenon—smog—irritated the eyes and reduced visibility.

After several years of research, it was ultimately determined that smog was caused by ozone and other oxidants which were "secondary" pollutants formed by the reaction in sunlight of hydrocarbons (or VOCs) and NO_x emitted by motor vehicles, backyard burning, and other processes, and aggravated by Los Angeles's peculiar geography and meteorology. This led to California adopting ambient air quality standards in 1959 for ethylene, NO_x, photochemical oxidants, SO_2 and CO.[16] People had long known that carbon monoxide could kill indoors if not vented properly, but it became a significant outdoor air pollutant with the increased use of motor vehicles.

To help meet its ambient standards, California established motor vehicle emission standards. For new cars, crankcase control requirements went into effect in 1961 and exhaust standards in 1965. Crankcase controls were also required for resales of any cars from 1955 on.[17]

These requirements came not a moment too soon. In the 1960s, one-hour ozone concentrations often exceeded 1,000 $\mu g/m^3$ and, occasionally, 1,200 $\mu g/m^3$ in the Los Angeles air basin.[18] By the end of 1970, ambient monitoring data showed substantial progress. Between 1966 and 1970, the number of hours that the future (1971) *national* ambient air quality standards (NAAQS) for photochemical oxidants were exceeded annually in downtown Los Angeles dropped from 1,163 to 602.

Concurrently, CO air quality also improved. In 1965, concentrations in downtown Los Angeles exceeded the future 8-hour CO NAAQS 78 percent to 99 percent of the days. By 1970, that frequency had dropped to 40 percent.[19]

By the mid- to late-sixties, the automobile was also becoming a problem in the urban areas of the Northeast. The New York and Pennsylvania legislatures even considered pollution control devices for new vehicles.[20] But outside California, the initial focus on the automobile was due to CO, rather than photochemical oxidants. In fact, the latter were generally considered to be peculiar to California's unique combination of vehicular emissions, poor meteorology, and topography. New York, for instance, only recognized the significance of oxidants after July 1970. In many other areas, the perception that oxidants were not their problem continued into the 1970s.

California's foray into motor vehicle emissions control and the broader concern for CO, energized Congress to pass the Motor Vehicle Air Pollution Control Act of 1965, giving the federal government the authority to regulate hydrocarbons and carbon monoxide from motor vehicles. Under this law, California's vehicle emission standards for the 1967 model year were extended nationally, starting with the 1968 model year. The rationale for this was that a study (disputed at the time) showed that any area with more than 50,000 people would have "enough motor vehicles to create the potential for an air pollution problem."[21] Thus, the argument went, control of vehicle emissions was necessary, but local controls would be inadequate for vehicles engaged in interstate commerce. Moreover, there would be tremendous confusion if each state had its own standards.

While the auto companies disputed the underlying premise, they acquiesced in the outcome, preferring to be subject to one set of non-California standards rather than forty-nine.[22] As the Automobile Manufacturers Association stated later, "A minimum of variation in requirements is in the best interests of the public, the industry, and, eventually, the regulatory agencies themselves."[23]

[A]vailable data suggest that air quality was improving, especially in the areas with the worst problems.

However, the 1965 Act was insufficient to deter other states from considering their own motor vehicle standards. For instance, in August 1966, Governor Nelson Rockefeller signed a law giving the New York Air Pollution Control Board the authority to establish motor vehicle emission controls "with due consideration being given to federal laws and regulations."[24] In response, the Air Quality Act of 1967, signed by President Johnson on November 21, 1967, explicitly preempted state regulation of automobile emission standards, except for California.

The Air Quality Act of 1967 required the federal government to designate air quality control regions and publish air quality criteria and control technology documents. Based on these, states were to develop ambient air quality standards and formulate implementation plans for federal approval.

By mid-1970, 21 states had established ambient air quality standards for total suspended particulates (TSP) and SO_2. In addition, 20 air quality control regions had also proposed or promulgated such standards.[25] While several states received federal approval for their ambient standards, none of the 21 implementation plans submitted received federal approval.[26] The process was deemed to be a failure.[27]

But while the *process* may have failed, available data suggest that air quality was improving, especially in the areas with the worst problems. As noted, O_3 and CO levels were improving in the Los Angeles area. More importantly, there was substantial progress in urban areas for the pollutants most directly associated with mortality and morbidity, i.e., TSP and SO_2,

In New York City, for instance, daily TSP levels, once as high as 1,000 $\mu g/m^3$, declined to 280 $\mu g/m^3$ by 1970, and SO_2 levels were reduced more than 50 percent between 1964 and 1970.[28] Similarly, TSP levels in Pittsburgh had also been halved between 1959 and 1970. Nationwide, between 1950 and 1970, SO_2, TSP, and CO emissions from the residential sector declined 76, 73, and 66 percent, respectively.[29]

The public health benefit of those reductions was very high because they improved air quality in the area where most people spend the majority of their time, namely, in and around their homes. As a result, as we shall see in greater detail in subsequent sections, the era of major episodes, with noticeably higher mortality rates, was virtually over.

Full-scale Federalization

Some observers imply that the 1963 Act was a failure because only one case ever went to court under the conference procedure. Similarly, the 1967 Act has been labeled "fundamentally defective because the enforcement provisions were weak."[30] This, of course, confuses form with substance, and "enforcement provisions" with progress in cleaning the air.

In fact, as the above anecdotes from New York, Los Angeles, and Pittsburgh suggest, air quality had been improving remarkably. Public health risks were greatly reduced. Perhaps the failure of the *processes* envisaged by the 1963 and 1967 Acts contributed to the perception that progress was too little and too late.

Several arguments were offered for a larger federal role in air pollution control.[31] First, air pollution does not respect political boundaries; without federal regulation, state and local authorities, supposedly, would not make any effort to reduce pollution originating in their jurisdictions that affected adjacent areas. Second, in the absence of federal regulations, states and local jurisdictions competing for jobs and economic growth, it was argued, would inevitably sacrifice the environment. In other words, there would be pressure to relax environmental standards, which would compromise social welfare, resulting in a so-called race to the bottom.[32] Third, it was claimed that the failure of the process outlined in the 1967 Air Quality Act proved that state and local authorities could not be trusted to improve air quality. Fourth, many industries saw federal regulation as a method of ensuring that they had a "level playing field," i.e., out-of-state competitors would not have an advantage because of low clean-up requirements elsewhere. Some may have seen federal regulations as providing them a competitive edge over smaller companies and upstarts that could not spread their costs over a large number of production units. Moreover, larger companies with plants in several states preferred to deal with one big chief rather than fifty "Indians."

Regardless of the merits of these arguments, the reports of numerous deaths associated with air pollution episodes in the sixties had heightened public concern. The air pollution problem cried out for a solution. And now that residential areas were cleaner, industrial areas seemed, by contrast, that much dirtier, and in greater need of control. People were living longer and healthier. As old risks were conquered, the smaller, remaining risks seemed to be even more threatening.

Moreover, it was argued, had not the United States sent a man to the moon? Compared to that, how difficult is cleaning the air? Surely, American ingenuity, money, and resolve were up to the challenge.[33]

In the meantime, President Richard Nixon tried to harness the forces of environmentalism to his advantage by establishing the Council on Environmental Quality on January 1, 1970.[34] The environment also received special mention in his "State of the Union" address. Nixon continued his offensive February 10 with a special message on the environment. That same day, the Administration introduced its clean air bill in the House. The bill would have substantially expanded the federal role to include setting national ambient air quality standards and technologically-feasible stationary source emission standards for both new and old sources.[35]

On March 4, Senator Edward Muskie, a potential 1972 presidential candidate, responded by introducing his own bill in the Senate. The success of the first Earth Day that year only escalated the stakes. On July 9, Nixon proposed establishing the Environmental Protection Agency. Senator Muskie, goaded by an earlier, widely-publicized Ralph Nader report questioning Muskie's environmental credentials, upped the ante considerably through the subcommittee and committee markups.[36] Claiming that "air pollution is more severe, more pervasive and growing faster than we had thought," he opined, "We have fallen behind in the fight for clean air, it is not enough to implement existing law. We must go further."[37] And indeed Senator Muskie did, and Congress went with him.

Ultimately, despite any misgivings, Nixon ended that year as he had begun it—on an environmental high note. On December 31, he signed the new Clean Air Amendments of 1970 into law.

The 1970 Amendments substantially expanded the federal government's role. They gave the federal government primacy; its relationship to state and local governments became that of a meddlesome and micromanaging superior to a group of recalcitrant and unreliable employees. The amendments asserted federal responsibility for stationary sources, whether or not the sources had an interstate impact. They set up the following basic framework for air pollution control: (1) national ambient air quality standards (NAAQS); (2) technology-forcing stationary source requirements, including New Source Performance Standards and national emissions standards for hazardous air pollutants; (3) the concept of Prevention of Significant Deterioration in areas with clean air; and (4) the requirement that state programs and policies gain federal approval.

The Amendments also established new motor vehicle emission standards requiring 90 percent reductions (relative to pre-1968 vehicles) of hydrocarbons and CO by 1975 and NO_x by 1976. In addition, the amendments established federal enforcement authority and allowed citizens to sue polluters and the EPA if compliance lagged.

Except for the establishment of NAAQS, the effects of most of these provisions on air quality or emissions were not felt until 1973, or even later in some cases. Existing air quality obviously was due to existing sources, but it was some time before provisions related to those sources became enforceable regulations and later still before the regulations had to be acted upon by individual sources. This was partly because of the cumbersome centralized planning and approval process.

In early 1971, EPA established NAAQS for SO_2, TSP, CO, oxidants and NO_2. EPA also administratively established relatively modest NO_x emission standards for 1972 model year automobiles, requiring less than a 10 percent reduction relative to pre-1968 cars.[38] An environmental bonus of the federal motor vehicle emission control program was that it also reduced lead emissions. Auto companies resorted to catalysts to reduce unburned VOCs and CO, and, because catalysts could be "poisoned" by lead-based additives, "leaded" gasoline was slowly phased out as newer, catalyst-equipped cars came into the market.

Just as reduction of lead in gasoline was incidental to reducing other motor vehicle emissions, lead emissions were reduced from stationary sources as a consequence of the cleanup of TSP sources. When separate NAAQS for lead were issued in 1978, compliance was relatively painless for most areas because of these previous control efforts.

The two oil shocks of the 1970s had a substantial effect on emissions and air quality. Across-the-board fossil fuel energy price increases unleashed major energy conservation and fuel-switching efforts in all economic sectors, including households. This arrested the growth of petroleum and natural gas usage but accelerated coal consumption. The net effect was to depress fossil fuel usage for more than a decade. (See Figure 1.)

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The 1977 Clean Air Act Amendments codified and tightened the Prevention of Significant Deterioration requirements, replaced the old set of deadlines with a new set (because many areas had missed the previous ones), and established sanctions against states and areas which failed to meet those deadlines or did not have approved plans.[39]

The latest amendments to the Clean Air Act were written in 1990. Recognizing, finally, that the magnitude of, and solutions to, the ozone problem varied from area to area, they allowed deadlines for NAAQS attainment to be determined by the severity of the problem. The amendments also established a formal program to reduce SO_2 and NO_x, because of their contribution to acid rain and visibility impairment, and, once again, changed the deadlines for "nonattainment" areas. The 1990 amendments established quantitative emission targets (caps) for SO_2 and took a small step away from the command-and-control mindset by allowing emissions trading for acid rain control.

II. Trends in Indoor Air Quality, 1940 to 1990 [40]

While governments and international bodies define healthy air in terms of the air quality at a fixed point outdoors, indoor air quality, particularly in the home, is a far better indicator of the impact of air pollution on public health.

Virtually no one spends an entire day, let alone an entire year, rooted at the same spot outdoors. In fact, most people spend the vast majority of their time indoors, generally at home. Studies of human activity patterns in the United States indicate that the average person spends about 93 percent of their time indoors, 5 percent in transit and the remaining 2 percent outdoors. About 70 percent of the average person's time is spent indoors *at home*. The average homemaker spends an even greater amount of time indoors at home (nearly 89 percent).[41]

[I]ndoor air quality, particularly in the home, is a far better indicator of the impact of air pollution on public health.

The quality of air is often worse indoors than outdoors. While the effects of outdoor sources may be attenuated indoors, traditional air pollutants sometimes have their own indoor sources. Indoor sources include the following: (1) heating and cooking equipment that uses fossil fuels and biofuels (e.g., wood and, in developing countries, dung), (2) smoking, (3) solvents, and (4) various cleaning solutions used or stored in the home. Thus, the relationship between indoor and outdoor concentrations is often weak. CO, NO_x and TSP are generally higher in homes employing natural gas than outdoors; SO_2 and O_3 are higher outdoors, by a factor of two to five.

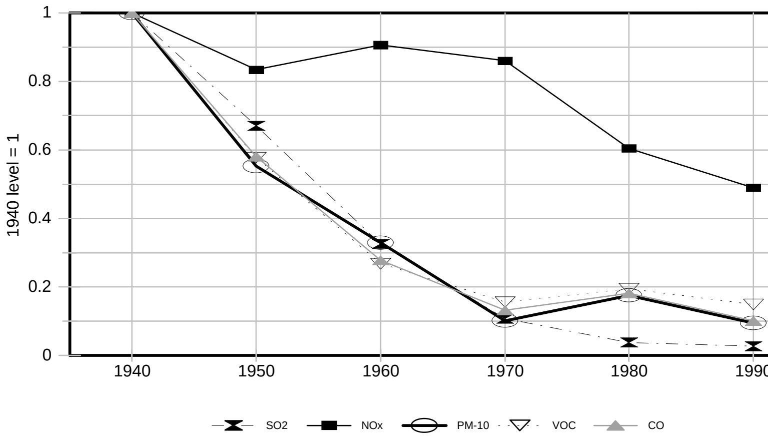
A factor contributing to this weak relationship is that the rate at which outdoor air enters a building (i.e., the air exchange rate) is relatively low, particularly in winter and, where air conditioning is prevalent, in summer. This precludes equilibrium being established between outdoor and indoor concentrations.

Not surprisingly, empirical studies of human exposure show that the concentration of a pollutant in outdoor air contributes only a small amount to the total dose of that pollutant received by human beings. For example, a U.S. study showed virtually no correla-

Figure 3

Indoor Air Quality, 1940-1990

(Using, as a proxy, residential emissions per occupied housing unit.)



Source: Historical Statistics of the United States (1975); *EPA* (1995).

tion between CO levels in the blood—the physiological route by which CO affects people—and outdoor monitored levels. Ambient concentrations explained less than 3 percent of variation of CO levels in the blood. Similarly, outdoor concentrations of nitrogen dioxide (NO_2) are relatively poor predictors of total population exposure, while average indoor concentration explains 50 to 60 percent of total exposure. Finally, calculations for the United States indicate that 1 gram of indoor PM emissions can have a greater effect on total population exposure than 1 kilogram (1,000 grams) released by a power plant with a relatively high stack.

Although air quality in the average home is the single most important indicator of air quality with respect to public health, no long term indoor air quality measurements are available for the home or elsewhere. A crude proxy for long term trends for in-home concentrations, particularly applicable to nonsmoking households, can be constructed for some pollutants by dividing EPA estimates of residential fuel combustion emissions by the corresponding number of occupied housing units.[42] (Fuel combustion is the major source of residential emissions for the traditional pollutants.) Also, residential emissions contribute a high fraction of that portion of total human exposure acquired *outdoors* because these emissions are expelled at low heights where people live and, as noted, spend most of their time.

Using this approach, I estimate that the average nonsmoking household's in-home concentrations between 1940 and 1990 declined (i.e., improved) 91 percent for PM-10, 90 percent for CO, 97 percent for SO_2 and 51 percent for NO_x (see Figure 3).

For PM-10, more than 99 percent of these improvements occurred before 1970, i.e., before federalization. The corresponding figures for CO, SO_2, and NO_x are 97, 92, and 27 percent, respectively. The relatively smaller effect on NO_x was due to the fact that switching from wood and coal to oil and gas decreases NO_x less than it does SO_2 or PM-10, and that many methods to burn fuel efficiently result in higher temperatures during combustion which increases NO_x formation.

Using the above methodology, I also estimate combustion-related VOC concentrations in a nonsmoking home to have declined 85 percent from 1940 to 1990. But this improvement may have been offset by increases in indoor emissions of solvents and other volatile substances stored or used in the home.

There are, of course, a number of complicating factors with respect to these estimates. On one hand, these improvements in indoor air quality could be *underestimates* because they ignore several factors that may have further reduced indoor concentrations over the last fifty years: (1) increases in the average house size, (2) improvements in capturing, exhausting, and filtering combustion gases, and (3) increased vacuuming of dust (as opposed to sweeping).

Much of this improvement in indoor air quality would be masked in smokers' homes because tobacco smoke contributes substantially to indoor levels of CO, NO_x, and particulates.[43] However, the average home should also have become cleaner with respect to tobacco smoke because between 1970 and 1990 the annual number of cigarettes sold per capita dropped from 4,000 to 2,800.[44]

On the other hand, through the years, the air exchange rate between indoors and outdoors has been reduced for the average home because of greater reliance on air conditioning and increased emphasis on energy conservation, particularly since the oil shocks of the 1970s. While lowered air exchange rates may result in a cleaner in-home environment if the concentration outdoors is higher than indoors, it would, *ceteris paribus*, make matters worse indoors by allowing concentrations or pollutants produced (or emitted) indoors to build up. Thus, while the massive federal effort initiated during the 1970s to conserve energy may have helped reduce energy usage somewhat, they may perversely have aggravated—though perhaps by not too much—public health effects of indoor air pollution.

III. Long-term Trends in Ambient (Outdoor) Air Quality in the United States

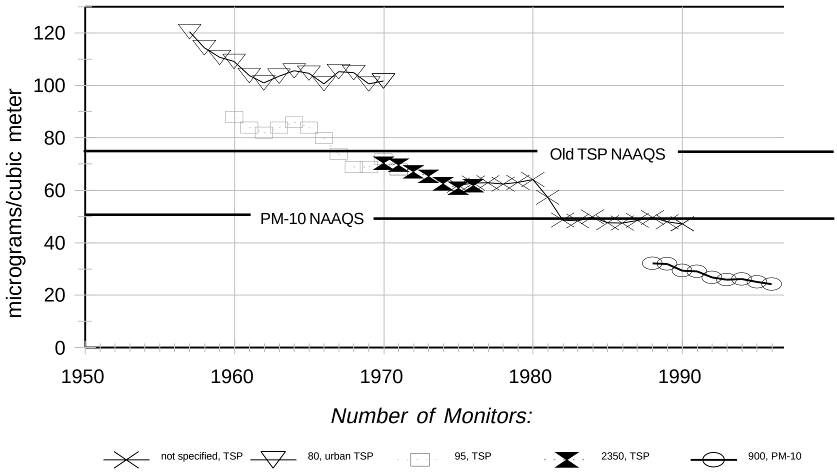
Systematic nationwide efforts to monitor air quality began in 1953, when the U.S. Public Health Service began sampling suspended particulate matter in 17 cities in cooperation with local (and a few state) agencies. By 1956, particulate sampling had expanded to 66 communities nationwide. In 1957, the National Air Sampling Network, which planned to operate about 100 sampling stations each year in urban and non-urban areas, was established. It was followed in 1959-1960 by the Gas Sampling Network, which was to collect 24-hour samples of SO_2 and nitrogen dioxide (NO_2). Then in 1962, the six-city Continuous Air Monitoring Project (CAMP) was begun to continuously measure CO, NO_x, SO_2, total hydrocarbons and total oxidants.[45] The order in which these monitoring programs came into being also reflects the order in which the various pollutants were perceived by national policy makers and the public as having significant public health effects. (See Section I.)

It is possible to construct "national" trends by stringing together data from various EPA annual reports on air quality trends, Council on Environmental Quality's annual reports (*Environmental Quality*), and the *Statistical Abstracts of the United States*. These publications usually provide data for 10 to 12 years at a time, which can be combined to construct a much longer time series. But it should be recognized that these trends are qualitative, rather than quantitative.[46]

Particulate Matter

A trend line can be constructed for urban TSP beginning in 1957. The following year 20 rural monitors were added to the federal network, providing a basis for a more representative, national trend line. Figure 4A gives an overview of national trends for particulate ambient air quality from the late 1950s to 1996.[47] It shows that the "nationwide" TSP levels, based upon the mean of the annual average concentrations for several monitors, declined by 40 to 50 percent between the late 1950s and 1990. The "national average," which used to be above the old primary (health-related) NAAQS

Figure 4A
Ambient TSP and PM-10 Concentrations, 1957-1996
Mean Annual Average



Sources: Environmental Quality, 1971, 1979, 1981, 1991; EPA, 1990, EPA/OAQPS, 1998.

of 75 µg/m^3, is now 35 percent below that level.

The ambient air quality data (Figure 4A) indicate that urban air quality for particulate matter, as measured by TSP, has been improving at least for as long as the data are available, i.e., since 1957. The mean of the annual average readings for an ensemble of monitors in 80 urban areas shows declines from 121 to 102 µg/m^3 from 1957 to 1970.

The story with respect to nonurban areas is mixed. The Council for Environmental Quality's 1971 report indicates that the average of 20 rural monitors rose from 23 to 37 µg/m^3 between 1958 and 1970. But subsequent trend analysis done by EPA for 1960 through 1971, using 18 nonurban monitors, showed annual TSP levels went up at two, declined at five and stayed constant for 11 monitors. Aggregating these results showed no overall trend because a decline in the 1960-68 period was offset by an increase in the 1968-71 period—the latter possibly due to decreased rainfall.[48]

Regardless of which set of trend data one employs for nonurban areas, their average levels were, at all times, far below urban levels and comfortably below either the primary (health-related) or the secondary (welfare-related) NAAQS. Most importantly, the worst areas (major cities) were getting better long before the 1970 Clean Air Act Amendments were passed or became effective, while rural areas may or may not have been getting worse.

Overall, these trends imply that adverse public health effects of TSP should have been declining. A "national" average based upon 100 monitors indicated an improvement from 96 to 89 $\mu g/m^3$ between 1958 and 1970.[49] Average levels for a second ensemble of 95 monitors showed a more rapid improvement nationally, from 84 to 72 $\mu g/m^3$ between 1960 and 1970, with a further decline to 68 $\mu g/m^3$ the following year.[50] These improvements apparently continued until 1975, about the time the federally enforceable state implementation plans were becoming more fully effective.

After a period of little change, TSP levels dropped sharply in 1981 and 1982, only to stabilize once again. One reason for the declines in 1980 and 1981 was the steep reduction in economic activity—the recession.[51] The rate of the decline, however, may be exaggerated because in 1979, EPA changed its supplier of filters used in the monitors to trap dust (particulates) and then reverted to the original supplier in 1982. The filters used in the interim were found to be more alkaline which may have inflated TSP readings—gases in the incoming air were more likely to form sulfates, nitrates and other secondary particulates on the filter.

In 1987, the TSP NAAQS were replaced by the PM-10 standards. This change was made because PM-10 is a better indicator of health impacts than TSP—smaller particles are more likely to be inhaled deeper into the lungs. The national composite annual average for PM-10 declined 25 percent from 33.2 to 24.2 $\mu g/m^3$ between 1988 and 1996.[52] For comparison, the primary annual NAAQS for PM-10 is 50 $\mu g/m^3$.

Sulfur Dioxide

Data on sulfur dioxide levels are available from 1962 to 1969 and from 1974 onward. (See Figure 4B.)[53] SO_2 concentrations declined quite dramatically in the 1960s. Between 1962 and 1969, based upon 21 urban monitors, the mean annual average dropped about 40 percent, from 69.4 to 42.5 $\mu g/m^3$.[54] The corresponding primary NAAQS is 80 $\mu g/m^3$. Between 1974 and 1996, the national "average" dropped more than 60 percent. The current national annual average is about 14.6 $\mu g/m^3$.

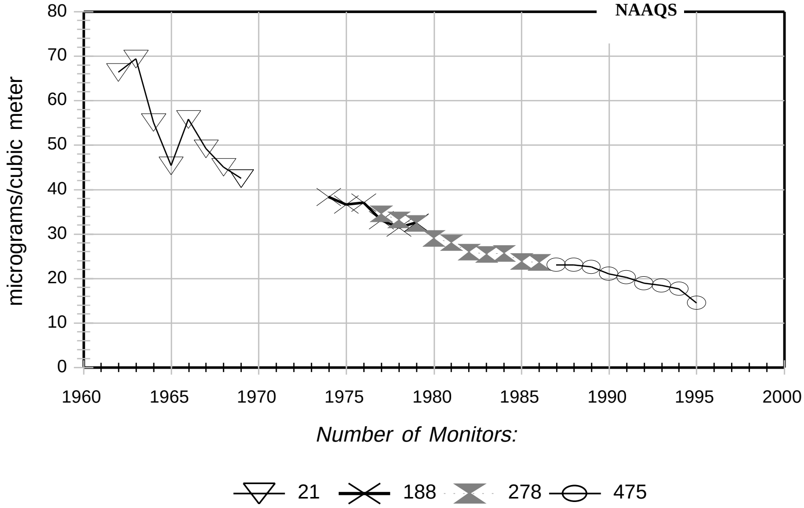
Carbon Monoxide

Data on ambient CO air quality are sparse until the early 1970s. What little data there are suggest that CO air quality may have begun improving, at least in urban areas, in the mid-sixties, as indicated by the short segment of data from 1963-

Figure 4B

Ambient SO_2 Concentrations, 1962-1996

Mean Annual Average



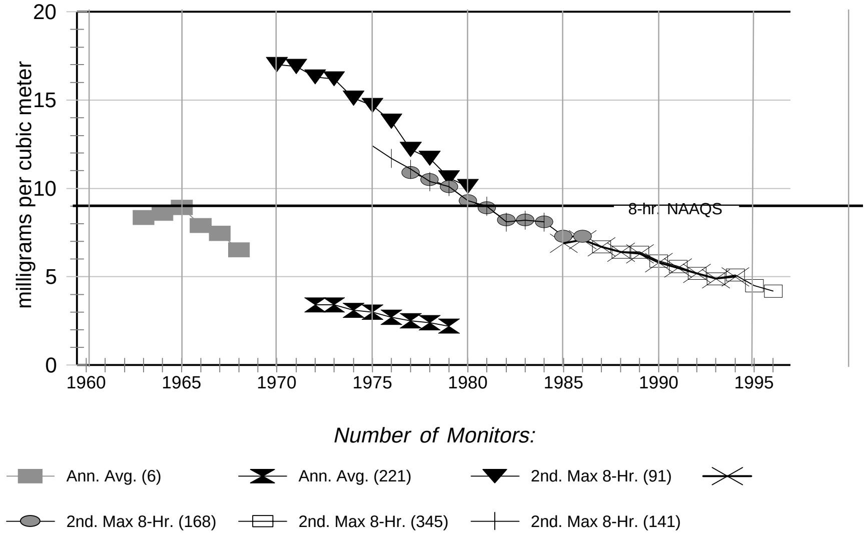
Sources: Environmental Quality, 1981; *Statistical Abstract*, 1981; EPA/OAQPS, 1998.

1968. (See Figure 4C.)[55] That segment was obtained from the federally operated six-city (Chicago, Cincinnati, Denver, Philadelphia, St. Louis, and Washington, D.C.) CAMP network which began collecting data in 1962.[56] The fact that declines apparently began before the Federal Motor Vehicle Control Program went into effect indicates that stationary source reductions may have played a key role in the initial turnaround. These improvements then gathered momentum as an increasing number of vehicles became subject to federal tailpipe controls, starting with model year 1968.[57]

Data from California also indicate that CO air quality, by and large, began to improve around 1965-67.[58] For example, in Long Beach, the frequency of days that exceeded the eight-hour CO NAAQS standards (established in 1971) peaked at 78 to 100 percent in 1964 and 1965, and declined to 32 percent in 1971. In Burbank, the daily frequency with which the CO NAAQS were exceeded dropped from 93-100 percent in 1966 to 34 percent in 1971.[59]

Figure 4C shows that between 1970 and 1996, the national mean CO concentration (based upon the mean of the second highest 8-hour concentration at each location) decreased about 75 percent.

Figure 4C
Ambient CO Concentrations, 1963-1996



Sources: *Environmental Quality* 1971, 1981; *Statistical Abstract*, 1981; EPA 1995, 1998.

Ozone

Most official data on ozone air quality are provided in terms of the statistic most readily compared with the NAAQS, i.e., the magnitude of the second highest one-hour reading in the year (after eliminating the day with the highest one-hour number). Because this number is very sensitive to meteorological factors, it is difficult to distinguish trends from year to year. Figure 4D indicates the trend in the national mean for this statistic.[60]

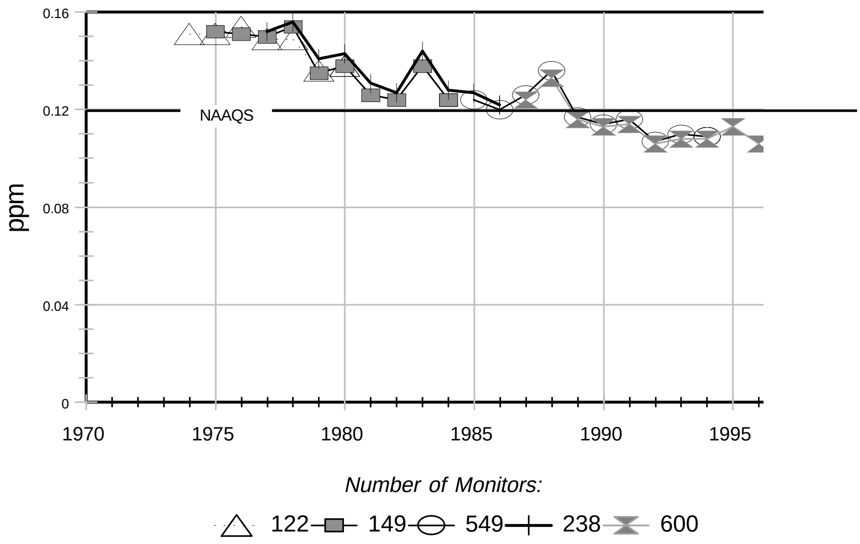
These data commence after 1974 because prior to that there were not enough monitors outside of California to allow a reasonable "national" trend to be constructed.[61] This poor national coverage only confirms that photochemical smog was not perceived by many to be a major national problem until the late 1960s, or even the 1970s.

The California data suggest that oxidant concentrations began declining there by 1966-67. For instance, in 1966 Azusa, in the Los Angeles basin, exceeded the 1971 one-hour oxidant NAAQS 1,636 times; by 1972 exceedences declined to 1,082.

Figure 4D

Ambient Ozone Concentrations, 1974-1996

Average of 2nd highest daily maximum value



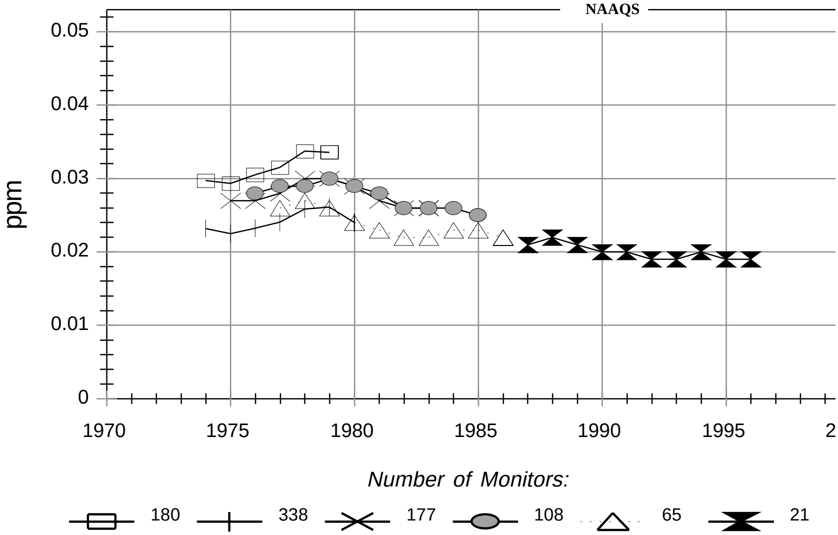
Sources: Environmental Quality, 1981; EPA 1995, 1998.

Similarly, the number of hours downtown Los Angeles exceeded the 1971 standards peaked in 1966 at 1,163 and dropped to 516 by 1972. Also, an EPA analysis of oxidant trends at three sites on the East Coast (Bayonne, Newark, and Camden, New Jersey) showed improvements in oxidant air quality between 1966 and 1969, and again between 1969 and 1972.[62]

National trends shown in Figure 4D indicate a roughly 30 percent improvement between 1974 and 1996 for the statistic plotted in Figure 4D. Between 1985-86 and 1993-4, the two-year average for this statistic declined about 10 percent.

Another statistic, the average number of exceedence days, which probably has greater significance for public health, improved by a greater amount. Based upon two-year running averages at 352 nationwide sites, the number of exceedence days decreased about 45 percent between 1985-86 and 1993-94.[63] Clearly, trends in the statistic that more closely correspond to the NAAQS do not tell the entire story regarding trends in the public health effects of ozone.

Figure 4E
Ambient NO_2 Concentrations, 1974-1996
Annual Average Concentrations



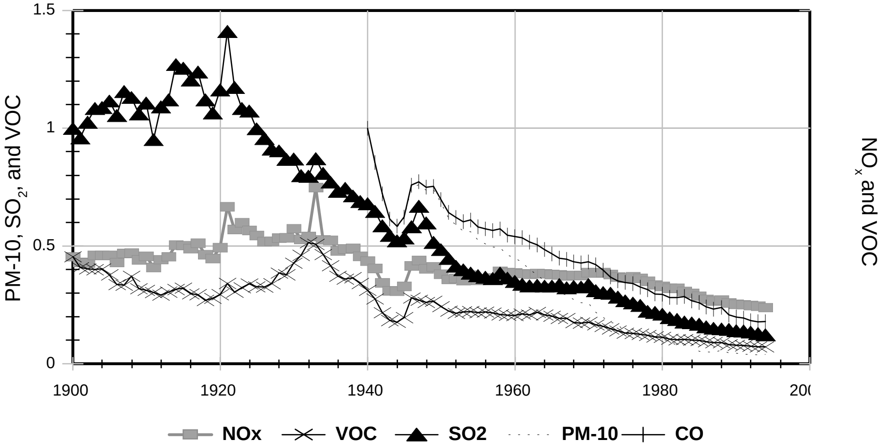
Sources: Environmental Quality, 1981, 1984; *Statistical Abstract*, 1981, 1988; EPA, 1998.

Nitrogen Dioxide

Reliable NO_2 monitoring data are available only after the early seventies. Figure 4E indicates that NO_2 concentrations peaked around 1978-79 and have declined by about 30 percent since then.[64] In the United States, Los Angeles is now the only area designated "nonattainment." However, the NO_2 standard of 0.053 ppm was not exceeded in Los Angeles from 1992 to 1996.[65] Between 1988 and 1996, the highest reading in Los Angeles County declined 22 percent from 0.061 to 0.048 ppm.

Figure 4E indicates that improvements came to NO_2 much more slowly than for other pollutants. There are several reasons for this. First, NO_2 health effects are relatively minor, making it a lower priority pollutant. Second, very few areas were ever designated nonattainment for NO_2, so it was never perceived to be a widespread problem. Third, many measures to increase fuel efficiency and reduce CO and VOC emissions increased combustion temperatures and, thus, increased NO_2 emissions. Finally, although nitrogen oxides were also implicated in ozone formation, the national emphasis

Figure 5
Emissions per GNP, 1900-1994



Note: For PM-10 and CO, E/GNP=1 in 1940; for SO_2, VOC and NO_x, E/GNP=1 in 1900.

Sources: EPA, 1995; Bureau of the Census 1975, 1995, 1996.

was on controlling VOCs, in large measure because of the relative control costs of reducing emissions of the two pollutants.

When Cleanup Commenced—Trends in Emissions per Unit of Gross National Product

In a society whose economy is expanding, emissions per unit of gross national product can serve, to some extent, as a "leading environmental indicator." Until a sustained decline in this leading indicator occurs, there will be no downturn in emissions. Accordingly, an examination of whether—and when—these leading indicators peaked, indicates the latest year by which "cleanup" efforts had commenced.

Trends in national emissions per unit of GNP (E/GNP) measure the aggregate effect of technological change on pollution emissions. E/GNP may, for instance, decrease if natural gas replaces coal, or if old processes are replaced by new, more efficient technologies (due either to economic factors or regulatory requirements). Alternatively, E/GNP may change with the structure of the economy—an increase in the service sector vis-à-vis manufacturing should improve (i.e., reduce) E/GNP. Emissions per unit of GNP peaked in the 1920s for SO_2, the 1930s for VOCs and NO_x, and the 1940s (or earlier) for PM-10 and CO, after which they have been declining, more or less, steadily. (See Figure 5.)

IV. Critical Milestones and Transitions in the Evolution of Air Quality Trends

Table 1 summarizes various milestones for several indicators for each traditional pollutant based upon the information provided in the previous sections. It identifies the "time of perception," when an air pollutant was first recognized or perceived by the general public and policymakers to need to be controlled. The table also indicates when federal regulations first went into effect for each pollutant.

Prior to the time of perception, one should not expect state or local jurisdictions to have required, or private entities to have voluntarily undertaken, any measures to specifically control that substance. Thus, air quality trends prior to time of perception tell us little about state or local jurisdictions' or private entities' desire or ability to control pollution.

Table 1 also lists for each pollutant, the year when each national indicator—indoor air quality, outdoor (ambient) air quality, and emissions per unit of GNP—peaked (or went through its *period of transition*).

Table 1 shows that:

- For each pollutant, the period of transition depends upon the precise indicator or leading indicator, e.g., whether it is indoor or outdoor air quality, or E/GNP.
- Based upon peaks in E/GNP, "cleanup" for each pollutant had, for whatever reason, *apparently* started decades before federalization, though one should be careful in using that term for periods prior to the time of perception, since one cannot, knowingly, clean what is not perceived to be dirty.
- Air quality had begun to improve substantially before federalization, particularly for the pollutants associated with excess mortality during the air pollution episodes of the forties, fifties and sixties (i.e., TSP and SO_2), and in the areas where their levels were the highest.[2] In addition, oxidant air quality had begun to improve in the Los Ange-

les area, the area with the nation's worst smog problem, before federalization had any effect in California.

V. The Environmental Transition

There is a relentless logic to Table 1. Improvements in the indicators of air quality for pollutants known (or perceived) to cause the largest public health impact came before those for the "lesser" pollutants; and indoor air quality improved before outdoor air quality.

It is possible to construct a framework to help explain the logic underlying Table 1 and the order in which the various peaks occurred for each pollutant and indicator. This framework, represented graphically in Figure 6, is based upon the hypothesis that society is on a continual quest to improve its "quality of life," which is determined by numerous social, economic and environmental factors. The weight given to each determinant is constantly varying depending upon economic circumstances and public perceptions.

In the early stages of economic and technological development (which go hand-in-hand) a society attempts to improve its overall quality of life by placing a higher priority upon increasing affluence than on other determinants. Some environmental degradation will be tolerated because greater affluence provides the means for obtaining basic needs and amenities (e.g., food, shelter, water and electricity) and thus reduces the most significant risks to public health and safety (e.g., infectious and parasitic diseases; child and maternal mortality). As a society gets wealthier, progress is made on these priorities but environmental degradation increases.

Eventually, environmental problems move up to a higher priority on the public's list of unmet needs, i.e, environmental quality becomes a more important determinant of the quality of life. Generally, a society will enshrine its priorities into laws and regulations unless a priority is self-executing (or perhaps even then, for the sake of symbolism).

Moreover, affluence makes it possible to support additional research and development of new, or improved, technologies. Equally important, greater wealth increases the ability to purchase these technologies, particularly if their up-front costs are higher, as is the case for any add-on or end-of-pipe technology and many process changes. In turn, technological change either reduces the cost of control or makes additional control possible at the same cost. More affordable controls also lead to greater compliance and, arguably, more stringent regulations.

Technological change and affluence reinforce each other, i.e., they co-evolve. Consequently, society goes through an "environ-

Table 1

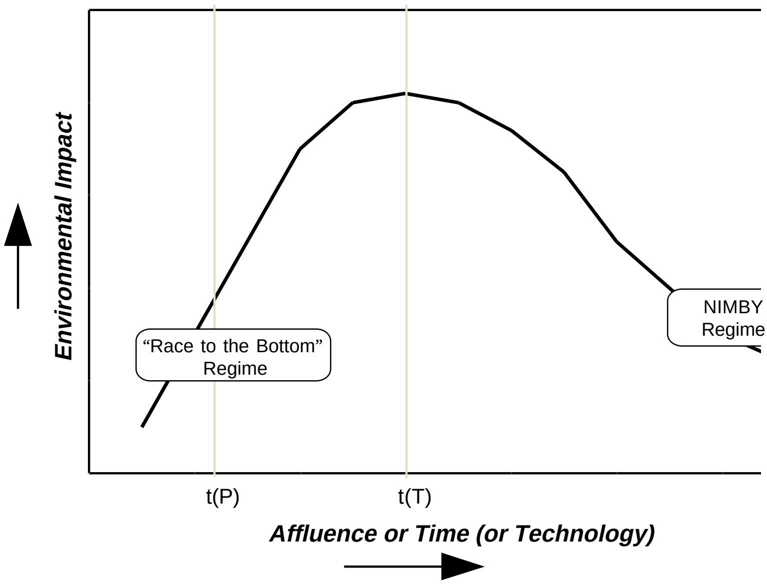
Milestones and Transitions for Various Pollutants and Indicators

Substance	*Year When Substance Was:*		*Worst Year(s) or Period (or Time) of Transition (Nationally, Unless Noted Otherwise):*		
	Recognized or perceived as a pollutant	First Federally regulated	Indoor Air Quality	Outdoor Air Quality	E/GNP[a]
PM	before 1900	1971[b]	before 1940	before 1957	1940s or earlier[c]
SO_2	approximately 1950	1971[b]	before 1940[g]	early to mid 1960s	1920s
CO	approximately late 1950s[d]	1967[e]	before 1940	mid 1960s (?), but not after 1970	1940s or earlier
VOC/O_3	CA, 1950s.	1971[b,g]	NE	CA,1966-1967	NE
	Elsewhere, 1960s or later	1967[e]	before 1940[f]	Elsewhere, mid to late 1970s	1930s
NO_x	CA, 1950s. Elsewhere, 1960s or later	1971[b]	before 1940, secondary peak around 1960[f]	1978-1979	1930s
Source	Section I	Section I	Fig. 3	Fig. 4 Secs. I & III	Fig. 5

Notes for Table 1:

a The peak in this leading indicator shows the latest time by which "cleanup" had begun either through deliberate actions or by happenstance (see text).
b The Clean Air Amendments of 1970 was signed on the last day of 1970, but most federal regulations went into effect later.
c For PM-10.
d CO: long known to be deadly indoors, but its status as an outdoor air pollutant was recognized much later.
e Model Year 1968 for automobiles.
f Not generally recognized by the public or policy makers as needing remediation indoors.
g Because federal vehicle emissions were borrowed from, and went into effect after, California's, federalization did not have any effect until after the 1970 amendments were signed.
NOTE: NE = "not estimated."

Figure 6
The Environmental Transition



Note: t(P) = time of perception
t(T) = period of transition

mental transition," environmental degradation peaks and, following that, further economic and technological development improves —rather than worsens—environmental quality.[66]

Because the nation has become progressively wealthier and technologically more advanced over the last century, an environmental transition is manifested as a peak in the trend line for environmental degradation, and the trend line looks like a stylized inverted-U. Figure 6 is a simplified representation of the trends exhibited in each of Figures 3 through 5 for the time period following t(P), i.e., the time when a substance was generally perceived to be an air pollutant deserving to be controlled. In some cases, e.g., indoor air and ambient TSP air quality (Figures 3 and 4A), there are no apparent peaks corresponding to any transitions because for these indicators trend data are available only for post-transition periods.

Environmental transitions were also aided by the process of economic development. At least over the last century or longer, U.S. economic development involved a technology-driven evolution in the structure of the economy. First, technological change was essential for the transformation from an agrarian to an industrial society. Without it, labor would not have been freed from the farm, nor would there have been factories to absorb the surplus labor. During this phase, E/GNP increased. Then, technological change was instrumental in the creation of a post-industrial society. In this phase, E/GNP decreased because economic growth was driven by relatively low-polluting enterprises.[67]

Based upon the processes responsible for bringing about environmental transitions, the timing of the transition for any pollutant should depend upon the general level of affluence, state-of-the-technology, the pollutant's effects relative to other societal risks, and affordability of control or mitigation measures for that pollutant. But these factors are not independent: affluence helps create technology, and *vice versa*; knowledge of a pollutant's effects is itself a product of technology; and affordability depends upon affluence and technology. In short, an environmental transition should ultimately be determined by affluence and technology.

Affluence helps create technology, and vice versa*; knowledge of a pollutant's effects is itself a product of technology; and affordability depends upon affluence and technology…*

Table 1 is, indeed, consistent with the environmental transition hypothesis. With greater affluence and the advent of new technologies in the early decades of this century, the worst problems — and the easiest to solve—were addressed first. Families cleaned their personal environment, i.e., their households, of the most obvious problems—smoke and, to some extent, CO—before anything else. They started switching away from wood and coal to gas, oil, and, sometimes, electricity for cooking and home heating. This also benefited the outdoor air in their immediate neighborhoods.

Next, attention turned to outdoor air. Once again, the first target was smoke because it was the most obvious, and an acknowledged pollutant. New technologies and prosperity helped move the industrial and commercial fuel mix from coal and wood toward oil and gas, and generally increased fuel efficiencies across all economic sectors. As a result, soon after World War II, if not earlier, most urban areas had gone through their environmental transitions for smoke and PM. (See Table 1.)

With greater prosperity, better health, and reduced mortality, the risks of other outdoor air pollutants became easier to infer or detect. In the years following World War II, deadly air pollution episodes occurred on both sides of the Atlantic, which were ascribed to PM, SO_2 or both. Thus, transitions for PM and SO_2 air quality came next, followed in time by CO and ozone. That the transition for NO_x came last is fitting for a pollutant that was never ranked very high in terms of adverse health effects at measured ambient levels and was the most expensive to control.

VI. Revisiting the Rationales for Federalization

Conventional wisdom is that federalization of air pollution control was necessary because "states had failed to act," that they "could not be trusted to adopt adequate environmental controls" because of interstate competition for business.[68] Thus, "Congress imposed national regulations to control pollution only after its efforts to prod states to act had failed."[69]

These assertions are not supported by the empirical data in Figures 3 through 5. In fact, there was remarkable progress in improving air quality prior to full-scale federalization. This is particularly true for those pollutants that were generally known or perceived at that time to be the sources of public health problems.

Moreover improvements in air quality for the recognized pollutants did not accelerate (i.e., the negative slopes of the trends don't increase) once federalization became effective. (See Figures 3-5.) Only motor vehicle emissions *outside* California improved more rapidly after federalization. Of course, the federal motor vehicle emission control program was, itself, derived from a state (California) program, and was enacted not because states were doing too little, but because auto companies and Congress feared some might do too much, resulting in separate and inconsistent laws.

Federalization was ostensibly imposed because in the three years between the 1967 Air Quality Act and the 1970 amendments state and local agencies had not moved fast enough to solve their air quality problems. Ironically, almost *three decades later*, numerous places are still not meeting *federal* air quality standards.[70] If the success of the 1970 federalization is judged by the same criterion that many of its proponents applied to state and local control and to the Air Quality Act of 1967, then federalization must also be judged to be a failure. And while judging success (or failure) on meeting unrealistic timetables for attainment was, and remains, flawed, it does undermine the credibility of one of the major arguments advanced for federalization.

Race to the Bottom?

Another rationale for federalization of air pollution control was that, in its absence, states would relax air pollution requirements, which would reduce social welfare. For such a race-to-the-bottom argument to be valid, there ought to have been little, or no, air pollution regulation before federalization. Nor should there have been any significant improvements in air quality anywhere (except by accident or happy economic circumstance).

The empirical evidence presented in this study does not support the allegation that at the time of federalization states were indulging in a race to the bottom. In fact, the race, if any, seems to have been in the other direction.

If the success of the 1970 federalization is judged by the same criterion that many of its proponents applied to state and local control and to the Air Quality Act of 1967, then federalization must also be judged to be a failure.

Table 1 shows that, for "national" air quality, TSP and SO_2 had gone through their environmental transitions and CO had either gone through or was on the verge of its own transition by the time the federal government began regulating those specific pollutants. No race to relax there.[71]

Local and state air programs grew significantly prior to the mid-sixties. (See Figure 2.) But the race to the bottom believers would suggest that such programs should never have developed, absent a federal stick, in the first place. Even if these programs were mere window-dressing—and Figures 4 and 5 suggest they were not—at the very least, the very presence of such programs would send the wrong signal to heavy industry considering locating in these areas.

Also, smoke and particulate matter emission standards were progressively tightened nationwide prior to the 1970 Clean Air Act, in effect bidding standards up, rather than down. This is the antithesis of an environmental race to the bottom. Dust collection efficiencies for power plants nationwide increased from an estimated 40 percent before 1940, to 75 percent in 1940 and 95.5 percent by 1966.[72] In other words, emissions for a ton of coal burned in the average power plant in 1965 were only 7.5 percent of what they were pre-1940. In fact, a 1970 report of the National Air Pollution Control Administration (EPA's forerunner) suggested that one reason for the limited acceptance of the American Society of Mechanical Engineers' 1966 model air pollution control regulations for fuel-burning equipment may have been because its "control requirements... are generally lenient compared to other modern regulations" and that "[m]any new industrial plants install equipment for purposes of eliminating all visible plumes, even if not required to do so" because this constituted good public relations and reduced complaints.[73]

Federal preemption of motor vehicle emission standards outside of California indicates that the automobile industry and Congress were concerned not about a race to relax regulations, but a movement of states toward greater control. Uniform standards were imposed to avoid a hodgepodge of requirements among other states that might engage in a "race to the top."

The empirical evidence presented in this study does not support the allegation that at the time of federalization states were indulging in a race to the bottom. In fact, the race, if any, seems to have been in the other direction.

Despite the lack of empirical support for the notion that states were racing to the bottom of environmental quality during the late 1960s, it is easy to see from Figure 6 how such an idea gained currency within the body politic. All else being equal, poorer societies (or individuals) are likely to weigh jobs and incomes more heavily than the environment because that is what it is needed to improve the quality of life at that stage of economic and technological development. Consequently, at this development stage, the race to the top for the quality of life may produce what appears to be a race to relax environmental protection.

On the other hand, as suggested by the various environmental transitions that predated federalization, wealthier and more technologically-advanced societies (or individuals) are more likely to tip the balance toward environmental quality. And if individuals' actions cannot affect their environment sufficiently, they will attempt, in a democratic society, to persuade their political jurisdictions to take action in consonance with their perceived collective interests.

This is precisely what leads to environmental transitions and, as we have seen, governmental regulation is almost a natural part of that process in a democracy. Once a society gets past the transition stage for a specific pollutant, the race to the top of the quality of life is associated with a race to the top for environmental quality.

Such a race to the top could create a not-in-my-backyard (NIMBY) situation if the benefits of control for the society (or group) are substantially less than its costs, or if the costs are shifted to others while benefits are retained. Thus, the *apparent* race to the bottom and the NIMBY effect are, in fact, two aspects of the same phenomenon, but the former occurs prior to—while the latter occurs after—an affluence- and technology-driven environmental transition.

For a brief period in this nation's history, when pollution was almost synonymous with progress, the race-to-the-bottom rationale may well have seemed valid. Today, greater affluence and improved technology have largely invalidated that argument for continued federalization.

VII. The Federal Role in Air Pollution Control

If the 1970 Clean Air Act Amendments and subsequent amendments were to be judged by adherence to mandated deadlines, they would have to be deemed failures. The 1970 Amendments required the entire nation to meet all health-related NAAQS by 1975 and all welfare-related NAAQS by 1977. Few places met these deadlines, or the new targets established in the 1977 amendments.

Even today—two decades and two major rewrites of the Clean Air Act later—many places are not in compliance. For instance, as of June 1998, despite an overall relaxation of the original 1971 oxidant standard (and specifically targeting ozone), 57 areas in the nation were designated "nonattainment areas" for ozone. In addition, 28 areas were nonattainment for the CO NAAQS; 34 for SO_2; and 1 for NO_2.[74]

The repeated inability to deliver on the deadlines in the 1970 and subsequent Amendments to the Clean Air Act should not be interpreted as lack of progress in improving the nation's air quality, however. Air quality in the United States is much better today than it has been for decades.

One positive feature of federalization was the establishment of the NAAQS as a yardstick for people to gauge whether their air quality is "healthful." Just as the mere existence of the Toxics Release Inventory has helped reduce the amounts of those emissions (yet another refutation of the race-to-the-bottom rationale), the very existence of NAAQS created pressures to improve air quality.[75]

Federal intervention also was, on the whole, effective in reducing motor vehicle emissions outside California. Uniform requirements enabled manufacturers to lower the costs of emissions controls by enabling them to design to one standard rather than multiple standards and to spread their fixed costs over larger numbers of vehicles. These mobile source emissions standards were important to reduce ozone and carbon monoxide levels. In addition, motor vehicle emission controls were instrumental in bringing about dramatic improvements in the amount of lead in the air, albeit as much by chance as by design.

Of course, these gains came at a high cost to all automobile buyers, regardless of whether any commensurate health benefits were to be derived by them. People living outside the urban areas and not part of the commuter pollution problems paid more for new automobiles as well.

Similarly, although New Source Performance Standards and Prevention of Significant Deterioration regulations were instituted partly as a *political* solution to the potential problem of the relocation of polluting industries from areas with dirty air to places with clean air, they helped ensure that emissions from new sources did not overtake emission reductions at existing sources. However, because New Source Performance Standards and Significant Deterioration Regulations effectively resulted in technology-forcing standards often set without consideration of overall ambient air quality, they were by design economically inefficient (except by accident).

Thus, while federal regulations share in the credit, the long-term trends presented above show that even before federalization, air quality was improving for the most serious pollutants in places where they were causing the greatest health risks. Given these underlying trends, the absence of any real race to the bottom, and the fact that democratic societies—no less than private individuals—hope to maximize the quality of life, there would have been continued improvements in air quality even in the absence of federalization.

There is little doubt that because of the Clean Air Act's command-and-control regime, the nation has paid excessively for the benefits obtained.[76] This is particularly true for federal regulation of new point sources of emissions.[77] The apparent success of emissions trading for the control of acid rain instituted under the 1990

Amendments hints at the inefficiencies inherent in a command-and-control approach. As an EPA official notes, "Not only are emissions reductions greater than expected, but compliance costs are now expected to be half that originally projected. The flexibility offered by the SO_2 allowance trading system deserves much of the credit."[78]

Thus, while federal regulations share in the credit... Given these underlying trends,...there would have been continued improvements in air quality even in the absence of federalization.

Furthermore, some of the recent high-cost, low-benefit expenditures on air pollution control could well have purchased greater improvements in public health and welfare if they had been diverted elsewhere. This is true even within the realm of air pollution control, itself.[79] Studies suggest, for example, that the benefit-cost ratio for controlling ozone is relatively low, while that of controlling fine PM is much higher.[80] Thus, society would be better off if the former was de-emphasized with at least some of the resulting savings applied to the latter.

Such "risk-risk" tradeoffs are best studied and implemented at state or regional levels rather than the national level. The relative risk-reduction-to-cost ratios for the various risks depend upon numerous local factors, such as the magnitude and mix of emissions, population density, geography, meteorology, and various socioeconomic factors such as income, education, and access to health care. Any one-size-fits-all approach to air pollution abatement is likely to be inefficient for the nation as a whole.

VIII. Policy Recommendations

The previous analyses suggest several improvements that would increase the efficiency and effectiveness of air pollution control in the United States without giving up the improvements in air quality that have occurred over the last several decades. Given how far states (and the average American) are along in their environmental transitions, states are unlikely to indulge in a race-to-the-bottom today. If they do, the powers that be will hear from their citizens. Therefore, for intrastate pollutants, i.e., relatively short range, primary pollutants, the federal government's role should be limited to undertaking research, providing scientific and technical information about benefits and costs of controls to the states and the public, and developing "advisory" national ambient air quality goals or guidelines. The states would, then, be responsible for translating those goals and guidelines into standards and attaining them at a pace dictated by their own political processes and their knowledge and perception of what balances need to be struck to optimize their quality of life. This is preferable to having such decisions made by those who do not directly bear either the costs or the benefits of attainment.

In light of the progress made in air quality, as well as in terms of the nation's and states' environmental transitions, and given that the easy—and several tough—reductions have already been made, further improvements in air quality may not be sustainable, if they come at the expense of the broader quality of life. To ensure that the two go hand-in-hand, emissions trading for a given pollutant should be allowed between all sources—new and old. That would reduce the costs of air pollution control significantly.[81] Also, because of diminishing returns from further tightening federal new source emission standards, the latter should be frozen at current levels. States, however, would be free to make them more stringent in their own jurisdictions. The pollutant-by-pollutant approach in trading also should be replaced by one that focuses on reducing overall risks to public health and welfare at local and regional levels.

For regional and interstate problems, such as ozone transport or acidic deposition, there are no easy answers. Interstate problems were an important part of the original rationale for federal intervention. Most observers have claimed that federalization has had little impact on interstate pollution, however.[82]

The Ozone Transport Commission established under the 1990 Clean Air Act amendments, while it may ultimately help reduce interstate pollution, is unlikely to help reduce risks to public health and welfare efficiently or raise the overall quality of life, except by chance. By design, the commission's charge excludes consideration of the broader factors that affect the overall quality of life.[83] Its focus ought to be expanded to include an examination of the cheapest methods of reducing overall risks to public health and welfare in a region, whether or not that includes ozone reductions. Downwind states may rightly prefer to divert money that would otherwise be spent on upwind ozone controls to be applied instead to, say, PM control or purchasing health insurance for the indigent or whatever public health and welfare measure would provide the largest benefits in their jurisdictions.

As the world's future environmental problems become more challenging, there will be an even greater demand for fiscal resources to research, develop and implement new technologies in order to bring about environmental transitions for those problems.[84] Thus, to continue further environmental progress, it is necessary to nurture the institutions that strengthen economic growth and technological change.

Notes and References

1. See, e.g., J. P. Dwyer, "The Practice of Federalism Under the Clean Air Act," *Maryland Law Review* 54 (1995): pp. 1183-1225; R. V. Percival, "Environmental Federalism: Historical Roots and Contemporary Models," *Maryland Law Review* 54 (1995): pp. 1141-1182; K. H. Engel, "State Environmental Standard Setting: Is There a 'Race' and Is it 'to the Bottom'?" *Hastings Law Journal* 48 (1997): pp. 271-377; H. N. Butler and J. R. Macey, "Externalities and the Matching Principle: The Case for Reallocating Environmental Regulatory Authority," *Yale Law Policy Review, Yale Journal on Regulation, Symposium Issue: Constructing a New Federalism: Jurisdictional Competence and Competition* 14, no. 2 (Symposium) (1996): pp. 23-66; P. P. Swire, "The Race to Laxity and the Race to Undesirability: Explaining Failures in Competition Among Jurisdictions in Environmental Law," *Yale Law Policy Review, Yale Journal on Regulation, Symposium Issue: Constructing a New Federalism: Jurisdictional Competence and Competition* 14, no. 2 (Symposium) (1996): pp. 67-110; D. Schoenbrod, *Time for the Federal Environmental Aristocracy to Give Up Power* (St. Louis, Missouri: Center for the Study of American Business, Policy Study No. 144, February 1998); D. Schoenbrod, "Why States, Not EPA, Should Set Pollution Standards," *Regulation* 19, no. 4 (1996); R. L. Revesz, "Rehabilitating Interstate Competition: Rethinking the 'Race to the Bottom' Rationale for Federal Environmental Regulation," *New York University Law Review* 67 (December 1992): pp. 1210-1254; R. L. Rabin, "Federal Regulation in Historical Perspective," *Stanford Law Review* 38 (1986): pp. 1189-1326; E. S. Muskie, "Role of the Federal Government in Air Pollution Control," *Arizona Law Review* 10 (1968): pp. 17-24; R. B. Stewart, "Pyramids of Sacrifice? Problems of Federalism in Mandating State Implementation of National Environmental Policy," *Yale Law Journal* 86 (1977): pp. 1196-1272.

2. Of the references cited in Note 1, Schoenbrod's is an exception to this statement. Based apparently upon particulate matter and sulfur dioxide air quality data from R. W. Crandall, *Controlling Industrial Pollution: The Economics and Politics of Clean Air* (Washington, D.C.: Brookings, 1983), pp. 18-19, he estimates that air pollution declined three times faster prior to federalization than just after it, concluding that "it was the federal government, not the states, that had been the laggard" in air pollution control. While he is, indeed, right about the states, he may be overly harsh on the federal government, perhaps reading more into that data than it can deliver. Trends from such data are best seen to be qualitative, rather than quantitative. Also, one would expect that the rate of improvement would decline since, in a rational world, once the easiest and cheapest reductions are obtained, additional reductions are harder to achieve. Furthermore, despite having caused economic slowdowns and increased pressures to conserve energy, the oil shocks of the 1970s also increased the pressure to reduce controls and use higher sulfur fuels, particularly coal. Any head-to-head quantitative comparison of air quality trends before and after federalization should take such factors into consideration. Discretion being the better part of valor, I will not attempt such a comparison, but I will, among other things, provide a much longer record of air quality trends and for more pollutants, as well as provide long term trends in emissions per unit of gross national product and a proxy for indoor air quality.
3. I. M. Goklany, "Factors Affecting Environmental Impacts: The Effects of Technology on Long-term Trends in Cropland, Air Pollution and Water-related Diseases," *Ambio* 25 (1996): pp. 497-503; I. M. Goklany, "Richer is Cleaner: Long Term Trends in Global Air Quality," in R. Bailey, ed., *The True State of the Planet* (New York: Free Press, 1995), pp. 339-377.
4. Stewart, p. 1197: "The failure of prior efforts (heavily dependent on state initiatives) to check air pollution prompted Congress to enact the 1970 Clean Air Amendments."; Dwyer, pp. 1191, 1193 (footnotes 32,37); Percival, pp. 1160-1161; Swire, p. 68.
5. Stewart, pp. 1211-1212; Revesz, pp. 1210-1211, 1224-1227; Swire, pp. 71-78.
6. U.S. Bureau of the Census (BOC), *Historical Statistics of the United States, Colonial Times to 1970* (Washington, D.C.: BOC, 1975), pp. 587-588.
7. J. A. Tarr, "The Horse—Polluter of the City" in J. A. Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, Ohio: University of Akron, 1996), pp. 323-333; Goklany, Note 3, above; BOC, *Historical Statistics*, pp. 41 and 716.
8. J. A. Tarr, *The Search for the Ultimate Sink*, p. 17.
9. Goklany, "Richer is Cleaner."
10. Standards for air quality are normally established in terms of air

pollutant concentrations at a fixed point in the outdoors over a specified period of time. One method of specifying air quality is based upon measuring the weight of pollutant (generally in micrograms—μg) in a fixed volume of air (1 cubic meter or m^3), i.e., in terms of $\mu g/m^3$. An alternative approach is to specify the number of molecules of the pollutant in a million molecules of air, i.e., parts per million (ppm). For instance, in the United States, the annual health related (or primary) air quality standard for sulfur dioxide is a never-to-be-exceeded average of 80 $\mu g/m^3$ or 0.03 ppm at any point outdoors. Levels for the short term health and welfare standards for SO_2 were set at 365 $\mu g/m^3$ (0.14 ppm) for 24 hours and 1300 $\mu g/m^3$ (0.5 ppm) for 3 hours, respectively, and could be exceeded only once a year without violating the standard.

11. Goklany, "Richer is Cleaner."
12. C.D. Yaffe, "A Roll Call of the States—Where Do We Stand in State and Interstate Air Pollution Control," and J.J. Scheuneman, "A Roll Call of the Communities—Where Do We Stand in Local or Regional Air Pollution Control," *Proceedings: The Third National Conference on Air Pollution*, PHS Publication No. 1649 (Washington, D.C.: Government Printing Office, 1966), pp. 359-363, 386-399.
13. S. Edelman, "Air Pollution Abatement Procedures Under the Clean Air Act," *Arizona Law Review* 10 (1968), pp. 30-36.
14 See, e.g., Crandall, 7; A.W. Reitze, Jr., "A Century of Air Pollution Control Laws: What's Worked, What's Failed, What Might Work," *Environmental Law* 21 (1991): pp. 1549-1646; and Stern, "History of Air Pollution Legislation in the United States," *Journal of the Air Pollution Control Association* 32 (1982), pp. 44-61.
15 Stern, "History of Air Pollution Legislation in the United States."
16. J.T. Middleton, "Future Air Quality Standards and Motor Vehicle Emission Restrictions," in *Proceedings: The Third National Conference on Air Pollution*, pp. 45-54.
17. *Ibid*.
18. Goklany, "Richer is Cleaner."
19. Environmental Protection Agency (EPA), *Monitoring and Air Quality Trends Report, 1972*, EPA-450/1-73-004 (Research Triangle Park, North Carolina: EPA/Office of Air and Water Programs), 4-21 to 4-26. The ranges in the frequencies of exceedences in the peak years are owing to the fact that Los Angeles County modified its instruments in 1968; the specified ranges account for uncertainties in converting pre-1968 readings into ones consistent with post-1968 instrumentation.
20. E.D. Elliott, B.A. Ackerman and J.C. Millian, "Toward a Theory of Statutory Evolution: The Federalization of Environmental Law," *Journal of Law, Economics and Organization* 1 (1985): pp. 313-340; *New York Times*, 29 March 1965, p. 39; 11 September 1965, p. 10.
21. Muskie, "Role of the Federal Government in Air Pollution Con-

trol," pp. 17-24.

22. Schoenbrod; Elliott, Ackerman and Millian.
23. F.W. Bowditch, "Introductory Statement," in *Proceedings: The Third National Conference on Air Pollution*, pp. 76-77.
24. A. Rihm, "Regulation of New Motor Vehicles," in *Proceedings: The Third National Conference on Air Pollution*, pp. 61-63.
25. Senate Committee on Public Works, *A Legislative History of the Clean Air Act Amendments of 1970* (Washington, D.C.: Government Printing Office, 1974), (henceforth, *Legislative History*), pp. 1104, 1126-1136.
26. Council on Environmental Quality (CEQ), *Environmental Quality 1970* (Washington, D.C.: CEQ, 1970), p. 75.
27. See, e.g., Elliott, Ackerman and Millian; Reitze.
28. Goklany, "Richer is Cleaner."
29. EPA, data underpinning *National Air Pollutant Emission Trends, 1900-1994*, EPA/450/R-93-032, Office of Air Quality Planning and Standards (Research Triangle Park, North Carolina: EPA, 1995), provided by Sharon Nizich.
30. Reitze.
31. See, e.g., H.N. Butler and J R. Macey; Revesz.
32. "So-called" because this "academic" definition of race to the bottom, the one employed here, conjures forth, to the non-specialist, visions of chimneys and vehicles belching forth uncontrolled smoke and toxic fumes and episodes of killer smogs. In fact, as defined by academics, the end result of such a race does not have to be zero environmental safeguards but any level below what would be "optimal" from the point of view of net social welfare, and a "race to relax" becomes a race to the bottom if, and only if, net social welfare also declines. See, e.g., Revesz, p. 1210; Swire.
33. E.S. Muskie, 21 September 1970, *Legislative History*, pp. 223-232.
34. Council on Environmental Quality (CEQ), *Environmental Quality 1970* (Washington, D.C.: CEQ, 1970).
35. Stern, "History of Air Pollution Legislation in the United States."
36. *New York Times*, 13 May 1970, p. 6; 14 May 1970, p. 10; 16 May 1970, p. 24; 12 June 1970, p. 38.
37. E.S. Muskie, 21September 1970, quoted in *Legislative History*, pp. 225-226. The first quote can also be found on p. 124, made on 18 December 1970.
38. CEQ, *Environmental Quality 1975* (Washington, D.C.: CEQ, 1975), p. 53.
39. The short time frames for developing, analyzing and executing state implementation plans precluded any real analysis, particularly with the threat of sanctions. It led to widespread paper showings of attainment, and many states adopted technology-

based standards for broad source categories as a substitute for credible analysis showing attainment. See, Pacific Environmental Services, Inc., *An Overview of the SIP Review Process at the State Level and the SIP for Particulate Matter, Sulfur Dioxide and Ozone*, report to the National Commission on Air Quality, NTIS No. PB81 1127573 (1980).

40. Goklany, "Factors Affecting Environmental Impacts"; Goklany, "Richer is Cleaner."
41. EPA, *Report to Congress on Indoor Air Quality Volume II: Assessment and Control of Air Pollution*, EPA/400/1-89/001C, Office of Air and Radiation, Environmental Protection Agency (Washington, D.C.: EPA, 1989); Goklany, "Richer is Cleaner."
42. The data used to construct this proxy are obtained from EPA, *National Air Pollutant Emissions Trends, 1900-1994*; BOC, *Historical Statistics*; and BOC, *Statistical Abstract 1992*.
43. EPA, *Report to Congress on Indoor Air Quality*.
44. BOC, *Statistical Abstract 1992*.
45. EPA, *Air Quality Data for 1968 from the National Air Surveillance Networks and Contributing State and Local Networks* (Research Triangle Park, North Carolina: EPA/Office of Air Programs, August 1972), pp. 1-3.
46. Goklany, "Richer is Cleaner," p. 360 and associated endnotes.
47. CEQ, *Environmental Quality 1971* (p. 242), *1979, 1981* (p.243), *1991*; EPA, *National Air Quality and Emissions Trends Report, 1990*; EPA, *National Air Quality and Emissions Trends Report, 1996*, EPA 454/R-97-013 (Research Triangle Park, North Carolina: EPA, 1998), henceforth EPA 1998.
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49. This average is based upon the data from CEQ's *Environmental Quality 1971*, p. 242.
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51. Environmental Protection Agency, *National Air Quality and Emissions Trends Report 1983*, EPA-450/4-84-029 (Research Triangle Park, North Carolina: EPA/OAQPS, 1985), pp. 3-5 to 3-10.
52. EPA 1998.
53. CEQ, *Environmental Quality 1981*, 243; *Statistical Abstract 1981*, p. 204; EPA, *National Air Quality and Emissions Trends Report, 1994. Data Appendix*, EPA 454/R-97-013 (Research Triangle Park, North Carolina: EPA, 1995), henceforth EPA 1995; EPA 1998.
54. CEQ, *Environmental Quality 1981*, p. 243.
55. CEQ, *Environmental Quality 1971*, p. 242*; 1981, p.* 243; *Statistical Abstract 1981*, p. 204; EPA 1995, 1998.
56. CEQ, *Environmental Quality 1971*, p. 242; EPA, *Air Quality Data for*

1968 from the National Air Surveillance Networks and Contributing State and Local Networks (Research Triangle Park, North Carolina: EPA/Office of Air Programs, August 1972), pp. 1-3.

57. CEQ, *Environmental Quality 1971*, p. 214 and p. 242.
58. EPA, *Monitoring and Air Quality Trends Report, 1972*, pp. 4-14 to 4-23.
59. *Ibid*, 4-23. The ranges in the frequencies of exceedences in the peak years are owing to the fact that Los Angeles County modified its instruments in 1968; the specified ranges account for uncertainties in converting pre-1968 readings into ones consistent with post-1968 instrumentation.
60. CEQ, *Environmental Quality 1981*; EPA 1995, 1998.
61. EPA, *Monitoring and Air Quality Trends Report, 1972*, pp. 1-11 to 1-12.
62. *Ibid*., pp. 4-23 to 4-28.
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64. CEQ, *Environmental Quality 1981, 1984*; BOC, *Statistical Abstract* 1981; EPA 1995, 1998.
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66. Goklany, "Richer is Cleaner"; I. M. Goklany, "Strategies to Enhance Adaptability: Technological Change, Sustainable Growth and Free Trade," *Climatic Change* 30 (1995): pp. 427-449.
67. I.M. Goklany, "Saving habitat and conserving biodiversity on a crowded planet," *BioScience* 48 (1998): pp. 941-953.
68. Dwyer, pp. 1191, 1193 (footnotes 32, 37). See, also, Stewart, p. 1197.
69. Percival, pp. 1160-1161.
70. As of June, 1998, 57 areas in the nation were designated "nonattainment areas" for the ozone NAAQS; 28 for CO; 34 for SO_2; 10 for lead; and 1 for NO_2. In addition, 77 areas were designated nonattainment for PM-10, which "replaced" the TSP standard. See EPA, *USA Air Quality Nonattainment Areas*. <http://www.epa.gov/airs/noattn.html> June 28, 1998.
71. This does not mean that in some jurisdictions regulations would not have been more stringent but for interjurisdictional competition. It, however, does show that the behavior is much more complex than that suggested by the Prisoner's Dilemma—that in fact jurisdictions were attempting to improve their quality of life, even if it risked adverse economic effects.
72. W.W. Moore, "Reduction in Ambient Air Concentration of Fly Ash—Present and Future Prospects," in *Proceedings: The Third National Conference on Air Pollution*, pp. 170-178.
73. T.L. Stumph and R.L. Duprey, "Trends in Air Pollution Control Regulations," in *Legislative History of the Clean Air Amendments of 1970*, pp. 1105-1125.

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75. EPA, *National Air Pollutant Emissions Trends, 1900-1994*, Chapter 8.

76. See, e.g., T. Tietenberg, *Emissions Trading, An Exercise in Reforming Pollution Policy* (Washington, D.C.: Resources for the Future, 1985).

77· CEQ, "New Source Performance Standards and the 'Bubble' Concept," *Environmental Quality*, Vol. 15, pp. 59-65.

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83. Engel.

84. Goklany, "Strategies to Enhance Adaptability"; Goklany, "Factors Affecting Environmental Impacts."

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