Octane, Ozone, and Obstinacy

C. Boyden Gray

As every student of the regulatory process knows, regulation often has unintended and unanticipated side effects. When it does, it frequently triggers the need for more regulation, which in turn leads to calls for even more regulation. Sometimes the spiral seems endless. The regulation of automobile fuels is a perfect example. First, the government required catalytic convertors on cars to reduce tailpipe emissions and the ozone they cause; then it banned lead in gasoline in part to protect the catalytic convertors; and now it is taking steps to limit the increased emissions caused by lead substitutes.

Regulatory controls on automotive fuels, even controls that cost "just pennies a gallon," rank among the most expensive federal regulations. Americans spend almost $100 billion per year on gasoline, so a mere 5 cents per gallon at the pump translates into $5 billion per year. For this reason alone, these regulations deserve careful scrutiny. But much more than money is at stake. Environmental regulation of automobile fuels is unintentionally discouraging technologies that would make available cleaner, safer, more efficient fuels—the supposed goal of federal regulatory policy.

This article is about technological innovations in automotive fuels and the hurdles they face in a highly regulated economy. The story is a familiar one, as it is being played out in one sector of the economy after another. Major technological breakthroughs are being discouraged and new innovations, forced to pass muster before federal regulators, are being delayed. The moral is this: The federal regulatory bureaucracy can be poor ground, indeed, in which to sow the seeds of innovation.

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Opportunity Knocks

The example I wish to consider is alcohol fuels. The story revolves around lead—its discovery, and its fall from grace—and it begins with Charles "Boss" Kettering, the legendary director of research at General Motors (GM) who invented the electric starter, among other things.

One of Kettering's concerns in the early 1920s was engine knock, the sound an engine makes when pockets of unvaporized liquid fuel detonate inside the cylinder. Engine knock reduces performance and, under extreme conditions, can even destroy the engine. More than just an annoyance, it has been one of the principal constraints on improving gasoline-burning engines. Internal combustion engines require a fuel that vaporizes, ignites at just the right moment, and then burns smoothly and cleanly. This is not an easy thing to achieve.

Kettering recognized that conquering engine knock would allow the development of high-performance, high-compression engines which could run on alcohol, the fuel of the future. This he saw as critical because he believed the world would run out of oil by the 1940s. Kettering saw his task, then, as finding something that would provide a bridge to the alcohol era.

What Kettering discovered was not something to improve vaporization and combustion; rather, it was something that worked in the opposite way: tetraethyl lead. This additive *slows* the burn rate of liquid gasoline enough so that unvaporized fuel does not detonate away from the spark plug. We now call this property octane, which measures the resistance of a fuel to knock (not its energy content, as is often supposed).

The High-Test Years

Lead improved octane cheaply and, apparently, safely. There was a serious refinery accident in the early days which resulted in the first ban on "loony gas" (as leaded gasoline was then called), but the ban was temporary and people did not pay much attention to lead's environmental or health consequences. One person who did worry about possible health effects was Henry Ford, who initially refused to build his cars to run with this newly discovered additive. He changed his mind after losing a sizable share of the market to better-performing GM vehicles in the early 1920s. Ford's octane candidate, by the way, was alcohol: "Alcohol is a much cleaner and better fuel for cars than gasoline," he said at the time.

By the end of the 1930s, everyone was driving on leaded gasoline. The idea of alcohols disappeared as low-cost oil fields in West Texas and the Middle East opened up and as low-cost lead nullified much of the octane advantage of alcohols. Leaded gasoline was as important as any innovation in the horsepower race that began in earnest after World War II and continued through the 1960s.

Get the Lead Out

The 1970s brought two sudden shocks to the automobile and automotive-fuel industries. One was the emergence of the Organization of Petroleum Exporting Countries (OPEC), which lead to dramatic increases in oil prices. The other was the emergence of a substantial federal regulatory apparatus overseeing automobile design, fuels, and highway safety.

When the Environmental Protection Agency (EPA) opened in 1969, the control of automobile emissions was high among its priorities, and lead in gas soon made its "most wanted" list. Lead had two strikes against it. First, it is very toxic. Second, it destroys the ability of catalytic convertors to control other emissions (carbon monoxide, hydrocarbons, and oxides of nitrogen) that pose additional health risks. The EPA's emissions standards for these other pollutants could not be met by cars without catalytic convertors, and thus by cars burning leaded gas.

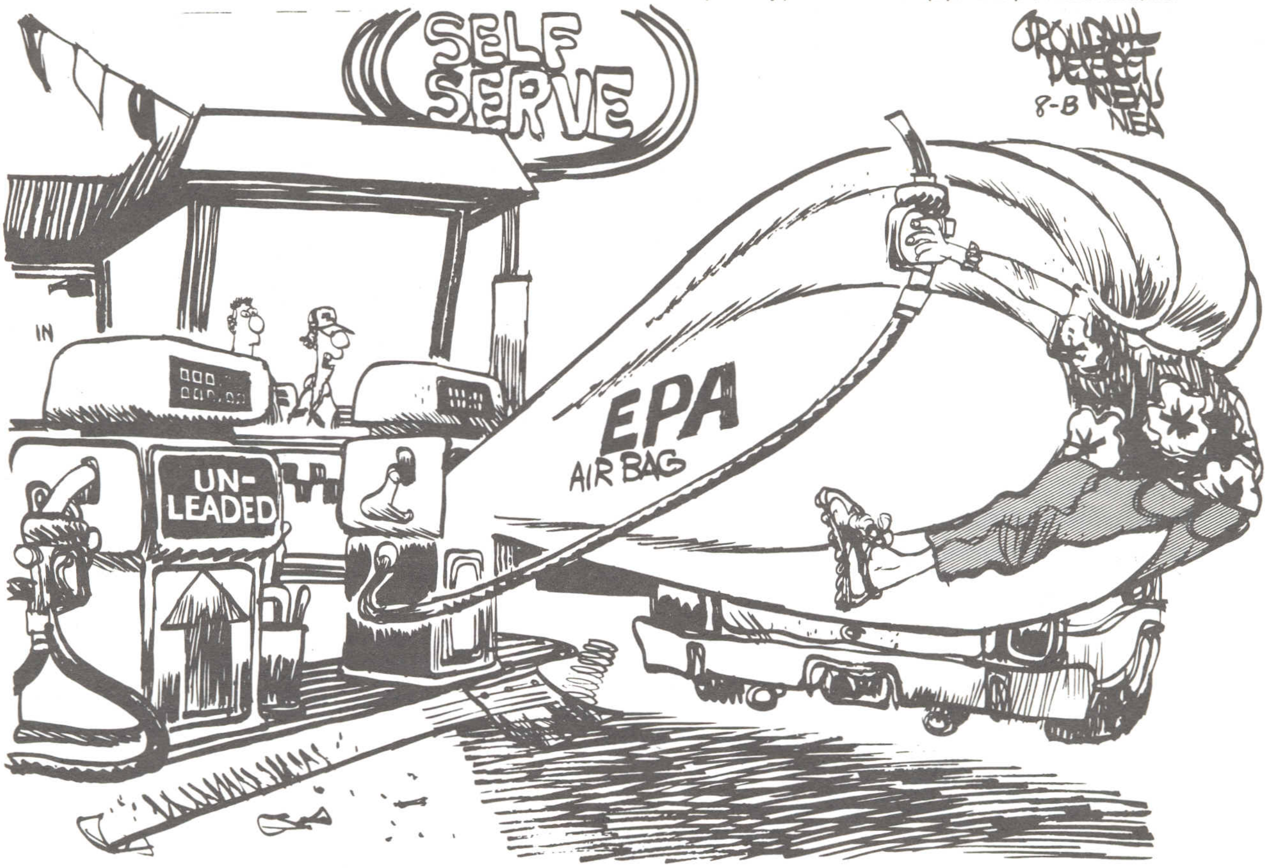
The EPA began the long process of phasing out lead when it prohibited the use of leaded gas in catalyst-equipped cars. Later it imposed a separate ceiling on the total amount of lead that could be used in making gas. Over the years, this ceiling has gradually been lowered. In 1982, the Reagan Administration replaced the existing regulations with a market-based system of tradable lead rights. This system was designed to achieve roughly the same level of lead use, but with fewer allocative distortions. Recently, as evidence of more serious adverse health effects has become available, the phasedown of lead has been accelerated. This year the last of the lead rights expire and only trace amounts of lead will be allowed in gasoline.

Even in this Administration, with its unwavering support for deregulation, there has been little question about the need to eliminate lead quickly. The problem is that at the time the lead phasedown decisions were made, no one had really focused on what could be substituted for lead to maintain high octane levels, and what health problems might be posed by the substitutes. The resulting regulatory regime, if not carefully monitored, could result in even greater health risks and much higher gasoline prices.

The Octane Box

The disappearance of lead has put gasoline producers in a box: given the technological and regulatory constraints on octane enhancement, there is simply not enough octane to go around. Each method of dealing with the octane shortfall has serious problems of its own.

Butane and Pentane. Butane and pentane are the lightest components of crude oil that can be used in gasoline, and they have very high octane ratings. They are available in large quantities



"Oh, oh — I think a customer just tried to use the leaded."

(through a refining process called isomerization) and are relatively inexpensive. Because of their relative low cost, butane and pentane have been refiners' top choice for producing octane.

There is a hitch, though. Butane and pentane are a little too light. (Butane is a gas at room temperature.) As a result, these components increase the volatility of gasoline, that is, more of it boils off into the atmosphere. This contributes to "vapor-lock," which can cause freeway stalling in the summer, and ozone formation.

BTX Compounds. Because of the vapor-lock problem, some states have imposed upper limits on gasoline volatility during the summer months. Responding to these limits, gasoline producers have turned to another octane-boosting ingredient, the so-called BTX group of aromatic compounds (Benzene, Toluene, and Xylene). Made in a process called "reforming," these additives are much more expensive than butane or pentane. In the summer, when the use of the lighter additives is constrained, BTX costs roughly 20 cents per gallon more than butane or pentane. By comparison, lead costs virtually nothing.

In addition to being expensive, benzene is a potent human carcinogen. Whether existing exposure levels pose a health risk is not known. But the fact is that increased use of BTX is increasing human exposure. The concern about possible health risks has led to a proposed regulatory initiative in California calling for drastic reductions in BTX. Since BTX compounds are also highly reactive in ozone formation, their substitution for butane and pentane offers no offsetting environmental benefits.

Alcohol Blends. Alcohols (or oxygenates, a somewhat more general term)—such as methanol (produced from natural gas or coal), ethanol (produced from corn or a sugar crop), and tertiary butyl alcohol (or its derivative, methyl tertiary butyl ether, MTBE)—can be blended with gasoline to enhance octane. Unlike the other octane enhancers, they can do so without creating offsetting environmental problems; yet, only alcohols are now regulated by the EPA.

In 1977, Congress gave the EPA the authority to control additives in unleaded gasoline to protect catalytic convertors and other emission control systems. Additives that are "substantially similar" to gasoline were grandfathered. As a result, the EPA does not limit additives (like benzene) that are highly polluting, but requires special approval—called "waivers"—for additives (like alcohols) that are comparatively clean. To date, the EPA has been reluctant to grant waivers for alcohol blends. Its concern is that most blends tend to make the gasoline more volatile. This is true, but hardly cause for blocking this important innovation. The emissions that result from alcohol-blends are photochemically much less reactive than gasoline hydrocarbons, and add little to ozone creation. More importantly, increased evaporative emissions are outweighed by greatly reduced *tailpipe* emissions. In addition, alcohol blends produce very significant reductions in emissions of carbon monoxide and fine particulates. (The City of Denver, which has an especially serious problem with carbon monoxide, has recently required the use of oxygenates for just this reason; other cities, including Phoenix and Albuquerque, are considering similar action.)

As lead has been phased out, the use of oxygenates has increased dramatically despite regulation. MTBE is one of the fastest growing chemicals and "gasohol" (gasoline containing 10 percent ethanol) accounts for approximately 8 percent of gasoline sales. But regulatory problems remain an ultimate constraint. The EPA limits MTBE blends to 11 percent, ethanol blends to 10 percent, and ethanol-methanol blends to 7.5 percent—and does not permit these limits to be added together. The use of 3 or 4 percent of MTBE, for example, precludes the use of any ethanol or methanol.

Jumping Out of the Box. There are ways to get out of the octane box, but most of them include substantial hurdles. For example, the entire fuel delivery-and-storage system—from the refinery, to the local gas station, to the gas tank in the vehicle, to the fuel injectors in the engine—could be made airtight. This would solve the volatility problem, allowing pentanes and butanes to be used with impunity. Indeed, it would allow the use of an even lighter fuel, liquefied propane, a widely available household fuel. If the system were beefed up enough, one could use compressed natural gas, the lightest of all hydrocarbons and an environmentally benign, efficient fuel. Any of these options, however, would require a huge investment in the entire fuel system.

Another option is to begin a modest conversion to neat (pure) alcohol fuels. While alcohols have a lower energy content than gasoline, and thus require larger gas tanks, they have much higher octane and greater thermal efficiency, allowing for higher compression engines with better performance. Existing cars could easily be made to run on neat alcohols. But there is a chicken-and-egg problem. The auto companies are reluctant to make even the modest changes required for alcohol use until there is some minimal alcohol distribution network; the oil companies are reluctant to begin the process of making the fuel available until there are cars on the road to use the fuel.

Lost in the Ozone Again

As serious as the octane problem is, federal regulatory policy regarding fuels has tended to concentrate on another problem: ozone. Ozone results from a complex interaction between nitrogen oxides (NOx) and hydrocarbon (HC) emissions, aided and abetted by sunlight.

As with all pollutants, there is a continuing debate about the precise level at which ozone triggers adverse health effects. Ozone at high altitudes is considered desirable because it blocks ultraviolet rays that contribute to skin cancer. (One of the current worries is the growing ozone "hole" over Antarctica, and the possibility of its thinning elsewhere.) At sea level, however, ozone can be undesirable, creating significant respiratory difficulties for some individuals even in relatively low doses. Ozone also causes smog in urban areas; it can inflict crop damage in rural areas; and it may turn out to be the real culprit in the forest damage that has been attributed to acid rain.

There are people on both sides of the issue of whether the current standard for ozone should be tightened or relaxed. This debate is beyond the scope of this article. Suffice it to say that no one defends the ozone (or smog) problem in Southern California. There, where one cannot see the length of a city block on a typical summer day, ozone levels are more than twice the national health standard.

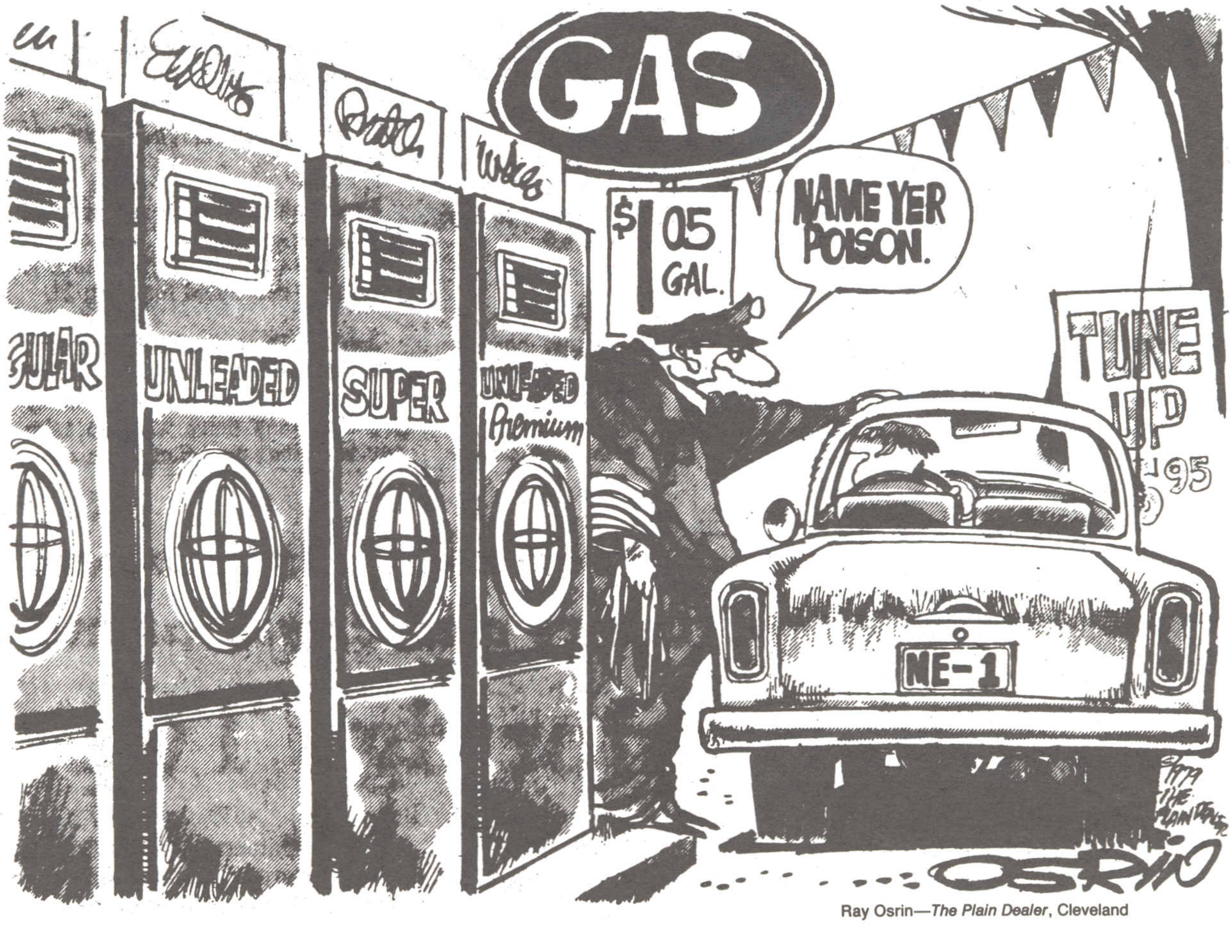
Automobiles are generally regarded as the principal culprit in ozone formation, but they are by no means the only culprit. In fact, sources such as utility boilers, manufacturing plants, refineries, and a host of small businesses (like laundries, paint shops, bakeries, and printing presses) produce more than 75 percent of the nitrogen oxides, and more than 60 percent of the hydrocarbons in Los Angeles. At least in California, which is empowered by the Clean Air Act to impose its own stricter standards, automobile regulation has just about reached its limit. Automobiles have been subjected to heavier regulation than "stationary" sources for a simple political reason: it is easier to regulate a handful of automobile manufacturers than it is to regulate thousands of small businesses.

Currently, 76 metropolitan areas fail to meet the ambient standard for ozone. The EPA estimates that most of these areas will fail to come into compliance by December of this year—the deadline imposed by the Clean Air Act. At least 30 of these are "hard core" cases, meaning that they cannot come into compliance even after implementing all ozone-reduction measures now being developed.

The Bureaucratic Response

Each state is responsible for meeting the federal ozone standard, and the EPA is empowered to step in when a state fails to comply. Moreover, the EPA has enormous indirect influence over the regulations chosen by the states because it tells the states what ozone reductions they can claim as credits for the rules the states impose. The EPA also has some limited authority to reduce ozone by imposing national regulations: its authority to regulate automobile emissions and its authority to regulate fuels. The agency is weighing its options on all of these fronts.

Controlling Cars. The automobile companies comply with EPA limits on evaporative emissions—those released from the carburetor, fuel lines, and fuel tank—by capturing the fumes in a charcoal canister and recycling them to the engine. The canister is not large enough, however, to absorb all the vapors that are displaced from the gasoline tank during refueling. The EPA has thus proposed a drastic enlargement of canisters.



Ray Osrin—*The Plain Dealer*, Cleveland

The exact cost of such "on-board" controls, imposed nationwide, is hotly debated, but it could be as much as $500 million a year—or $8,000 per ton of pollutant reduced. In addition, this strategy would take at least 15 years to become fully effective since it requires a complete replacement of the automobile fleet. Before a nationwide rule could be enforced, the EPA would have to establish that this approach was more cost-effective than the selective control of refueling vapors at the gas pump in ozone nonattainment areas.

Controlling Gas Pumps. A faster way to control refueling emissions is to modify gasoline pumps so that they capture the displaced vapors. These so-called "Stage II" controls (Stage I controls apply a similar technology to the wholesale fuel distribution system) have the advantage that they can be implemented locally. If applied in this way, Stage II costs would be considerably less on a cost per ton basis than on-board controls, but again the cost figures are hotly debated. The major unknown is the cost of "inconvenience"—the regulated gas pump would be heavier and less convenient for people to use.

Controlling Gasoline. Another approach to controlling hydrocarbon emissions is to mandate a lower level of gasoline volatility. This would dictate that oil refiners, rather than gas stations or auto makers, make the adjustment.

An argument in favor of fuel controls is that they can be implemented quickly. Like the Stage II controls, they do not depend on a 15-year turnover of the automobile fleet. Volatility limits are not as effective as canisters or Stage II controls in reducing refueling emissions, but they do help reduce non-refueling emissions from automobiles and throughout the fuel distribution system. It is worth keeping in mind that the increased volatility now prompting regulation is itself the result of an earlier regulation (lead phasedown), which increased the use of volatile compounds like butane and highly reactive compounds like benzene.

The Wrong Options?

In debating the relative costs of on-board controls versus Stage II controls versus volatility controls, it is easy to lose the forest for the trees. None of these major undertakings, which would cost upward of $1 billion, would have *any* impact on ozone where the problem is most severe. These controls are already in place in Southern California. California limits nitrogen oxides to .7 grams per mile, while the national standard is 1.0 gpm; it limits fuel volatility to 9 pounds per square inch in the summer months, while the national average is approximately 11 pounds; and it requires Stage II refueling emission controls on all large gasoline dealers. Yet the ozone problem persists.

Rather than reassessing the strategy for California, the EPA is considering extending these costly and marginal programs *nationwide*—not just to the other (less serious) ozone nonattainment areas, but *everywhere*. A more logical approach would be to compare which strategies would be most beneficial in California, then to urge California and other states to implement these in ozone nonattainment areas.

Given the localized nature of ozone nonattainment and the ineffectiveness of nationwide controls, additional ozone controls should be left to the localities where the problem exists. This, of course, is exactly what the Clean Air Act contemplates. There is little reason to require residents of the Pacific Northwest, where ozone is not a problem, to pay for additional controls on their cars.

An Alcohol Solution

Is there any strategy or combination of strategies that can produce results in California? The answer is yes, and it involves the cleanest, the cheapest, and ironically, the most highly regulated substitute for lead: alcohol. Although accurate predictions are difficult to make, it has been estimated conservatively that by converting Los Angeles' commercial fleets (fleets of 10 cars or more) to run on alcohol, almost as much ozone reduction would be produced as by *all other* possible approaches combined (including banning spray deodorants and closing paint shops).

There is nothing new about this particular technology. Both Kettering and Ford assumed that cars would eventually run on alcohol. Presently, several methanol fleets are operating in California, most notably the Bank of America's 300-car fleet. (There is a joke at the bank that the air coming out of a methanol car's tailpipe in California is cleaner than the air going into the combustion chamber.) The biggest laboratory of all is Brazil, where two-thirds of the cars run on a blend of 22 percent ethanol, and all new cars (including one-third of the cars now on the road) run on 100 percent ethanol.

Of the two competing alcohols, ethanol and methanol, ethanol has received more attention (not only because it is imbibable). As a renewable farm product, ethanol is popular with farmers, and also with people worried about dependence on Persian Gulf oil and the threat of protectionism arising from massive grain surpluses. It also has a higher energy content than methanol, and is more compatible with existing automobiles. But it is more expensive to produce than methanol and, until biotechnology significantly reduces the cost of fermentation, ethanol will not be able to compete with other octane enhancers without subsidies—unless blended with its cheaper cousin, methanol. Methanol, on the other hand, could compete without any subsidies, but it cannot be blended into gasoline without a co-solvent such as ethanol. Moreover, methanol cannot yet be used as a neat fuel without some gasoline to help it start—again requiring ethanol or some other co-solvent for optimum performance. Ethanol and methanol thus have an economic, as well as a chemical, affinity for each other.

The EPA, working with the Presidential Task Force on Regulatory Relief, is taking steps to achieve methanol fleets without actually mandating anything. The EPA is planning to issue a guidance document that allows emission reductions by alcohol-burning fleets to be sold or traded as part of an emissions trading policy, or to be claimed as credits in State Implementation Plans. This would recognize, and monetize, the emissions-reduction benefits of alcohols, and the entire program could pay for itself. Commercial fleets can easily overcome the chicken-and-egg problem. Wider use of alcohols could follow.

The Bureaucratic Politics of Innovation

In the bureaucracy, there is real resistance to innovations that could help solve the nation's ozone, carbon monoxide, and particulate problems, and could head off the growing benzene problem. This stems, no doubt, from an inherent property of bureaucracies—reluctance to give up control. If we were simply to compare the relative cost-effectiveness of available strategies, and urge the states to adopt the most effective, it would be letting the facts, not the bureaucrats, dictate the results. Fragmented regulatory strategies based on design standards and micro-management tend to maximize control and bureaucratic employment, although not necessarily the bottom line results.

All bureaucracies discourage the development and implementation of new technologies by requiring that they adhere to much higher standards than the products or processes they would replace. (This principle is sometimes known as "the perfect being the enemy of the good.") Presumably bureaucracies do this in the

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hope of accelerating progress. But there is also the bureaucratic tendency to say no to everything rather than say yes to something that may turn out to have problems. Backing them up, there are powerful lobbies for the existing technologies and products hoping to protect their business by exaggerating the defects of upstart competitors. In addition, there is a feeling among some that proponents of new technologies and processes, if they wish to be granted the right to compete, should sacrifice potential profits and shoulder a disproportionate share of the clean-up burden. Whatever the cause, the bias against new technologies and processes has the perverse effect of delaying the clean-up of existing problems.

Conclusion

Innovation can undermine obsolete regulatory systems even as it undermines obsolete technologies. This has been happening in communications, in financial markets, and in transportation. It would also be happening in automotive fuels except that the acquiescence of the regulators is required. The development of alcohol fuels is a technological revolution that has yet to overcome bureaucratic inertia. It will be ironic if environmental and safety regulations continue to inhibit the use of fuels that have many advantages over gasoline in terms of cleanliness, safety, and energy security. ■