From: The Half-Life of Policy Rationales: How New Technology Affects Old Policy Issues, F.E. Foldvary and D.B. Klein, eds.. New York University Press, 2003, pp. 86-106.

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Fencing the Airshed

Using Remote Sensing to Police Auto Emissions

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In a famous article, Garrett Hardin explains the problem:

> The tragedy of the commons reappears in problems of pollution. . . . The rational man finds that his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them. Since this is true of everyone, we are locked into a system of "fouling our own nest." . . . [The air] surrounding us cannot readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, by coercive laws or taxing devices. (Hardin 1968, 116–17)

Where Hardin says that the air "cannot readily be fenced," he is pointing out that transaction costs stand in the way of otherwise mutually advantageous agreements.

In very local matters of air quality, traditional tort doctrines such as Nuisance can cope with unneighborliness. Whether a laissez-faire society working within a reasonable tort system could cope with large-scale and not very local matters of air quality involving tens of thousands, even millions, of people, such as smog in the Los Angeles basin, is a matter of speculation. In such a society there would be private ownership of roads, which, like stationary sources, would be subject to class-action suits for emissions-related damages (Rothbard 1982, 90). Libertarians might argue that tort action, as well as social esteem and moral suasion, would discourage fouling of the common nest.

Putting such speculation aside, let's agree that government ought to pursue proactive policies against air pollution where the problem is serious. In pursuing proactive policies the government might be able to choose between either *property-rights approaches* or *command-and-control approaches*. Economic principles strongly support the conclusion that property-rights approaches, provided that they are available, impose a smaller burden on society and produce better results. New technologies are making available a sound property-rights approach to the problem of auto emissions. Rather than maintaining and enlarging the current array of expensive and burdensome controls, government can "fence the commons" using new technologies.

Auto Emissions, Remote Sensing, and Smog Checks

Most auto emissions come from the dirtiest 10 percent of the fleet, the gross polluters. More than 50 percent of on-road carbon monoxide (CO) comes from just 5 percent of the cars. The same is true of hydrocarbon (HC) emissions. In each case the cleanest 90 percent of cars—the low and marginal emitters—taken together generate less than 15 percent of the pollution (Lawson 1998; see also the data at www.feat.biochem.du.edu). Because of the extreme skewedness of emissions and because most of the reductions of emissions come from the gross polluters, the chief task is targeting the gross polluters (Glazer, Klein, and Lave 1995; Lawson 1995).

A new device called a *remote sensor* is capable of doing just that. An infrared beam is shone across the road. As a car passes along the road, the exhaust plume absorbs some of the beam's light waves, and the sensor receiving the beam can measure the concentrations of pollutants in the exhaust. The remote sensor can be set up on many streets and highway ramps and can be attached to video and computer equipment that automatically reads the license plate of the passing vehicle. The device is mobile and extremely inexpensive per test. If government can use this device to identify the minority of gross polluters, it can clean the air at a low cost to the public.

Smog check programs around the nation usually require cars and light trucks to pass an inspection every two years (in some cases, every year). Motorists, of course, can prepare for the inspections, but on the other 729 days of the biennium they can drive a dirty car. Some motorists get their gross-polluting cars through the smog check by tampering with the car or bribing the private inspectors. Some keep their defective vehicle unregistered, thereby avoiding smog checks altogether (Glazer, Klein, and Lave 1995; Lawson 1993). Some register defective vehicles just outside the smog check region but drive inside the region (Stedman et al. 1998). Some station mechanics often tinker with cars so they can pass the test without fixing serious problems. Some cars simply deteriorate long before the next scheduled inspection. The program requires all motorists, even the vast majority with clean cars, to incur the cost and hassle of obtaining a smog certificate.

Smog checks are an example of the command-and-control approach to the problem. In command and control, the government regulates *your use of your property*, whether or not you have damaged the property of others. At present, governments rely mainly on command and control for auto emissions. The major examples of command-and-control policies are

- Smog check programs.
- Restrictions on the content of gasoline.
- Quotas and mandates for the use and development of alternative fuels and alternatively fueled vehicles.
- Quotas and mandates for the use and development of electric vehicles.
- Design and emission requirements imposed on automobile manufacturers.
- Promotion of carpool lanes and (in the past) mandatory carpooling.

By contrast, in a property-rights approach the government regulates *your use of others' property*; that is, the government monitors for infractions but otherwise leaves people free to use their own property. The government is the sentinel guarding and securing the fair use of property. It is the quiet nightwatchman, called in only when a tort or wrong has been committed.

The common airshed may be regarded as the property of the local or regional government. In 1968, when Garrett Hardin wrote his famous article on the tragedy of the commons, the air around us could not readily be "fenced." But technology has since enabled government (or others) to monitor fouling of the common nest and otherwise leave citizens free in the use of their automobiles.

In this paper I juxtapose remote sensing and smog check, but smog check is only one of a number of command-and-control approaches whose effectiveness often also pales relative to remote sensing.

The Economist's Framework: Thinking about How Inputs Are Best Combined to Yield the Desired Output

When we go into a restaurant and order a bowl of French onion soup, we specify only the desired output. We do not tell the chef how to slice the onions, grind the pepper, or grate the cheese. We do not tell the restaurant manager where to get the ingredients, how to store them, or how to train the employees. Customers merely specify the outputs, and entrepreneurs in the market attend to the inputs. Successful entrepreneurs are expert in finding local opportunities for effectively combining inputs, and they compete for customers by producing outputs that customers desire.

As steward of the commons, the government must attend to the problem of air quality. The logic of incentives still applies: if technology permits, government ought to address the problem by treating outputs directly, not by treating inputs. In other words, it should police abuses of the common property, not indiscriminately restrict individuals in the use of their own property.

The alternative is command and control, which tries to achieve output goals by specifying inputs. Those who favor command and control do not put much faith in the invisible hand. They do not believe that once property rights are established and outputs are specified, people will respond to those incentives and arrange the inputs appropriately.

Figure 5.1 is a conceptual diagram for the smog check program. Fleet-emissions reduction is the state's output goal. An *input* it has pursued to serve this goal is the smog check program. But from the motorist's point of view, the program creates the *output* goal of passing the test. One way that motorists or their mechanics serve this goal is to keep their cars running clean. But other ways are tampering with the car, obtaining temporary emission reductions, and obtaining a smog certificate illegitimately. Because such tactics are common and inspection is infrequent, the connection between the state's goal and the motorist's goal is *weak and distant.* In regulating your use of your property, the state has mandated an input process that doesn't deliver. Rather, it has implemented an *input-oriented program,* which is expensive and burdensome for all motorists.

A remote-sensing program would better connect state and motorist goals, as illustrated in figure 5.2. The state pursues its output goal by deploying remote sensors, automatically reading license plates, and sending warnings and citations to gross polluters. For motorists, the program

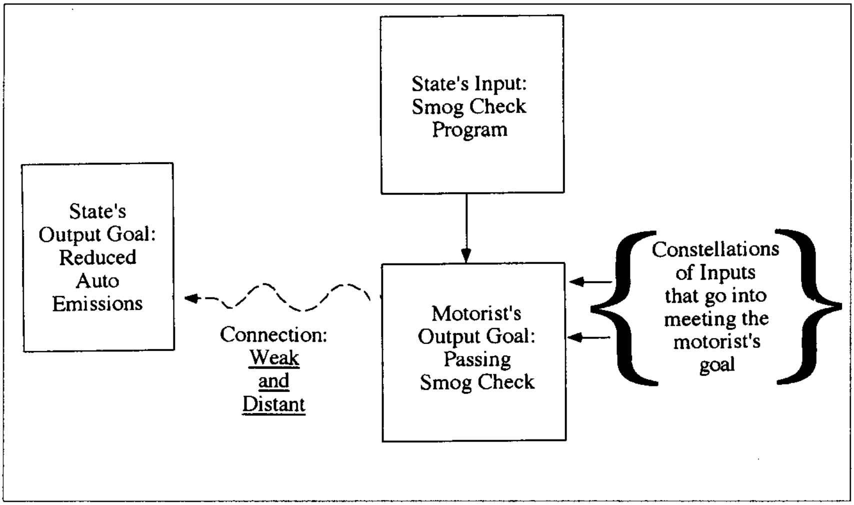

Figure 5.1

generates the output goal of avoiding smog citations. We say that this program is *output oriented* because the connection between the state's goal and the motorist's goal is *strong and close.* This program is very similar to the consumer's asking for a bowl of soup and leaving the rest to the entrepreneurs.

Five Reasons That Property-Rights Approaches Are Superior

There are five reasons that property-rights / output-oriented programs (assuming they are available) are superior to command-and-control / input-oriented programs. Each reason poses a criticism of input-oriented programs, illustrated by actual experience with smog check programs.

1. Programs that specify inputs are not tailored to individuated conditions but tend toward a policy of one size fits all. Yet the technique for transforming inputs into outputs is not singular but *plural.* Every motorist has his own distinct sets of opportunities for getting his car to run clean. In the absence of governmental regimentation, the entrepreneurship of the market would discover better ways to keep cars clean. Nonetheless, the required inspection by a certified station lays down a blanket procedure for getting

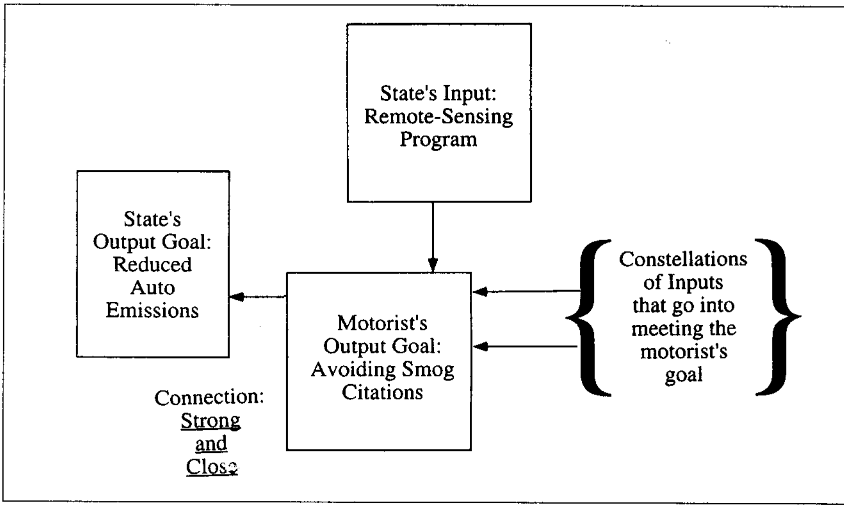

Figure 5.2

cars clean, a procedure that forsakes special opportunities and diverse conditions and chokes off entrepreneurial creativity.

Smog check experience: The smog check program forces most motorists to participate in a biennial practice that they may not need. As many as 90 percent of all vehicles are clean for all relevant pollutants, but most of them must participate in an input ritual (smog check) that may be appropriate only for the other 10 percent of cars. Indeed, only 3 percent of 1982-and-newer model cars failed the test for tailpipe emissions in Colorado's smog check program in 1998 (Colorado AQCC 1998, 1999). And owners of the dirtiest 10 percent might be able to make their cars clean by obtaining proper and legitimate service from *unlicensed* stations or *unlicensed* inspectors. Without input mandates, entrepreneurs would come up with good ways of serving motorists' desire to avoid smog penalties.

2. A government program that specifies inputs runs the risk of specifying the *wrong* inputs. Government proceeds by the blunt forces of bureaucratic, interest-group politics. Rather than relying on competitive market selection of inputs, the government adopts input strategies that may well be *ineffective* in producing the desired outputs.

Smog check experience: California's smog check program has not lived up to its original promises. Most research indicates that smog check programs have hardly any smog-reduction benefits (Hubbard 1997; Lawson 1993; Lawson and Walsh 1995; Scherrer and Kittelson 1994; Stedman et al. 1997; Zhang et al. 1996). Indeed, Lawson (1995) found, remarkably, that 40 percent of the vehicles repaired at smog check stations were found to have an *increase* in emissions.

3. The government's input strategies display very little ability to adapt to changing conditions. Unlike the free-enterprise market, which is driven to discover new combinations of inputs to produce the outputs that consumers desire, command-and-control programs become locked into yesterday's ostensible solutions and are very difficult to restructure or dismantle.

Smog check experience: Smog check programs have become part of "the Establishment." Because smog checks belong to the status quo, they have become a focal point for discussion and planning. And as the status quo, they have created concentrated and well-organized interest groups standing behind it, including both private smog check mechanics and inspection facility contractors.

4. A program that specifies inputs inevitably entails large administrative and bureaucratic costs for managing the program and policing compliance. If these efforts are inadequate, corruption, fraud, and malfeasance may become widespread.

Smog check experience: It is well known that corruption, fraud, and malfeasance have significantly undermined the effectiveness of smog check programs (Glazer, Klein, and Lave 1995; Hubbard 1997; Stedman et al. 1997, 1998). Smog check programs must attend to the training of licensed inspectors, the integrity of inspection equipment, the enforcement of honest inspection service, and the evaluation of the program procedures. Corruption, fraud, and policing costs inevitably grow larger as government requirements reach deeper into the input stages of the production process.

5. The less directly that programs are connected to public-interest goals, the more likely it is that they will be hijacked and led astray. Influential special interests, including regulators, are tempted to favor their own interests in deciding which inputs should be adopted. When policies treat outputs directly, it is much more difficult for interest-group tendencies to cloud the issue and usurp power.

Smog check experience: Debates rage over the input specifications of smog check programs. Should the inspection use treadmill-style dynamometers or less expensive equipment? If it chooses dynamometers, should they simulate loads over a continuous range or only discrete loads? Should they report an emissions trace over the entire test or only peaks and averages? And so on. Every interest group takes its place in the political process and, in doing so, often obscures the fundamental issue, which is clean air at the lowest cost. These politicized debates could be largely avoided if we had a strategy that dealt directly with outputs and was *silent about inputs*. The public interest would then be better recognized and have a greater chance of being well served.

Remote Sensing: A Feasible Technology for Treating Outputs

The success of an output-oriented policy for auto emissions depends on a "fencing" technology that is accurate and withstands circumvention. Does remote sensing measure up to the task?

Accuracy of Remote Sensing

All kinds of test systems can make two types of errors. A *false failure* occurs when the system identifies a clean car as dirty; false failures cause motorists to incur unnecessary costs. A *false pass* occurs when the system identifies a dirty car as clean; false passes are undesirable because high-emission cars are not cleaned up.

It is well established that remote sensing takes a reasonably accurate snapshot of the CO, HC, NO, and CO_2 emissions from a car's tailpipe and does so relative to levels in the ambient air (Ashbaugh et al. 1992; Lawson et al. 1990; Popp, Bishop, and Stedman 1999). In determining whether CO emissions, say, are excessive, CO emissions are measured in relation to CO_2 emissions. It is the ratio of CO to CO_2 that really matters. A low ratio is good; a high ratio is bad. That's why accelerating or idling does not matter as much as one might have thought: if CO and CO_2 increase proportionately, the ratio stays the same.

The "snapshot" taken by remote sensing is perhaps a little "blurry," but it tells us whether we are looking at an antelope or a vulture. The potential problem with emission snapshots is that they might capture the car's emissions performance at an uncharacteristic moment. A simple case is the cold start: during the first one to two minutes it takes to warm up, many cars produce high emission ratios. Vehicle emission ratios also vary with speed, grade, load, and acceleration. Rain and fog may prevent remote sensors from working properly. If there were no way to control for these factors, the usefulness of remote sensing would indeed be doubtful.

But these factors can be controlled. Officials can select sites removed from residences and parking areas to eliminate the cold-start problem and find road features or use orange cones to put narrow bounds on the grade, speed, and acceleration variables. They might be confined to work in dry weather or, during precipitation, in covered areas such as underpasses or tunnels. Remote sensing is most accurate when it reads cars under light acceleration, so a slight incline would be a benefit. Highway exit ramps are ideal. If site selection cannot eliminate variation in driving modes, program officials can easily measure speed and acceleration using light beams that cars break as they pass by.

In one remote-sensing study, cars that had been read by a remote sensor were pulled over and given a regular smog check on the spot. Of those cars that had exceptionally high CO readings (above 4 percent), 91 percent failed the on-the-spot smog test (Lawson et al. 1990). Other studies have replicated this high correlation, and further developments would surely make the match even closer (Ashbaugh et al. 1992; Lawson et al. 1996). (For a thorough overview on accuracy, see Schwartz 1998, 4–19; for online scientific data on remote sensing, see the University of Denver site www.feat.biochem.du.edu.)

Errors Must Be Construed on a Systemwide Basis

A report on California's smog check program (Calif. I/M Review Committee 1993, 129) discusses how likely it is that a remote sensor will wrongly identify a car as "clean" or "dirty." Let's say the sensor identifies a car as dirty if it reads the CO emissions as exceeding 4 percent of adjusted emissions. A car in the set of clean vehicles, with "clean" defined in the study, has, on average, less than a 1 percent chance—0.64 percent—that it will exceed this 4 percent "cut point" at a single reading. A car in the set of dirty vehicles has, on average, a 66 percent chance that it will *not* exceed the cut point at a single reading. If we must use only a single snapshot, we apparently must accept a lot of false passes. Alternatively, we could reduce the false passes by lowering the cut point, but doing so would then increase the number of false failures.

But officials do not face such a harsh trade-off. Instead of thinking of the errors in a remote-sensing program on the basis of a single snapshot, we should construe errors on a systemwide basis of *multiple snapshots*. Remote sensing is a remarkably inexpensive test—a conservative estimate is 75 cents per test—so we can multiply the remote sensors on the roads and use a pass/fail criterion based on a *pattern* of readings. In a significant sense, it really is the biennial scheduled test (regardless of its technical sophistication) that is limited to a once-every-two-years snapshot, while pervasive remote sensing could get a bona fide "nickelodeon" show capturing the emissions during the biennium.

Consider a remote-sensing program whose average number of readings for the entire fleet over a biennium is eight. Cars that travel more than average are read more than eight times, and cars that travel less are read fewer than eight times. Consider a standard that fails a car if it exceeds the 4 percent CO cut point at least once over the entire biennium.

- A clean car, tested eight times, stands (on average)[1] a 95 percent chance of never exceeding the cut point. That's a 95 percent chance of remaining undisturbed, which (unless it is a new car) is 95 percent better than its prospects under the current program!
- A dirty car, read eight times, stands (on average)[2] a mere 3.5 percent chance of not exceeding the cut point and getting away with a false pass over the course of the biennium.

On a *systemwide* basis, the program registers few false failures *and* few false passes.

Remote sensing is a little less accurate at reading NO emissions than it is at reading CO and HC emissions, but again the issue in not one of pinpoint accuracy. When gross polluters emit three times or ten times as much as normal cars do, catching them with multiple sensors is a turkey shoot. By increasing the cut point, officials can reduce the number of false failures, and by increasing the number of tests per year, they can reduce the number of false passes.

Moreover, the margin of error can be further reduced. The straight cut-point criterion just presented is unnecessarily simple. Deploying many remote sensors would generate a wealth of information, leading to the development of more sophisticated criteria. A salesman who travels a lot in his clean car would have a chance of exceeding the 4 percent CO mark during the biennium greater than the 5 percent just implied. But the system will have registered *numerous clean readings* for this motorist and, on that basis, can pardon a single dirty reading. A criterion might say, for example, that three clean readings cancel a single dirty reading. Or it can forgive first offenses or evaluate on the basis of running *averages rather than cut points.* It can blend the readings for the different pollutants into a composite variable. It can scan for engine behavior that alternates between running clean and running dirty (sometimes called "flipper" behavior). It can adjust for the measured speed and acceleration of the vehicle at the moment of emissions readings. And so on.

Outputs That Remote Sensing Does Not Measure

Policymakers can police the CO, HC, and NO exiting the tailpipe. But are tailpipe CO, HC, and NO the only outputs that matter? Are there other emissions that in fact cannot be found by remote sensing at the output stage and hence need to be controlled by other means?

Evaporative Emissions

Another source of noxious outputs is evaporative HC emissions. These are produced when gasoline mixes with air in a carburetor, when the fuel line has a leak, when the charcoal canister system malfunctions, or, most simply, when the gas cap is missing. There is considerable debate about the magnitude of these types of emissions (Calif. I/M Review Committee 1993, 97; Gertler et al. 1993; Douglas R. Lawson letter to Richard J. Sommerville, November 6, 1992; U.S. EPA 1992). Evaporative emissions of the fleet are declining steadily as new engine technology has replaced older technology, particularly the replacement of carburetors by fuel-injection systems. Evaporative emissions are continuing to decline as fuel tank vapor recovery systems come into use. These positive developments are, however, the direct result of federal command-and-control regulations imposed on automakers.

Although remote sensing does not read evaporative emissions, it might help reduce evaporative emissions because they are correlated with tampering and inadequate maintenance, and these in turn are correlated with high tailpipe emissions (Lawson et al. 1996; Pierson et al. 1999). Motorists who are induced to cut their tailpipe emissions make repairs that sometimes also reduce nontailpipe emissions.

Evaporative emissions elude not only remote sensing but also any inspection system. No existing inspection system can test the vehicle's evaporative filter/purge system. Although the EPA has proposed doing pressure/purge testing, it has been abandoned because those tests were too intrusive and actually damaged hoses, for example.

Particulate Matter

Another form of noxious emissions is particulate matter, like the smoke from diesel engines. Remote sensors (based on reflectometry or absorption) have been created to measure the concentration of particulates in auto exhaust (Lowi 1996; Stedman, Bishop, and Aldrete 1997). Researchers believe that better roadside units could be developed. Hence, particulate matter does not elude the output-oriented approach of remote sensing.

CO_2

Some people might argue that excessive carbon dioxide (CO_2) emissions exacerbate global warming. Views on global warming vary greatly. To some people also, it is unclear that global warming is (or will be) a reality, whether the supposed warming should be deemed detrimental, and whether, in the case of warming, it could be mitigated by simple, low-cost cooling strategies rather than emission-control strategies (Benford 1997).

CO_2 emissions are closely and inversely correlated with the car's gas mileage (the distribution of CO_2 emissions does not look like that of CO or HC), so controlling CO_2 emissions amounts to regulating gas mileage. One might argue that regional governments would not have an incentive to mitigate global warming, so command-and-control programs at the national level are necessary. In response, it could be said that the potential benefits of such a policy are too hypothetical and too insignificant to warrant intrusive measures at the national level. Command-and-control damages general prosperity, and general prosperity is the surest aid to environmental improvement (Wildavsky 1988).

Lead

A car running on leaded fuel emits lead. Federal command-and-control laws between 1976 and 1986 virtually eliminated the availability of leaded gasoline. The current remote-sensing technology cannot measure lead emissions, however, and Donald Stedman reports that remote-sensing technology *cannot* be adapted to do so. Lead emissions, therefore, cannot be controlled at the output level, so some form of input control is presumably necessary. It bears consideration whether federal law is the appropriate way to do so. Regional governments could rule on the permissibility of selling leaded gasoline in their own territory and leave manufacturers and distributors free to work around such regional restrictions. In areas where lead emissions are not deemed a serious problem, consumers would be free to enjoy the benefits of leaded gasoline.

Remote sensing, then, is not able to measure the full range of emission outputs that concern us, but its ability to measure CO, HC, and NO covers most of the problem. In an otherwise laissez-faire society, the problems of evaporative and lead emissions might remain and might call for measures farther down the command-and-control end of the policy spectrum.

Will Scofflaws Learn to Foil Remote Sensing?

Output-oriented policy remains silent on inputs. It unleashes entrepreneurial creativity to discover and combine inputs to produce customers' desired outputs. However, the output that a remote-sensing program sets for motorists is avoiding smog citations. It is possible that the process of entrepreneurial discovery will respond not by cleaning up cars, but by foiling or circumventing the system. A pure remote-sensing program will yield emission reductions only if human cunning cannot find convenient ways of foiling its efforts. (Smog check itself is an object lesson of this hazard.)

To thwart circumvention, a remote-sensing program should deploy a small number of on-road pullover teams. If a car exhibits a suspicious feature, the computer will signal the attendant, and the car can be stopped on the spot. On-road teams would not stop mere gross polluters, but those suspected of subterfuge or rank noncompliance.

The five methods of foiling remote sensing are as follows:

1. Obstructing the license plate with mud or putting a trailer hitch in front of it. This problem can be easily policed by pullovers. When the computer receives information that a car has an illegible plate *and* high emissions, it will signal authorities to pull the car over. Even without on-road forces, the problem could be resolved with elementary detective work using multiple video images of cars with illegible plates.
2. Keeping the car unregistered so the program is not able to identify the car and notify the motorist. Again, the computer could be programmed to signal on-road forces to nab unregistered vehicles.
3. Evading remote-sensing sites. This will be difficult for motorists because the sites could be numerous, unannounced, and disguised and be changed daily.

4. Conniving to eliminate the exhaust plume as observed by the remote sensor, such as altering the tailpipe or turning off the car as it passes by a remote sensor. The computer could flag these cars for pullover.
5. Tampering with the contents of the exhaust plume. This requires an additional gas source, to be mixed with the true exhaust, or perhaps an additive to the gasoline. More specifically, motorists might be able to foil remote sensing if they can make their car emit excessive carbon dioxide emissions (CO_2), because remote-sensing measures CO, HC, and NO_x each as a ratio to CO_2 emissions. Increasing the CO_2 content would therefore disguise gross emissions of the regulated pollutants. That motorists would go to such lengths is highly unlikely.

It appears that scofflaw tactics pose no real threat to a program vested with on-road pullover power. That power, even if exercised only rarely, would place a significant check on evaders. The accumulated record of license-plate snapshots that are taken concurrently with remote-sensing measurements would supply incontrovertible evidence of subterfuge.

Recommended Features of a Remote-Sensing Program

The desirable features of a remote-sensing program are carefully explored elsewhere (Klein and Koskenoja 1996; for similar and more current analyses, see Schwartz 1998). Here I summarize the basic components of a property-rights policy based on remote sensing:

- *On-road remote-sensing units coupled with automatic license plate readers*: The program should deploy numerous unannounced remote-sensing teams. In addition, many units could be permanently bunkered and operate unmanned.
- *No periodic inspection*: The program would deploy enough mobile remote-sensing units to read cars an average of four to eight times over two years. The cost of traditional ("decentralized") smog check inspection is about sixty times higher than the cost of a single remote-sensing inspection (Klein and Koskenoja 1996, 19). Periodic inspections add little to the surveillance achieved by remote sensing and should be discontinued.

- *Smart signs*: At the Speer Boulevard exit ramp off southbound I-25 in Denver, a consortium of public and private sponsors erected, with public-sector approval, a permanent "Smart Sign." It operated around the clock for sixteen months and has lately been relocated. Motorists driving by see an electronic billboard that automatically and instantaneously reports (at a cost of 3 cents per reading) the car's emissions as "good," "fair," or "poor." Governments should install these inexpensive "smart" signs to allow motorists to check their emissions and to advance public awareness and understanding. (On smart sign costs and performance, see Bishop et al. 2000; Schwartz 1998, 29.)
- *Early driver notification*: The program should notify motorists whose cars are within smog limits but are approaching the limits or showing deterioration. The state would invest in a postcard to notify the motorist that he may wish to service his car. The notification card would cite three good reasons for doing so: helping clean the air, improving gas mileage, and reducing the likelihood of being subject to future penalties. Early driver notification would be a positive service to the motorist as well as a sort of warning. It would prompt some people to reduce their emissions preemptively before being compelled to do so. Demonstration projects have proved the power of voluntary notification to clean the air (Bishop et al. 1993). The program should also extend a "notice of appreciation" to motorists with clean cars, perhaps after a series of readings has been compiled. This would reassure the motorist of his clean status and would build goodwill with the public.
- *Citation by mail and clean screening*: The program would issue citations by mail to motorists with high-emission vehicles. The citation would call for some kind of redeeming action to be made within a certain time period. Perhaps the motorist would be allowed to escape penalty by visiting a fixed remote-sensing site and demonstrating low emissions—an arrangement that remote-sensing advocates call "clean screening."
- *Monetary Fines Imposed on Gross Polluters*: When a motorist receives a citation for exceeding the speed limit, driving recklessly, or parking illegally, he is to pay a fine. A similar system of penalties could also be used for smog violations and would have those who damage the common property *compensate* those who have been harmed. Revenues from fines would go toward financing the program, which would benefit the community as a whole. Like speeding tickets, fines for smog violations could be graduated with the extent and frequency of the vio-

lation. A program of monetary penalties would induce motorists to value and, if necessary, to seek in the marketplace their own prevention of citations. Under such a program, this good would be a normal private good like hamburgers or handkerchiefs; the free, private market would be best at producing and supplying it. Consumers might demand and mechanics would offer a warranty on smog repairs. Perhaps entrepreneurs would open drive-through testing facilities using remote sensing and charging just a few dollars (like the "smart sign" proposal). Getting one's car tested might be quicker and cheaper than getting a car wash.

- *Enforcement: DMV records and on-road pullovers*: The California Department of Motor Vehicles is empowered to impose fines, deny vehicle registration, and impound vehicles that do not comply with citations (California Health and Safety Code, sec. 44081, 1994). In a remote-sensing program, driver's licenses, vehicle titles, and registration could be frozen until fines were paid. Using automatic license plate readers, on-road units could easily identify and pull over rank noncompliers and impound their vehicles. *Remote sensing is a means of both identifying gross polluters and apprehending them.* But the pullover forces would act only as the last resort. They should not be authorized to accost the mere gross polluter, the mere unregistered vehicle, the mere license plate obscurer, and so forth. Rather, they would pull over only gross polluters who are unregistered, who have illegible license plates, and who have not complied with previous citations. Thus, only the hard-core problem cases would be subjected to an on-road pullover. The program might create its own "smog squad," separate from existing police forces, that enforces only emissions violations, just as parking patrols enforce only parking violations.
- *Repair subsidies and waivers*: For reasons of equity, enhanced compliance, and political acceptability, it makes sense for the program to offer repair subsidies to the poor. Using deductibles and copayments, a subsidy program could mitigate opportunism and moral hazard. For cars in need of extremely expensive repairs, the government might issue waivers, as do smog check programs today.

A detailed examination indicates that a program consisting of all these features would cost society much less, and benefit it much more, than do current smog check programs. The cost of valid remote-sensing readings would range from $0.35 to $1.35 per reading (see Klein and Koskenoja 1996, 18–33; Schwartz 1998, 26–27).

Enforcing Property Rights Means Cleaning the Air

Besides offering lower costs, the remote-sensing approach delivers more air quality benefits than do smog check and other command-and-control policies. As mentioned, most of the fleet emissions comes today from about 10 percent of the cars. The majority of high emitters would receive a warning or a citation. And the majority of those receiving citations would consequently make their cars clean because leaving their car dirty would put them in constant jeopardy of penalty. We do not know how long a repaired car remains low emitting, but we do know that repairs vastly reduce the emissions of high emitters (Lawson 1995) and that if the car resumed high emissions, the system would probably detect it promptly.

Remote sensing has been used on a pilot or supplemental basis in Arizona, California, Colorado, and Ontario. Schwartz (1998, 22) summarized the results: "[Remote sensing] seems capable of identifying significant portions of the on-road fleet that are low-emitting, while allowing relatively few high emitters to slip through the cracks."

The EPA and most allied agencies have been slow to embrace remote sensing; indeed, the EPA's guidelines deflect state governments from remote sensing. The bad politics of remote sensing appear to stem from several unfortunate factors: (1) a not-invented-here attitude toward remote sensing; (2) an apprehension that remote sensing will find fault with long-favored auto-emission control programs; (3) an apprehension that remote sensing will work so well, so easily, that bureaucracies will lose budget and staff; (4) the possible influence of the smog check industries and other command-and-control related industries; (5) the ownership of important remote-sensing patents by a company that sells expensive alternative smog check equipment and therefore has an incentive to suppress remote sensing; (6) the lack of support by environmental groups, who seem more interested in imposing command-and-control and combating automobility than in cleaning the air (Klein and Saraceni 1994; Stedman 1995).

The Challenge to Auto Emissions Command and Control

Smog check is just one program aimed at reducing fleet emissions. Other programs are carpooling programs, emissions requirements on new cars, electric vehicle quotas, and alternative fuel mandates.

The case against command and control applies to these other programs as well. They are extreme examples of input-oriented strategies that fail to go to the heart of the problem and impose enormous costs. Recent literature shows convincingly that these programs rate low in cost effectiveness (for example, Orski 1994).

Although smog is a problem in only certain regions, the EPA's new-car emission requirements mean that many car buyers have to pay more for a new car even when they do not live in an area with a smog problem. The smog problem is thus best addressed by regional, decentralized programs. With a functioning remote-sensing program, regions can police excessive emissions. To pass muster with remote sensors, motorists will have to keep their cars clean. That demand will induce automakers, the energy industry, and the repair and inspection industry to produce cleaner cars. In the property-rights approach, made possible by new technology, inputs are selected by competitive, spontaneous market forces, not by government agencies. The likely result is less bureaucracy and cleaner air.

NOTES

I thank Gary Bishop, Douglas Lawson, and Donald Stedman for important feedback.

1. We should further recognize that of the cars in the set defined as "clean," the relatively dirty ones are most likely to fail. They may not be officially guilty, but they won't be entirely innocent.
2. The relatively less guilty cars are most likely to sneak by.

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