Economic Incentives in
Motor-Vehicle Inspection and Maintenance Programs

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I Introduction

U.S. air-quality legislation and regulation has sought for several decades to reduce air pollution from motor vehicles. The most effective and important policy to this end has been a series of increasingly stringent emission certification standards. However, the equipment responsible for controlling pollution in certified engines can degrade with time and use, and air quality management authorities in the U.S. and elsewhere have struggled since the early 1980s to develop effective and politically acceptable policies to ensure that motor vehicle emission control systems remain in good working order over the life of the vehicle.

The success of such policies to control emissions of vehicles “in use” has been decidedly mixed. On the one hand, data from a variety of sources show that emissions of constant-aged vehicles have steadily declined since the 1984 model year.\(^1\) Probably the main reason for the improvement has been rapid technological progress, especially in electronics, which has led to much more robust emission control systems than were available in the early 1980s. Some of the improvements in emission-system durability would have occurred no matter what, but they were no doubt encouraged by more demanding warranty requirements written into the Clean Air Act of 1990.

On the other hand, no similar successes have been experienced in inspection and maintenance (I/M) programs, still considered by the USEPA as the flagship policy to control in use emissions. By 1990 it was clear that existing state and local I/M programs were quite ineffective (Lawson 1992, Schwartz 1992, Anderson 1992), although their costs were low. Accordingly, the 1990 Amendments to the Clean Air Act directed the EPA to develop an “Enhanced I/M” program to deal with perceived inadequacies in the state programs.\(^2\)

As data from state programs becomes available, it has become increasingly clear that Enhanced I/M is not nearly as cost-effective in the field as EPA had hoped and expected. In a previous paper (Harrington, McConnell and Ando 1999), we analyzed the cost and emission reductions of the Enhanced I/M program in Arizona. We found costs in Arizona to be about the same as EPA had predicted when promulgating the regulation,\(^3\) but the emission reductions were only about a third of what EPA predicted. That is, the cost-effectiveness of the program is quite disappointing.

Enhanced I/M is a command-and-control policy; this leads economists to wonder whether an incentive policy might be devised that could deliver equal or greater goods at lower cost. We examine this question below, using a simulation model that applies a variety of decision rules to a sample of about 57,000 actual emission-test and repair experiences from Arizona.

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\(^1\) Stedman et al. (1995)


\(^3\) The Enhanced I/M rule was a “major regulation” requiring a regulatory impact analysis (RIA) that, among other things, estimated the costs and emission reductions expected to be achieved by the regulation. See USEPA 1992.
An earlier paper suggested that indeed there were gains to be achieved from implementation of an economic incentive policy (Harrington, McConnell and Alberini 1997). The simulation model in this paper contains a more detailed representation of the multistage decision problem facing the motorist and takes particular care to specify the information available to the motorist at the time the decision is made. In addition, the model explicitly includes a number of important transaction costs, including the time and travel cost associated with visiting a repair shop or test facility and the cost of diagnosing emission test failures. These costs do not appreciably affect the outcomes in the command-and-control case, because motorists have little discretion about whether to continue the process. In the EI case, on the other hand, the motorist can always terminate the process and pay the fee, so transaction costs might substantially affect outcomes.

With these modifications in place, the advantages of economic incentives, are no longer so clear, and in fact depend on what elements are allowed to enter into the motorists’ decision-making. If, for example, motorists accept the predictions of fuel economy improvements that appear to accompany emission repair, then emission fees do perform somewhat better than the standard policy. If not, they don’t. At low levels of emission reductions, we find that the CAC policy is slightly more cost effective, while at higher levels the advantages of fees are relatively small. As it turns out, the performance of the EI policy is particularly affected by the high level of uncertainty at the earliest stages of the process, before the motorist has obtained any detailed (and costly) information about the costs and expected effectiveness of repair. These results suggest that in this case at least, there might be more to efficient policy than simply “getting the prices right.”

II Background and Data

Maricopa County, Arizona (in which the city of Phoenix is located) has had a biennial centralized enhanced vehicle emission inspection program in place since 1995. Each vehicle registered in the county must be subjected to an Enhanced I/M test at test-only stations every two years. The test consists of a four-minute tailpipe emission test designed by EPA, called the IM240 test, an examination of certain components of the evaporative emission system, and a check to ensure that the vehicle has not been tampered with. But although the Arizona program does require some evaporative

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4 In addition a few other papers have examined the properties of emission fees based on emission test data (Sevigny 1998; EEA 1994).
5 There is no discretion in the CAC simulation model, at least. In actuality, over twenty percent of all vehicles never exit the process with a passing test.
6 We are also in the process of modifying the model to examine the role of risk aversion. Our goal is to have these results in time for the workshop on July 18.
7 Much of the “tampering” violations also appear to involve evaporative emissions. In Arizona, the most common “tampering” repair is the replacement of a damaged or missing gas cap.
emission repair, our analysis focuses entirely on tailpipe emissions. Any motor vehicle with emissions rates of hydrocarbons (HC), carbon monoxide (CO), or oxides of nitrogen (NOx) that exceed a set of emission standards or “cutpoints” must be repaired to meet those standards in order to remain registered.

This paper exploits data on vehicle tests and repairs from the Arizona program for January 1, 1995 through May 1996. We work with a sample of 56,706 of the vehicles that failed the test over this 17-month period. When a vehicle fails, it is required to be repaired and then retested until it passes. Each time it comes back for a retest, the owner must submit a repair summary which shows the types of repairs that were made and the costs of those repairs. Each retest marks a round of repair that has been completed. There are in total 68,404 rounds of repair in our working data set.

Table 1 presents some summary statistics regarding the apparent effects of repair on emission rates and fuel economy. Note that while it is difficult to define a single measure of the “output” of vehicle repair in the form of reduced pollution, such a measure is convenient to have in order to develop a simple, if crude, notion of cost effectiveness. Thus, we create a measure of “pollution” which is a weighted sum of emissions of the three pollutants that are the targets of the program. In grams, “pollution” = HC + .1CO + 2.5NOx. The weights are inspired by estimates of the ratios of marginal benefits that result from reducing the emission rates of the pollutants as calculated by Small and Kazimi (1996) for the Los Angeles region.

The table shows that, on average, repairs do seem to reduce emission rates and improve fuel economy. However, there is great variation in those changes. It is not even uncommon for some emission rates to appear higher after a round of repair, or for recorded fuel economy to worsen.

Table 2 presents similar summary statistics for the data on repair costs. It also illustrates one of the challenging features of the repair-cost data, namely, that many

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8 Evaporative emissions are those that are emitted from other parts of the vehicle besides the tailpipe. Because it is impossible to measure evaporative emissions cheaply, they provide no base for determining the kinds of emission fees we examine.

9 There were initially 135,734 failing vehicles out of a total of 995,904 tested vehicles during the entire 17 month period. We cleaned the data extensively, dropping vehicles that were plagued by any of a number of random data problems. For example, some had bogus license numbers, or multiple “initial tests.” We also dropped failing vehicles which had no retests at all because we had no repair information for them. Finally, for the purposes of the simulations in this paper, we dropped vehicles that had rounds of repair that were not recorded to have any costs or repairs, since it is impossible to tell whether those records represent missing data or merely the presence of car owners that retest their vehicles without having repaired vehicles, in hopes of a more favorable test outcome.

11 The raw emission-rate data reported from the Arizona program are not consistent across tested vehicles. This is because the test protocol allows vehicles to “fast pass” or “fast fail” in less than the full 240 seconds of the test if early readings indicate that they are particularly clean or dirty. To have emission-rate test results that are consistent across vehicles, we forecast full 240 second readings from fast-pass or fast-fail results; for a detailed discussion of the methodology involved, see Ando, McConnell and Harrington (1998).
rounds of repair have costs recorded as zero even though repairs are reported to have been performed. This phenomenon may simply reflect missing data. However, there are other legitimate explanations. Repairs done under warranty may be reported as free, and zero costs may be reported for repairs done at home by do-it-yourself mechanics. Regardless of the explanation for the zero reported costs, we want to know the costs of all repairs performed (regardless of who is performing them and paying the bill) in order to determine the total costs to society of I/M-induced repair. Thus, for some purposes we use the data with non-missing costs to generate an equation that is, in turn, used to impute costs for rounds of repair that report costs to be zero.\footnote{For more information on the methodology, see Ando, Harrington and McConnell 1999.}

Regardless of which set of cost figures is used, average repair costs are reasonably high – in the neighborhood of $100 per round. Furthermore, they vary a great deal from car to car. While some vehicle owners can deal with emission-rate problems with essentially no expenditure, others may spend over a thousand dollars on a single round of repair. This variation interfaces with the heterogeneity in repair effectiveness shown in Table 1 to render the cost-effectiveness of the rounds of repair found in these data highly variable. The reduction in aggregate “pollution” rates a car owner can expect to get for a dollar of repair has a standard deviation (around 0.3) which far outstrips its mean of only 0.05 to 0.06.

These results make it clear that emission reduction from motor vehicles has the potential to be accomplished much more cost-effectively than the current I/M system that requires repair of all vehicles with emissions above the I/M standard. Figure 1 further illustrates this point. The figure shows the relationship between costs and emission reduction from repair. The dark line traces repair cost and emission reduction from vehicles in our sample as they occurred in real time in the Arizona I/M program from January 1996 to May 1997. The lower line shows costs and emission reductions taking the most cost-effectively repaired vehicles first, and then moving up to successively less cost-effective repairs. The backward bending part of that curve shows that some repairs actually increase emissions. The potential for more cost-effective repair is striking - about 99% of the emission reduction of the full I/M program could be obtained at only about 57% of the cost if only those vehicles with the potential for the most cost-effective repair were fixed.

However, it may be difficult for a real incentive policy to succeed in capturing those efficiency improvements. For example, such success is contingent on the ability of owners to predict with at least some accuracy whether or not repairing their own cars is likely to be cost-effective. The exercises conducted here are designed to simulate the decision process followed by motorists deciding how to comply with the I/M program, and evaluate the likelihood that a system of fees would in reality outperform the current command-and-control style framework.

\textbf{III Framework}
We simulate the outcomes of command-and-control (C&C) policies that are almost identical in structure to the actual policy in place in Arizona, with emission-rate cutpoints that vary in stringency. By definition, car owners have little discretion over how they comply with a C&C policy, so there is no real modeling to be done.

The fee policies (economic incentives, or EI) we simulate have the following general structure. We suppose that the motorist is subjected to an emission fee equal to the fee rate times the excess of measured emission rates over the cutpoint, summed over the three pollutants. The motorist may choose to pay this fee, or he may repair the vehicle and retake the test and have the fee calculated on the basis of the new test. This process repeats until the motorist opts to pay the fee, which may or may not have been reduced to zero by repair.

In the context of an EI policy, we model the motorist’s decision-making process roughly according to Figure 2 (the notation is defined in Table 3), though several permutations appear in the paper. The discussion of the model presented here will be conducted under the assumption of risk-neutrality; that assumption will be relaxed in some future runs of the simulations. We allow the motorist to be somewhat forward looking, in that she recognizes at the beginning of the process that a single round of repair may not succeed in reducing the fee she must pay down to zero. However, we constrain the consumer to have limited rationality in this regard. Specifically, we assume that after the first round of repair, the car owner becomes irrationally myopic and limits her consideration to this round. This simplification may be justified by the fact that 93% of all failing cars have 2 or fewer rounds of repair in our data set (78% have only one round). A consumer stuck thinking about the ex ante (rather than conditional) probabilities of the need for further rounds of repair might be inclined not to think about supernumerary rounds.

The motorist begins by taking the mandatory initial test. If she learns that her vehicle has failed the test, she is faced with a choice between investigating a round of repair and simply paying the fee required to register the car with its current emission rates. There are two transaction costs associated with simply going to a mechanic to get the car diagnosed. The mechanic charges a diagnostic fee ($TC_D$) if it is the vehicle’s first round of repair. There is also a cost associated with the unavoidable hassle of driving to the garage and possibly having to leave the car or wait at the garage for some time while the diagnosis takes place ($TC_M$). The motorist incurs both of these costs if she chooses to explore an initial round of repair.

Unfortunately, she must decide whether to pursue a diagnosis on the basis of relatively little information (information set $I_{1A}$); all she knows is the initial test results and some basic information about her car (like how old it is.) She must form an opinion about the expected net cost that is likely to arise if she chooses to repair the car, in order to compare that quantity to the fee ($fee_0$) she may choose to pay instead.

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13 We plan to add a third option – namely, that of getting rid of the vehicle, either through scrappage or sale out of the region. With that addition, the motorist compares the option of repair to the smaller of two costs: the fee and the cost of losing the vehicle.
That total net cost begins with expenses associated with the first round of repair. She will have to pay the diagnostic transaction costs and the actual repair costs ($\text{CR}_1$), although the latter may be mitigated by benefits stemming from repair-induced fuel-economy improvements ($\text{MPG}_1$). After that repair is done, she will have to bear another transaction cost ($\text{TC}_T$) in the form of time lost getting a retest. The motorist expects to respond to the results of that retest by paying the resulting new fee ($\text{fee}_1$), or (if it is cheaper) by performing a second round of repair, getting another retest, and paying the fee associated with those results ($\text{fee}_2$). Given all these considerations, the decision rule that determines the car owner’s course of action is:

Get first-round diagnosis iff:

$$\text{fee}_0 > \text{TC}_M + \text{TC}_D + \text{E}[	ext{CR}_1 | I_{1A}] - \text{E}[	ext{MPG}_1 | I_{1A}] + \text{TC}_T + \min \{ \text{E}[	ext{fee}_1 | I_{1A}], (\text{TC}_M + \text{E}[	ext{CR}_2 | I_{1A}] - \text{E}[	ext{MPG}_2 | I_{1A}] + \text{TC}_T + \text{E}[	ext{fee}_2 | I_{1A}]) \}$$

If the owner decides to get the diagnosis, she obtains more information about the repair she must now decide whether or not to have done. She gets a price quote for the cost of the repair ($\text{CR}_1$). She also learns what parts the mechanic proposes to replace, adjust or fix, and what the mechanic expects the emission rates and fuel economy to be if the repair is done. Given this new and improved information set ($I_{1B}$) the consumer decides whether or not to authorize the repair in a manner similar to her decision regarding the preceding diagnosis:

Perform first-round repair iff:

$$\text{fee}_0 > \text{CR}_1 - \text{E}[	ext{MPG}_1 | I_{1B}] + \text{TC}_T + \min \{ \text{E}[	ext{fee}_1 | I_{1B}], (\text{TC}_M + \text{E}[	ext{CR}_2 | I_{1B}] - \text{E}[	ext{MPG}_2 | I_{1B}] + \text{TC}_T + \text{E}[	ext{fee}_2 | I_{1B}]) \}$$

If the repair turns out to be wholly successful in reducing the fee faced by the motorist ($\text{fee}_1$) to zero, then she “pays” the fee and the process stops. If, however, one or more of the emission rates is still above the cutpoints, then she faces once more the decision of whether to pursue repair. The first part of that decision is still whether to go to the mechanic and get an estimate on the new repairs proposed by the mechanic (though we assume that the mechanic no longer charges for the diagnosis itself.) Because we assume that the motorist now becomes myopic, that decision is made in a more simple minded fashion; she effectively assumes that if she does the repair, she will then pay whatever fee results ($\text{fee}_2$) rather than pursue yet another round of repair. Thus we have:

Get second-round diagnosis iff:

$$\text{fee}_1 > \text{TC}_M + \text{E}[	ext{CR}_2 | I_{2A}] - \text{E}[	ext{MPG}_2 | I_{2A}] + \text{TC}_T + \text{E}[	ext{fee}_2 | I_{2A}]$$

Similarly, once the mechanic has conveyed the new cost quote and described the likely effects of the new repairs, the motorist decides whether or not actually to do the second round of repair according to:
Perform second-round repair iff:

$$\text{fee}_1 > CR_2 - E[\text{MPG}_2 | I_{2B}] + TC_1 + E[\text{fee}_2 | I_{2B}]$$

Decisions (3) and (4) are repeated (with the round-number subscripts incremented appropriately) until the vehicle owner stops the process by paying a fee (which may simply be equal to zero).

**IV Simulation Method**

We simulate the C&C program and various emission fee policies for all the vehicles in the Arizona repair data set described above. Many vehicles have more than one round of repair because in the Arizona I/M program, many failed again after the first repair attempt. Therefore, in the simulation, the unit of analysis is the repair round. The simulation replicates the motorist’s decision at each round, effectively asking the question, “Would this round of repair have been completed if the vehicle had been subjected to alternative policy X?” This means that we cannot analyze any policy that results in more emission reductions for any vehicle than are observed in the actual Enhanced I/M policy in Arizona. Also excluded is the possibility of repair on any vehicle that passes the Arizona test. Both these limitations will tend to reduce the comparative cost-effectiveness of EI policies in the simulations.

There are a number of vehicles which pass the tailpipe tests in the Arizona program, but which still are recorded as failing the I/M test. Without better information, we have had to treat these vehicles as having emissions-related tampering. In both the C&C and EI simulations, we treat these repairs as mandatory. These repairs are constants and are carried along in the reporting of results of both simulations.

There are several points in the emissions testing and control process at which motorists face transactions costs in this model. The first is the expense and time involved in going to a mechanic to get a diagnosis about what is wrong with the vehicle. We assume this cost is about $5 per trip. The diagnostic cost itself is assumed to be one-half of the reported repair cost, or $35, whichever is lower.\(^{14}\) Another transactions cost is the cost of testing or retesting the vehicle to determine the extent of the emissions reductions from repair. This cost we assume to be the cost of an emissions inspection at a centralized station or about $26.75 including motorists time and inconvenience costs and the inspection cost itself.\(^ {15}\)

For each simulation, we track the total motorists costs of repair, the full opportunity cost of repairs including costs imputed to repairs that appear to be home or warranty repairs, fuel efficiency changes resulting from repair, the various measures of

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\(^{14}\) For rounds assumed to have such diagnostic costs, the repair cost used in the simulation is equal to the reported repair cost minus the calculated diagnostic cost.

\(^{15}\) See Harrington, McConnell and Ando (1999) for more detail about these cost estimates.
transactions costs and changes in emissions of all three pollutants resulting from repair, and finally in the case of fees, the total amount of fees paid by motorists.

**C&C Policy Simulation**

The simulation of the C&C policy is straightforward. Repairs proceed through successive rounds until either the vehicle no longer fails the emission test, or the repair rounds observed in the data set are exhausted. The decision rule for a repair round, in other words, is to proceed with an observed round of repair if the vehicle has been tampered with or if the measured emissions exceed the cutpoint, \( S_{ijk} \), for a vehicle of vintage \( i \) and type \( j \), for any pollutant \( k \) (\( k=\text{HC,CO,NOx} \)).

To achieve different levels of emissions control, we just make the cutpoints less stringent and skip vehicles that pass or stop the process as soon as the new cutpoints are reached. To be precise, there are a set of possible cutpoints \( S_{ijk} \), that are less stringent than the actual cutpoints \( \overline{S}_{ijk} \) in use in Arizona (i.e. \( S_{ijk} \geq \overline{S}_{ijk} \)). To simplify the options to be considered, we examine only scalar multiples of the actual cutpoints in place in the Arizona program:

\[
S_{ijk} = h\overline{S}_{ijk}, \quad h > 1.
\]

As \( h \) increases, emission reductions are lower and the associated mpg effects and costs of repair are also lower.

**EI Policy Simulations**

For the EI policy, the decision process is much more complex. For each round of possible repairs, we assume the motorist is informed that he can pay an emission fee equal to the fee rate times the excess of measured emission rates over the cutpoint, summed over the three pollutants. This no-repair fee, \( f_0 \), can be calculated as follows:

\[
f_0 = V(n) \sum_{k=\text{HC,CO,NOx}} \max \left( t_i (Z_{r}^{\text{bef}} - S_{ijk}), 0 \right)
\]

where

- \( t_i \) is the fee rate, per gram-per-mile of emissions of pollutant \( i \), per year;
- \( Z_{r}^{\text{bef}} \) are the emission rates before repair of pollutant \( i \).

\[
V(n) = \sum_{k=0}^{n} (1 + r)^{-k} \quad \text{is the annuity factor for the duration of repairs. We assume } n=1.
\]

The motorist may choose to pay this fee right away, or he may opt to take the vehicle to a repair shop to learn the cost of repair, plus the mechanic’s estimate of the emission reductions for all three pollutants and the estimate of potential improvements in fuel economy. He then decides whether to forgo the repair and pay the fee, or to go ahead with the repair, retake the test and have the fee calculated on the basis of the new
test. For motorists in the first round of repair, the decision about whether to repair the car is also influenced by expectations about the costs of repairs and fees in future potential rounds, as described in Section III above.

There are two important decisions the motorist must make. First, there is the decision about whether to pay the fee immediately or go to a mechanic to obtain more information about the possible costs and effectiveness of repairs. The motorist must make this decision based on very limited information, having no mechanic input at this stage of the process. We assume that motorists have some expectations ex ante about what the costs and effectiveness of repair will be both for the first repair and any subsequent repairs the motorist might decide to make. We determine these expectations by estimating separate regression equations for emission reductions for each pollutant, cost and mpg as a function of information the motorist has about factors that might influence the effectiveness or cost of repair. The explanatory variables include the amount by which each of the three pollutants is above the cutpoint, vehicle model year, and other vehicle characteristics such as number of cylinders and the type of vehicle. For rounds of repair beyond the first one, we also include a set of dummy variables which identify which pollutant or combination of pollutants failed the test in previous rounds. We use these equations to predict the emission changes, costs and fuel efficiency changes the motorists believes will result from each round of repair.\[16\]

Next, if the motorist has decided to go to the mechanic to get the diagnosis he must then decide whether to get the repair, based on the information received. We assume that the mechanic can tell the motorist the costs with certainty, based on the repairs that will be made. But the emissions reductions and fuel economy improvements are estimated by the mechanic. We estimate four equations to be used for predicting repair effectiveness, one for each pollutant -- HC, CO, and NOx -- and one for fuel efficiency.\[17\] We regress these variables on vehicle characteristics, the amount by which each of the three pollutants is above the baseline, and dummy variables on all the parts that were repaired. We use the 56,706 repair rounds as observations. Again, for repair rounds after the first round, we include dummy variables for which combination of pollutants had failed in earlier rounds of repair. We use the estimated coefficients from these equations to predict the mechanic’s assessment of emission changes and fuel economy savings for any possible round of repair.\[18\]

To obtain different possible levels of emissions control under the fee policy we start with an emissions weighting of all three pollutants and vary them by the same scalar. The particular fees on HC, CO, and NOx emission rates are allowed to vary in absolute size, but the magnitudes of CO and NOx fees, relative to HC, are fixed at 0.1 and 2.5,

\[16\] The $R^2$s for these equations vary from .79 for the mpg equation, to .35 for the HC equation, to .33 for CO, .28 for NOx and .07 for costs. The equations for predicting the change in emissions and mpg from more distant repair rounds have slightly lower $R^2$s.\[17\] The $R^2$s for these equations were .39 for the change in HC, .42 for the change in CO, .46 for the change in NOx, and .15 for the change in mpg.\[18\] The $R^2$s for the equations for current round repairs are roughly .8 for mpg, .37 for HC, .37 for CO and .30 for NOx. The equations for predicting the change in emissions and mpg from more distant repair rounds have slightly lower $R^2$s.
respectively. As with the weights used to generate a measure of aggregate “pollution,”
these ratios approximate the ratios of marginal damages calculated by Small and Kazimi
(1996) for the Los Angeles region. These would be the ratios of the optimal fees to one
another if the production of emission reductions were produced independently. 19

We first simulate baseline scenarios for both C&C and EI policies. In both baselines,
we assume that transaction costs exist as outlined above. In the EI baseline, we assume
that motorists’ repair decisions are made on the basis of “private” repair costs (which
exclude the costs of repairs done under warranty or at home) and transaction costs. We
also assume that they neglect the benefits of potential fuel-economy in their decisions,
since there exists some empirical work to support the notion that consumers under-invest
in energy efficiency. 20

Then we run a number of simulations under alternative assumptions. The first such
scenario is that of the “no-hassle” world. This exercise is meant to investigate the impact
of transaction costs on the ability of EI programs to achieve efficiency improvements. In
particular, we run both C&C and EI simulations with the baseline assumptions changed
such that all transaction costs are equal to zero. We aim to see by how much less costly
C&C and fee programs are with transaction costs reduced (and thus, whether policies to
reduce those costs might be worthwhile.) We also look to see whether the comparison
between C&C and EI is altered much by eliminating these sources of friction in the
system.

The second alternative scenario is that of the “savvy motorist.” This EI simulation
differs from the EI baseline in that now we let motorists give full consideration to the
fuel-economy benefits of repair when deciding whether to repair their cars or pay fees.
This scenario is designed to indicate how much better a fee policy would work if
motorists were educated to take fuel economy effects into account.

The third scenario is an EI simulation with “no free lunch.” In other words, while
consumers still make decisions based on the baseline transaction costs and ignoring fuel-
economy benefits, they consider total (rather than private) repair costs when deciding
whether to engage in repair or pay fees. The results can be viewed as an indication of
how much more efficient I/M might be if we could design a policy to align private with
social repair costs (e.g. eliminate warranties). What do we lose in efficiency as a result of
the current structure of incentives?

The final alternative simulation is of an EI policy faced by the “psychic motorist.” Here, we artificially remove all uncertainty, such that the vehicle owners knows exactly
what the costs and results of all possible rounds of repair will be. The motorists still
make decisions according to the same criteria in the baseline, however: private repair
costs, ignored fuel-economy benefits, and hefty transaction costs. While no policy can
actually eliminate all uncertainty, some government actions might improve motorists’

19 However, as shown in Ando, Harrington, and McConnell (1999), emission reductions for a given vehicle
are very much jointly produced. Thus, the true optimal fees are unlikely to hold to that principle.
20 See Jaffe and Stavins (1994).
ability to forecast the outcome of repair; this simulation can place an upper bound on the gains to society of that improvement.

V Results

We begin by evaluating the efficiency improvement EI policy brings to I/M pollution reduction under conditions we consider to be the most realistic. Figure 3 shows total social costs, which include transaction costs, all repair costs, and monetized fuel-economy benefits, as a function of total pollution. With the baseline assumptions about vehicle-owner behavior, the fee policy does not really yield much more efficient outcomes than the current C&C policy. In fact, at low levels of pollution reduction, a given level of cleanup may even yield slightly greater costs under a fee system.

These findings are, at first blush, surprising to economists conditioned to expect incentive policies to dominate rigid command-and-control. Thus, we use the other scenarios to evaluate which features of the baseline assumptions are driving the results. We turn first back to Figure 3 to investigate the role played by transaction costs in the performance of these policies. It certainly is true (indeed, almost tautological) that eliminating those costs from the system lowers the total social costs of reducing air pollution from motor vehicles under both C&C and EI policies. The cost savings are on the order of 25% if one looks at programs roughly as stringent as that currently found in Arizona. It is also true that in the absence of transaction costs, even a fairly low fee rate is enough to induce a relatively large amount of pollution reduction. However, the absence of transaction costs is not enough to improve the performance of EI relative to C&C.

Part of the problem may be that the baseline EI simulation has decision makers ignoring two components of the social costs of repair when deciding upon a compliance strategy: monetized changes in fuel-economy, and repair costs not really paid by the motorist (such as warranted repair.) In Figure 4, we investigate the importance of these features of motorists’ decision-making process (among other things).

We find here that a fee program yields much more cost-effective emission reduction than does C&C if motorists are “savvy” and take fuel-economy improvements into account when deciding whether to repair their vehicles. Social costs can be lowered by as much as 40 percent; this element of the baseline assumptions is clearly a large factor in the failure of EI to improve upon C&C. Other features of this simulation are of interest as well. The presence of some fuel-economy benefits means that even low fee rates induce a fairly large amount of emission abatement. On the flip side, however, some repairs can be expected to make fuel economy worse; this leads to a high marginal cost of emission reductions once the program has gotten fairly stringent.

The “no free lunch” simulation forces car owners to bear the costs of all repairs, including those (warrantied, home repair) that might in reality have no private costs. This

21 Recall that “pollution” is a weighted sum of HC, CO, and NOx emissions.
change does produce EI policy outcomes that have slightly lower total social costs than in the baseline EI scenario. The improvement is miniscule, however, and still does not produce outcomes that are substantially more cost-effective than C&C. This may be because the gap between private and total repair costs is not an issue for all rounds of repair. It is also true that the rounds of repair with zero private costs just happen to be relatively cost-effective even when social costs are accounted for.

The failure of EI to dominate C&C under the baseline assumption may also be a function of the uncertainty under which motorists are forced to decide whether or not to repair their cars. Even with proper incentives, car owners may not have enough information about the likely costs and effects of repairs to succeed in consummating only cost-effective rounds of repair. The final set of results presented in Figure 4 bears this suspicion out. If we allow the decision makers to be “psychic” (i.e. have perfect knowledge about the costs and emission reductions associated with repairs), the total social costs associated with EI policy outcomes can be as much as 35 percent lower than the costs generated by C&C.

Economists tend to focus on efficiency when evaluating public policies, but other aspects of a policy’s performance are of interest as well. Figure 5 compares motorist expenditures associated with the different policy scenarios. Those expenditures include private repair costs, transaction costs, and fees (in the case of EI policy simulation) and are net of monetized fuel-economy improvements. In the baseline scenarios, motorists spend more money in the fee program than C&C. However, it is interesting to note that the gap between the two is small if the policy is either very strict or very weak. These expenditures are roughly in the middle of the field. Not surprisingly, if warranties and free home repairs were to be eliminated as in the “no free lunch” scenario, motorist expenditures are very high. At the other end of the spectrum, if vehicle owners were to be “savvy” and factor fuel-economy improvements into their decisions, they could accomplish emission reductions with relatively low net expenditures by exploiting opportunities for such improvements. Finally, “psychic” consumers with perfect knowledge of the outcomes of repair rounds end up with extremely high expenditure levels as the simulations push emission reductions up to the maximum observed in the data.

This latter pattern is easily understood by looking at Figure 6. The psychic consumers know about the rounds of repair that turn out to be expensive disasters, and are willing to pay extremely large fees to avoid them. Hence, revenue grows enormously in that scenario as the simulation approaches the point where the only way to accomplish more pollution reduction is to do those incredibly cost-ineffective rounds of repair.

In the other simulations, in contrast, total revenue tends to rise and then fall with overall program stringency. At very low fee levels, many motorists pay the fee but revenue is low because the rate is so small. As fee rates grow, revenue per car may rise, but more car owners repair their cars rather than pay the government for the privilege of driving a dirty car. Eventually, very high fees induce almost everyone to bite some proverbial bullets and repair their cars. In the absence of warranties (“no free lunch”)
revenue is relatively large because high fees are needed to induce car owners to actually reduce their vehicles’ emission rates. Conversely, “savvy” owners aware of fuel economy benefits need little inducement to accomplish a fairly large amount of initial pollution reduction; revenue there only catches up to that in the other scenarios once the rounds of repair that yield fuel-economy benefits are largely exhausted.

VI Conclusions

Basic environmental economics tells us that command and control policies, such as the enhanced I/M programs supported by EPA, are often inefficient. Indeed, on the surface it appears that there is some tantalizing evidence that air-pollution reduction from mobile sources can, in theory, be accomplished in a more cost-effective fashion. However, the simulations presented here reveal that there are some complications in the real world that may prevent an economic incentive policy such as an emissions fee to deliver substantial cost saving over current vehicle emissions programs.

We find that, given a set of realistic “baseline” assumptions about consumer information and behavior, the emission fee policy considered here did not result in much more cost-effective repair than the current I/M policy which requires all repairs to be done. This is primarily because of motorist uncertainty about the effectiveness of repairs. In order to be able to make the right decisions about which repairs to do, motorists need to have a good idea about how much repair will cost, and how much emissions will be reduced. The equations we generate, based on information motorists and mechanics are likely to have available, have only moderate predictive ability. Particularly for motorists trying to decide whether to take their vehicle to a mechanic, there is a great deal of uncertainty about how easy and effectively emissions can be reduced.

We also find that if individual motorists’ incentives do not incorporate all elements of repair that affect social welfare, emission fees will likely fail to outperform C&C. Motorists are unlikely to be aware of and therefore to consider fuel economy benefits when they are deciding whether to get a vehicle repaired. This makes them miss out on some very cost-effective repairs under the fee policy. Also, private motorists will also only consider repair costs they pay out of pocket. Hence, vehicles still under warranty, for which the costs to the motorist are effectively zero, will be repaired regardless of cost-effectiveness. The implication of this finding is that fees are likely to be more effective under a policy that places property rights for clean cars either in the hands of the motorists with no warranty provision, or entirely in the hands of the vehicle manufacturers. In either case, full costs will be considered by the parties making the decision to repair.

Not surprisingly, the simulations show that if transactions costs can be reduced, through the use of on-board diagnostics or remote sensing, for example, then both C&C and EI policies are rendered more cost-effective. There is no evidence, however, that a

22 We expect risk aversion also to push revenues (and consequently motorist expenditures) up, since higher fees are likely to be needed to induce risk-averse car owners to purchase repair with uncertain outcomes rather than pay fees of certain magnitudes.
reduction in transaction costs strengthens the case for using fees instead of C&C. Transaction costs might discourage consumers from acquiring as much information as they can about the likely cost-effectiveness of a repair before deciding whether to just pay the fee, but that dynamic does not seem to be an important factor in the failure of EI to yield more efficient program outcomes than C&C.

It is important to point out that the results presented here give only a partial picture of the response to vehicle emissions fees. First the analysis was constrained to only consider rounds of repair that had been done in the Arizona I/M program. In response to emissions fees, different and perhaps more effective repairs might have been performed. There would even be incentives to reduce emissions to very low levels under a pure fee with no zero-payment baseline. In addition, we were not able with this data set to consider the impact of fees or the C&C policy on vehicle scrappage rates. For example, under emission fees, if the fees and the repair costs are both high enough, getting rid of an old car may provide an important opportunity for emissions reduction.

One other caveat to our results that fees may not be much of an improvement over C&C is that we have not accounted for some of the underlying incentives for information collection with the two policies. Fees may have better potential to improve cost-effectiveness because they may induce better information collection, and then better diagnosis and repair in the future. Under C&C, when vehicles have to be repaired, there is not as much incentive to predict the effectiveness of repairs, or to find the most cost-effective methods of repair. In addition, we have certainly not exhausted the possible types of economic incentives; we have only examined one type of emission fee. More radical departures from the current policy may yield more exciting results, or they may not. (See Harrington and McConnell, 1999 for a discussion of some possible alternatives.)

Finally, the simulations ignore the possibility of companion policies that might improve the performance of the economic incentive policies in this context. An example of a companion policy would be an information campaign to raise motorist awareness of the potential fuel-economy benefits of vehicle repair. Nonetheless, our results make clear that the imperfections of reality may well prevent a theoretically cost-effective economic-incentives program from performing any better than the current inflexible policy regime.
References


Fullerton, Don and Sarah West. 1999. “Tax and Subsidy Combinations for the Control of Car Pollution.” Working paper, University of Texas, Austin, TX.


Table 1: Emission Rate Reductions and Fuel Economy Improvements\textsuperscript{a}

<table>
<thead>
<tr>
<th>Test Result Change</th>
<th>Mean</th>
<th>Stand. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \text{HC (g/m)})</td>
<td>.67</td>
<td>1.55</td>
<td>-10.31</td>
<td>13.25</td>
</tr>
<tr>
<td>(\Delta \text{CO (g/m)})</td>
<td>10.19</td>
<td>31.23</td>
<td>-259.30</td>
<td>327.27</td>
</tr>
<tr>
<td>(\Delta \text{NOx (g/m)})</td>
<td>.80</td>
<td>1.80</td>
<td>-12.58</td>
<td>13.80</td>
</tr>
<tr>
<td>(\Delta \text{Pollution}^b (g/m))</td>
<td>3.69</td>
<td>5.11</td>
<td>-27.67</td>
<td>51.15</td>
</tr>
<tr>
<td>-(\Delta \text{MPG})</td>
<td>.65</td>
<td>2.59</td>
<td>-21.86</td>
<td>24.70</td>
</tr>
</tbody>
</table>

\textsuperscript{a} There are 68,404 rounds of repair summarized.

\textsuperscript{b} “Pollution” is \(\text{HC} + .1\text{CO} + 2.5\text{NOx}\).

Table 2: Cost and Cost-Effectiveness of Rounds of Repairs

<table>
<thead>
<tr>
<th>Cost Statistic</th>
<th>#Observations</th>
<th>Mean</th>
<th>Stand. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported cost\textsuperscript{a} ($ in 1995-6)</td>
<td>68,404</td>
<td>80.01</td>
<td>135.35</td>
<td>0.00</td>
<td>1400.00</td>
</tr>
<tr>
<td>Total cost\textsuperscript{b} ($ in 1995-6)</td>
<td>68,404</td>
<td>128.19</td>
<td>126.02</td>
<td>0.00</td>
<td>1400.00</td>
</tr>
<tr>
<td>(\Delta \text{Pollution}^c (g/m) / \text{reported cost})</td>
<td>39,800\textsuperscript{d}</td>
<td>.06</td>
<td>.33</td>
<td>-14.72</td>
<td>16.15</td>
</tr>
<tr>
<td>(\Delta \text{Pollution}^c (g/m) / \text{total cost})</td>
<td>68,377\textsuperscript{d}</td>
<td>.05</td>
<td>.27</td>
<td>-14.72</td>
<td>16.15</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Reported cost is the raw repair cost data, which includes many zeros.

\textsuperscript{b} Total cost includes potentially non-zero imputed values for costs reported as zero.

\textsuperscript{c} “Pollution” is \(\text{HC} + .1\text{CO} + 2.5\text{NOx}\).

\textsuperscript{d} These statistics are not defined for observations that have costs equal to zero.
### Table 3: Model Notation

<table>
<thead>
<tr>
<th>Notation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_n$</td>
<td>Information set at a given point in time</td>
</tr>
<tr>
<td>Res$_n$</td>
<td>Results of the $n$th IM240 test: fuel economy, emission rates, corresponding fee</td>
</tr>
<tr>
<td>$TC_D$</td>
<td>Transaction cost associated with getting diagnosis from mechanic: diagnosis fee</td>
</tr>
<tr>
<td>$TC_M$</td>
<td>Transaction cost associated with getting diagnosis from mechanic: hassle involved in travel, leaving car, etc.</td>
</tr>
<tr>
<td>CR$_n$</td>
<td>Cost of repairs for round $n$</td>
</tr>
<tr>
<td>PER$_n$</td>
<td>Emission reductions predicted by the mechanic during diagnosis</td>
</tr>
<tr>
<td>ER$_n$</td>
<td>Emission reductions actually yielded by repair</td>
</tr>
<tr>
<td>PMPG$_n$</td>
<td>Monetized benefits of repair-induced fuel-economy improvement predicted by the mechanic during diagnosis</td>
</tr>
<tr>
<td>MPG$_n$</td>
<td>Monetized benefits of repair-induced fuel-economy improvement actually yielded by repair</td>
</tr>
<tr>
<td>$TC_T$</td>
<td>Transaction cost associated with getting another IM240 test</td>
</tr>
</tbody>
</table>
Figure 1: Costs of Emission Reduction Depending on Choice of Rounds of Repair

- Chronologically chosen
- Cost-effectively chosen

Cumulative costs of repair rounds ($)

Cumulative tons of emissions reduced
Figure 2: Decision Tree

$I_{1A} = \{ \text{car features, } R_{e0} \}$

1A: Go to mechanic for round 1 diagnosis?

No: Pay fee$e_0$  Yes: Pay $T_C + T_D$

$I_{1B} = \{ \text{car features, } R_{e0}, CR_1, PER_1, PMPG_1 \}$

1B: Actually do round 1 repairs, retest car?

No: Pay fee$e_0$  Yes: Pay $CR_1 - MPG_1 + T_C$

$I_{2A} = \{ \text{car features, } R_{e0}, CR_1, MPG_1, R_{e1} \}$

2A: Go to mechanic for round 2 diagnosis?

No: Pay fee$e_1$  Yes: Pay $T_C$

$I_{2B} = \{ \text{car features, } R_{e0}, CR_1, MPG_1, R_{e1}, CR_2, PER_2, PMPG_2 \}$

2B: Actually do round 2 repairs, retest car?

N: Pay fee$e_1$  Y: Pay $CR_2 - MPG_2 + T_C$

$I_{3A} = \{ \text{car features, } R_{e0}, CR_1, MPG_1, R_{e1}, CR_2, MPG_2, R_{e2} \}$