Chapter 5

Alternative Market-based Incentives

We concluded chapter 4 by saying that traditional market-based incentives such as a Pigovian tax are generally more efficient than command and control policies but require the measurement of emissions. In the case of vehicle emissions, such traditional incentives are therefore still unavailable to policy makers. So, we explore alternative market-based incentives that can be used to mimic the effects of an ideal, but unavailable, tax on vehicle emissions. The goal of the emissions tax is to raise the price of pollution and to affect behavior in a variety of ways. To be as efficient, alternative instruments must also induce consumers' responses that are identical to those responses induced by the emissions tax. But to avoid the problems involved in measuring vehicle emissions, these instruments can apply to activities that are market transactions.

If a true Pigovian tax on vehicle emissions were available, it would reduce pollution by inducing households to drive fewer miles, to buy fuel-efficient cars, to install and maintain pollution control equipment, to purchase cleaner fuel, to perform general maintenance, to avoid cold start-ups, and perhaps to drive less aggressively.[1] Households would choose between paying more in emissions taxes or taking steps to reduce pollution. We presume that these households would take these pollution-reducing steps if the costs of doing so were lower than what they would pay in emissions tax. Households with lower abatement costs would reduce pollution by more than households with higher abatement costs. For example, drivers that live

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[1] Because of cold start-up emissions, Burmich (1989) finds that a 5-mile trip has almost three times the emissions per mile as a 20-mile trip at the same speed. Sierra Research (1994) finds that a car driven aggressively has a carbon monoxide emissions rate that is almost 20 times higher than when driven normally.

close to gas stations with cleaner fuel might buy this fuel and abate more than those who live far from these stations. And, households with vehicles that are very dirty simply because pollution control equipment is not connected would make this inexpensive repair, while households that could only reduce emissions by making more costly repairs might elect instead to pay taxes on the extra emissions.

Any efficient alternative policy would need to induce this same set of behaviors. We focus on policies that apply to those behaviors that are associated with measurable market transactions. To determine the specific form of these alternative policies, in Fullerton and West (1999), we derive a mathematical model of each different household's choice of miles, vehicle attributes, pollution control equipment *(PCE)*, fuel cleanliness, and other goods and services. We use the model to solve explicitly for the optimal tax on emissions, and to examine precisely how consumers would respond to such a tax. And, we use the model to solve for and investigate combinations of policies that would, like an emissions tax, influence people to drive fewer miles and to buy smaller cars, newer cars, better pollution-control equipment, and cleaner fuel.

In this chapter, we present a non-technical description of our model and results from that more-rigorous derivation. We provide a theoretical framework for household choice, compare these choices with the socially optimal choices, and provide intuition for why and how our alternative market-based incentives can mimic an ideal emissions tax.

Other researchers explore market incentives that could be used in place of the emissions tax.[2] Because vehicle emissions cannot be monitored at the source, Eskeland and Jimenez (1992) analyze indirect instruments relating to cars and fuels. Eskeland (1994) expands this

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[2] Plaut (1998) compares instruments one at a time. Kohn (1996) shows that any combination of a tax on emissions and subsidy to abatement are equivalent. For any such combination to be administered, however, emissions must be measurable. Train, et al. (1997) analyze "feebates," in which rebates are provided to vehicles with higher-than-

analysis and builds a simple model with identical consumers. These papers explore optimal combinations of mandates and taxes that can mimic the unavailable emissions fee, with identical consumers. Eskeland and Devarajan (1996) proceed to discuss the problem when consumers are not identical, and they show how combinations of policies can be used to approach the effect of a Pigovian tax.

Harrington, et al. (1998) consider the cost-effectiveness of a mandated vehicle inspection and maintenance (I/M) program compared to an incentive program. The incentive is a fee that is based on the vehicle's emission *rate*, assuming miles are not observable. Thus, motorists can reduce their fee by repairing their vehicle, but not by driving less. Sevigny (1998) incorporates the choice of miles with an emissions tax, but this tax requires knowledge of each vehicle's average emissions per mile and the accurate measurement of miles traveled.[3] Innes (1996) also analyzes combinations of feasible policy instruments when consumers differ. Our model clarifies Innes' results, and expands the model to allow consumers to differ in three ways rather than two.

Using our model, we examine five kinds of policies. First, we solve for the ideal Pigovian tax on emissions. Second, we find that the emissions tax can be replicated by a complicated tax on gasoline. However, this ideal outcome requires that the gasoline tax depend on vehicle characteristics. Third, if vehicle characteristics cannot be measured at the pump, the efficient outcome could instead be attained by a vehicle tax that depends on miles driven.

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average fuel efficiency and fees are levied on less efficient vehicles. These feebates are feasible incentives because fuel efficiency can be measured, but they are not perfectly efficient because they do not depend on miles driven.

[3] All of these schemes are imperfect. Emissions per mile *(EPM)* cannot be measured perfectly, because it depends on how the car is driven. Miles cannot be measured perfectly, because drivers can roll back the odometer. Harrington et al (1994) discuss remote sensing at a selection of locations as a good approximation, but some drivers may disproportionately miss or intentionally avoid those locations. Our schemes are not perfect either, as they miss some behaviors mentioned above (cold start-ups, aggressive driving).

Fourth, if policymakers cannot assess individual-specific rates, they could implement uniform rates on gasoline and on vehicle characteristics calculated using the population averages of miles and vehicle characteristics. Such rates would not fully account for the technological relationships between vehicle characteristics and emissions per mile and fuel efficiency, nor would they fully account for the possible correlation in consumers' tastes for miles and vehicle characteristics. These rates, therefore, may reduce emissions by too little or by too much. Fifth, policymakers could explore these technological relationships and correlation among tastes, and impose uniform taxes that more fully account for these relationships. This method, while still imperfect, would enable policymakers to more closely approximate the effects of an ideal emissions tax.

Section I presents the household choice framework. Section II contrasts household choices with socially optimal choices. Section III discusses the five alternative market-based incentives and Section IV concludes.

I. The Household Choice Framework

In this section, we use a theoretical framework to provide the intuition behind our mathematical model of household choice. In the spirit of Baumol and Oates (1988), we assume perfect information, perfect competition, and no market failures other than a negative externality from emissions.[4] Each household owns one vehicle, and each vehicle is made up of characteristics that affect emissions such as engine size, vehicle vintage, fuel efficiency, and

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[4] We ignore existing mandates in the theoretical framework below, but we recognize that these mandates affect the estimated ways in which actual emissions per mile depend on engine size and other car characteristics. Thus, incentive policies may work because they encourage purchase of regulated cars.

PCE, and characteristics that do not affect emissions (such as leather seats or a sunroof). Households buy gasoline in order to drive miles, and they choose among grades of fuel-cleanliness. They also buy other goods. Figure 5.1 provides a schematic diagram of household choice.

We measure engine size as cubic inches of displacement (CID). We use “newness”, the counterpart of vehicle age, to describe the household’s choice of vintage. Pollution-control equipment *(PCE)* includes catalytic converters and other emissions-reducing equipment directly installed on a vehicle. In general, consumers also choose the condition as well as the amount of *PCE*. Fuel cleanliness is an attribute of gasoline such as volatility or oxygenation.[5] We assume that cleaner fuel is more expensive. Households enjoy driving and consuming other goods, and they are negatively affected by total auto emissions.

Cars with larger engines have greater emissions per mile *(EPM)*, and cars that are newer have more or better pollution control equipment and have lower *EPM*. Obviously, households that buy cleaner fuel will also generate lower *EPM*. Each household’s emissions can be calculated by multiplying their *EPM* by the number of miles they drive. Then total emissions is calculated by adding together all of the households’ emissions. Each car’s fuel efficiency is measured in miles per gallon *(MPG)* and depends on vehicle newness, engine size, and the quantity of the clean-car good *(PCE)* on the vehicle.[6] Cars with larger engines get lower gas

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[5] More volatile gasoline leads to more evaporative emissions. The addition of oxygenates to gasoline alters the stoichiometric air/fuel ratio. Provided the carburetor setting is unchanged, this alteration may reduce emissions of carbon monoxide (CO) and hydrocarbons (HC), but can also increase emissions of oxides of nitrogen (NO_x). And, if the mixture becomes too lean (high air/fuel), HC emissions can increase due to misfiring (OECD, 1995).

[6] Fuel efficiency may also be affected by the clean-fuel characteristic. Oxygenated fuel contains methyl tertiary butyl ether (MTBE) or ethanol, each of which have lower energy content per gallon than conventional gasoline. For simplicity, we do not incorporate the clean-fuel characteristic into the calculation of *MPG* .

mileage, while newer cars get higher gas mileage. The addition of a clean-car characteristic such as a catalytic converter adds weight to a vehicle, and diminishes fuel efficiency.[7]

Consumers do not purchase miles directly, but through the combination they choose of gasoline, vehicle newness, engine size, and the clean-car characteristic *(c).* To determine each household's demand for gasoline, we divide their desired miles by *MPG*. Since fuel efficiency depends on vehicle characteristics, so does demand for gasoline and miles.

While we allow tastes for miles and vehicle characteristics to differ among households, in order to analyze different choices and abatement costs, we are not concerned with differential benefits from environmental protection. We therefore assume that households experience the same detrimental effects of aggregate pollution.

II. Household Choices versus Socially-Optimal Choices

To decide how much of each good to purchase, each household weighs the benefits they receive from consuming an additional unit of each good with the costs of that consumption. Our mathematical formulas assume that consumers "maximize utility," which just means that each keeps buying more of a good until the marginal *private* benefits fall to the level of private marginal cost—the price for one more unit. They take into account any tax or subsidy on each good, but households do not recognize that their own choices affect total emissions. For example, when deciding whether to drive another mile, a household only takes into consideration the private costs of doing so: the cost of gasoline, wear on tires, and other per-mile costs. Its decision does not depend on environmental costs of driving the extra mile.

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[7] According to Dunleep (1992), the addition of one cylinder decreases fuel efficiency by 3 percent. Also, the equipment mandated in U.S. tier 1 emissions regulations lowers fuel efficiency by 1 percent.

So, as we graphed the costs and benefits of pollution in Figure 4-1, we can graph the costs and benefits of buying a market commodity. We use one diagram for consumption of a "dirty" good (one that increases pollution, such as gasoline or engine size), and a different diagram for consumption of a "clean good" (one that reduces pollution such as cleaner fuel, *PCE*, or other clean car characteristics).

Figure 5-2 shows a household's choice of a dirty good such as gasoline or engine size. The horizontal axis represents the amount of either gasoline or engine size consumed (X), and the vertical axis represents a price or cost (in dollars per unit of that good). The private cost of the good, P^o, represents the price per gallon of gasoline or the price per cubic inch of displacement. We assume that these prices are constant, and so households again face a flat private marginal cost (PMC). The demand for gasoline or engine size ("marginal benefits") starts out high, as some minimal amount of each is necessary for driving. Each additional unit of the good is less important than the previous good, and so the marginal benefits curve slopes downward. In the absence of any taxes on gasoline (or engine size), the household would face price P^o consume X^o units of gasoline (engine size). Each different household would be represented by a different version of the graph in Figure 5-2, however, since some households drive more miles, or purchase more gasoline, or have larger vehicles than others.

To determine the "optimal" choices, we introduce the concept of an informed and benevolent policymaker. This decisionmaker *does* recognize that individual amounts of gasoline and engine size affect aggregate emissions. We assume that this policymaker chooses the amount of each dirty good for each household to maximize utility, but we assume that this takes into account the additional environmental damage caused by an increase of one gallon of gasoline or one cubic inch of displacement. That is, the decisionmaker perceives the social marginal cost of the good, which includes the private marginal cost plus the value of the environmental damage per unit of the good. In Figure 5-2, social marginal cost is labeled SMC. The net gain to society of gasoline and engine size is maximized by consuming these goods as long as the social benefits exceed the social costs. The intersection of marginal benefits and social marginal costs indicates the optimal amount of the dirty good, X'.

The next problem for policymakers, then, is how to cut consumption of the dirty goods from X^o to X'. Since each household has different marginal benefits, even for the same marginal costs, the optimal reduction of each dirty good would be different for each household. For those households that particularly enjoy driving, the marginal benefits of gasoline or larger cars would be higher, and so their socially-optimal abatement would be lower than that of other households.

Figure 5-3 shows the household's choice of a clean good, that is, a good that reduces pollution when consumed. In our model, these goods are newness, a clean fuel characteristic, and *PCE*. Consumption of each of these goods results in environmental benefits. When households decide whether to buy a newer car rather than an older one, they weigh their own private costs of buying one versus the other, but they do not consider the benefits of pollution reduction that would result from buying the newer vehicle. The social marginal benefits (SMB) of such a good in Figure 5-3 includes both the private marginal benefit (PMB) plus the environmental benefits per unit of the good. In the absence of any subsidy on newness (or clean fuel characteristic or *PCE*) the household consumes Y^o. The net gain to society of this clean good is maximized by consuming it as long as the social benefits exceed the social costs. The intersection of social marginal benefit and marginal cost indicates the optimal amount of the clean good, Y'. The problem for policymakers in this case is to *increase* consumption of the clean goods from Y^o to Y'. A subsidy can decrease the private marginal cost of the good to P'.

Then, when the household follows PMB down to P', it chooses the optimal quantity. Since each household has different marginal benefit and different marginal cost, each will have a different optimal increase in consumption of each clean good.

Households also weigh the costs and benefits of consuming other goods. For each good that neither increases nor decreases pollution, the private marginal cost is the social marginal cost and the private marginal benefit is the social marginal benefit. Policymakers need not act directly to change consumption of these other goods. However, when households respond to policies that induce them to consume more or less of emissions-related goods, they may substitute toward or away from consumption of other goods.

III. Solutions

The goal of this research is to find a combination of taxes on dirty goods and subsidies to clean goods so as to replicate the effects of the ideal-but-unavailable tax on emissions. The problem is that vehicle emissions cannot be measured accurately, in order to apply that tax. We seek to induce the same behaviors, however, with the right tax rates on gasoline and engine size, plus subsidies to newness and pollution control equipment. We use our mathematical model to determine the forms of these tax rates.

Using our model, we examine five kinds of policies. Implementation of each policy requires different information. Table 5-1 summarizes these policies.

Table 5-1: Five Alternative Policies for the Control of Vehicle Emissions

Policy Set	**Effect**	**Efficiency**	**Information Requirements**
Policy 1: Pigovian Emissions Tax	Reduce gasoline, miles, and engine size; Increase newness, *PCE*, *MPG* and fuel cleanliness	Most efficient	Constant measurement of emissions during driving
Policy 2: Complicated Gas Tax		Most efficient: Identical to emissions tax	
Gas tax differing by vehicle at the pump	Reduce gasoline, miles, and engine size; Increase newness, *PCE*, *MPG* and fuel cleanliness.		Identification of vehicle type at gas pump
Policy 3: Miles-specific Vehicle Tax			
Vehicle tax that depends on miles and on vehicle characteristics	Reduce gasoline, miles, and engine size; Increase newness, *PCE*, *MPG* and fuel cleanliness.	Most efficient: Identical to emissions tax	Measurement of miles driven: Odometer readings or accurate estimate of lifetime miles
Policy 4: Uniform Rates Based on Averages (ignore PCE and clean-fuel characteristics):		Least efficient: Do not fully account for technological relationships and correlation among tastes	
Gas tax using average vintage and engine size	Reduce gasoline and miles; Increase *MPG*		Average vintage and average engine size
Newness subsidy using average miles	Increase newness and *MPG*		Average miles
Engine size tax using average miles	Decrease engine size, increase *MPG*		Average miles
Policy 5: Alternative Uniform Rates (ignore PCE and clean-fuel characteristics):		Less efficient: More fully accounts for technological relationships and correlation among tastes	
Gas tax	Reduce gasoline and miles; Increase *MPG*		Information about the distribution of vintage, engine size, and miles over the population
Newness subsidy	Increase newness and *MPG*		
Engine size tax	Decrease engine size, increase *MPG*		

First, we use our model to solve for the ideal Pigovian tax on emissions (Policy 1). To assess this tax, policymakers would need to be able to measure tailpipe emissions. Second, if emissions cannot be measured, we find that the emissions tax can be replicated by a complicated tax on gasoline (Policy 2). However, this ideal outcome requires that the gasoline tax depend on vehicle attributes. Third, if vehicle characteristics cannot be measured at the pump, a vehicle tax that depends on miles driven can also attain the ideal outcome (Policy 3). Fourth, if policymakers cannot assess individual-specific rates, they could implement uniform rates calculated using the population averages of miles and vehicle characteristics (Policy 4). Such rates would not fully account for the technological relationships between vehicle characteristics and emissions per mile and fuel efficiency, nor would they fully account for the possible correlation in consumers' tastes for miles and vehicle characteristics. Fifth, policymakers could explore these technological relationships and correlation among tastes, and impose uniform taxes that more fully account for these relationships (Policy 5). This method, while still imperfect, would enable policymakers to more closely approximate the effects of an ideal emissions tax.

Because consumers differ, the decisionmaker cannot seek the best outcome by considering the choices made by one household. No one household is perfectly representative of the rest. Instead, the decisionmaker must maximize a weighted sum of household utilities, and therefore must give each household a certain weight in this sum. To simplify this problem, we specify household weights that meet two criteria. First, in order to focus on efficiency rather than on distributional considerations, initially, we choose weights so that a dollar given to any household has the same effect on social welfare. Second, in the counterfactual case where an emissions tax *is* available, we want the maximization of our social welfare sum to yield the Pigovian emissions tax. These two considerations determine the weights, but we then use that same set of weights when the ideal emissions tax is *not* available. In this way, we ensure that the effects of our policies are directly comparable with the effects of an ideal emissions tax.

A. First-best Policies

1. Policy 1: A Pigovian Tax

A tax on emissions provides the basic efficient policy against which alternatives can be compared. Given the weights we have chosen, our model with heterogeneous consumers generates a result that matches the result of a simple representative-household model. In particular, a uniform Pigovian tax that is equal to the marginal environmental damages per unit of emissions at the same rate for all households, will induce all households to make all the optimal choices about miles, car size and vintage, fuel, and pollution control equipment. In response to the one tax rate on emissions, each household chooses the extent to which it will reduce consumption of gasoline or engine size (from X^o to X' in Figure 5-2). In addition, each would choose the optimal extent to which it will increase consumption of vehicle newness, the clean fuel characteristic, and PCE (from Y^o to Y' in Figure 5-3).

2. Policy 2: A Complicated Gas Tax

In the case where the measurement of emissions were difficult or impossible, so that an emissions tax could not be implemented, we then find a different policy that attains the exact same efficient outcome. This policy is a tax schedule for gasoline that depends on characteristics of the gasoline *and* on characteristics of the car at the pump. This tax is equal to the damage per unit emission *(MED)* times emissions per mile *(EPM)* times miles per gallon *(MPG)*. Emissions per mile and miles per gallon both depend on vehicle characteristics, and so therefore does this gas tax.

Since the gas tax depends on vehicle characteristics, are separate taxes on newness, engine size, and *PCE* necessary? Under some assumptions, these additional policies may not be necessary (Innes, 1996). Assuming individuals know that their individualized gas tax rate will depend on their own choices of newness, engine size, and *PCE*, then that gas tax alone can induce the optimal size, vintage, and pollution-control equipment. To influence drivers to reduce gasoline or engine size consumption from X^o to X', the gas tax effectively raises the private cost of these goods from P^o to P'. And, when consumers see that their gas tax rate depends on the type of car they drive, they increase their purchase of newness, the clean fuel characteristic, and *PCE*: the gas tax effectively lowers the private cost of these goods from P^o to P'.

3. Policy 3: A Miles-Specific Vehicle Tax

The gas tax in Policy 2 is very complicated. It seems reasonable for a gas tax to depend on the characteristics of the fuel. But in order for the efficient outcome to be attained using just the complicated gas tax, it must depend on vehicle characteristics. Individual-specific gas taxes would be costly to administer:

> For example, a tamper-resistant computer code would likely be required on each automobile; similarly, gasoline pumps would have to be equipped to automatically tack the appropriate tax onto any gasoline that is dispensed to a particular automobile. Moreover, since a simple siphoning of gas will permit consumers to bypass taxes on high-emission vehicles, the scope for abuse, particularly among those high-emitting

> consumers who are arguably the most important targets of the tax, would be tremendous. (Innes, 1996: p. 226).

As it turns out, a different combination works just as well as the complicated gas tax. To induce drivers to buy newer, smaller cars with more *PCE*, policymakers can use a tax on vehicles that depends on miles driven. To implement this tax, policymakers would calculate each vehicle's emissions per mile by using the *EPM* function, which relates emissions per mile to engine size, vehicle vintage, fuel cleanliness, and pollution control equipment *(PCE).* Then, to determine the household's total emissions, policymakers could multiply the vehicle's *EPM* by the number of miles driven in the car. The vehicle tax rate would be higher for vehicles with larger engines, and lower for cars that are newer or that have more *PCE.* When consumers see that their vehicle tax rate depends on the number of miles they drive, they decrease their purchases of gasoline. Because the vehicle tax effectively raises the private cost of engine size from P^o to P', it would induce drivers to reduce consumption of this good from X^o to X'. And because the vehicle tax would effectively lower the private cost of newness and *PCE* from P^o to P', drivers would increase consumption of these goods from Y^o to Y'.

Implementing the miles-specific vehicle taxes would also be difficult or costly. If the vehicle tax were assessed when the vehicle is purchased, then some measure of the total expected miles for the life of the vehicle would be necessary. Since conditions change, however, the one-time vehicle tax would not provide the right subsequent incentives (e.g. choice of mileage, choice of *PCE* maintenance or purchase, and choice of retirement date). If the vehicle tax were assessed annually, then annual odometer readings could be helpful. However, this would provide incentive for individuals to roll back their odometers to reduce their vehicle tax.[8]

4. Additional Implications for Policy 2 and Policy 3

Both the complicated gas tax (Policy 2) and the miles-specific vehicle tax (Policy 3) induce households to make optimal choices, given that they consume positive amounts of each good. A more complete analysis is required to deal with situations in which households do not wish to consume any of the clean fuel characteristic or any *PCE*. If households dislike pollution control equipment enough, then the subsidy to *PCE* within the complicated gas tax or within the vehicle tax may not induce them to buy any of it. In this case, the subsidy to *PCE* can only induce consumers to buy any pollution equipment if it is equal to the *entire private cost of PCE*, including both the direct cost of equipment and the extra gasoline costs incurred due to the negative effect that *PCE* has on fuel efficiency. With a 100 percent subsidy, however, the choice of *PCE* is indeterminate. That is, with the subsidy, consumers may buy less, more, or exactly the socially optimal amount of *PCE*. Thus, if people do not care for *PCE*, but also are not hurt by *PCE*, then incentives do not work. The optimal *PCE* can only be achieved by a mandate (as in Innes, 1996).

The same analysis applies to the clean-fuel characteristic. For households to choose cleaner gas, the subsidy must equal the entire cost of the attribute.

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[8] "Even if only a small proportion of consumers cheat in this way, those who cheat are likely to be those who drive the most, who therefore have the greatest incentive to cheat and who are arguably the most important targets of mileage taxation" (Innes, 1996: p. 226-227).

We think that people are unlikely to feel exactly neutral about clean cars and clean fuel. People may like using the latest technologies, or feel peer pressure to do so. On the other hand, *PCE* may negatively affect performance by increasing vehicle weight and decreasing acceleration. In addition, if cleaner fuel can be found only in a limited number of locations, the inconvenience costs of refueling could be high. A high enough subsidy could then induce households to purchase the optimal amount of clean fuel and clean car characteristics.

The optimality of these results also depends on our assumptions about the available abatement technologies. Since emissions depend on newness, engine size, clean fuel, and *PCE*, both the complicated gas tax and the miles-specific vehicle tax attain the same efficient equilibrium as that reached by the Pigovian tax. Despite the fact that emissions are never measured, both policies can attain 100 percent of the improvement in social welfare achieved by the Pigovian tax. If technologies that we do not consider here also increase or reduce emissions, then those technologies would need to be taxed or subsidized in order to achieve the greatest possible welfare gains.

B. Second-best Policies: Uniform Tax Rates

If the gas tax cannot be made to depend on vehicle type, or a vehicle tax cannot be made to depend on miles-driven, then separate taxes on size and gasoline and a separate subsidy to newness become important.

In the next sections we therefore go on to consider taxes or subsidies that do not vary with vehicle characteristics at the pump or with mileage. Because of this extra complication, we now drop consideration of the clean-car and clean-fuel characteristics. Since we know that these goods would require subsidies equal to their total cost, further discussion would provide no additional insight. And, doing so enables us to focus on the problems of setting only three tax or subsidy rates. Thus fuel efficiency and emissions per mile depend only on newness and engine size. We consider two ways to set uniform rates. First, we examine the use of average values of vehicle characteristics to set the gas tax, and average miles to set the tax rates for size and newness. Rates set using this method do not fully incorporate information about the technological relationships between vehicle characteristics and *EPM* and *MPG*, nor about the correlation among tastes for miles, size, and newness. Some households facing these rates, therefore, would reduce emissions by too much, and others would reduce emissions by too little. Then, we discuss a method that would more fully account for these technological relationships and correlation among tastes. This method, while still imperfect, would enable policymakers to approximate more closely the effects of an ideal emissions tax.

1. Policy 4: Setting Uniform Tax Rates Using Averages

To set the uniform gas tax rate, policymakers could use the averages of engine size and newness. For example, in 1994, the average U.S. vehicle was six years old and had six-cylinder engine. Such a vehicle would have, on average, an engine with about 170 cubic inches of displacement. If the policymaker knows the mathematical relationship between these vehicle characteristics and emissions per miles and fuel efficiency, she could estimate the average vehicle's *EPM* and *MPG*. Then, she could plug these values into the equation for the vehicle-specific gas tax rate (in Fullerton and West (1999a)), and impose this rate on all vehicles.

This is a fairly straightforward process, and so the information requirements for this averages-based rate is low. If the relationship between vehicle characteristics and EPM and MPG is a simple one, and in particular if the relationship is linear, then these rates would be the same as the average of all of the individual-specific rates. Then knowing all of the vehicle's individual EPMs and MPGs would not give the policymaker any additional helpful information. The tax rate set using averages would be the same as the best uniform rate that could be set using information about each vehicle. If, however, the technological relationships are more complicated, then the use of averages would ignore important information. Rates set using averages would be different from the best uniform rates set using information about each vehicle. For example, if emissions per mile increase very rapidly with engine size, a vehicle with an engine double the size of another would emit more than double the amount of pollution per mile. Or, if fuel efficiency decreases very quickly with vehicle age, a car that is double the age of another would use more than double the amount of gasoline. A gas tax rate calculated using average values of size and newness simply does not incorporate these kinds of relationships. In the next chapter, we provide evidence that these relationships are important.

For now, we just consider the case where tax or subsidy rates for newness and engine size, are set by the policymaker using the characteristics of the average vehicle. For miles, she could use the average number of miles driven. Doing so would not only ignore the potentially-complicated technological relationships discussed above; it would also ignore the fact that households' tastes for driving-related goods may be correlated. For example, those households who live far from their place of work have a high demand for miles, and so they may prefer either a small car (for better gas mileage) or a large car (for comfort and safety). Households that prefer older cars may do so because these vehicles are larger. And, households that own newer, more-reliable vehicles may drive more miles than households with older vehicles that are more likely to break down.

These kinds of correlation among tastes imply that the tax on size, for example, would affect not only the choice of engine but also the characteristic with which taste for engine size is correlated. If households that drive more miles prefer smaller cars, then a tax on size that induces households to purchase even smaller cars would also induce them to drive more miles, because their cost per mile is lower in the more fuel-efficient car. If households that drive more miles prefer larger cars, then a size tax would induce them to drive fewer miles, because their commutes are no longer so comfortable.

The same is true for a newness subsidy. In the presence of correlation among tastes, such a subsidy affects not only the choice of vintage, but also the choice of the characteristic with which taste for newness is correlated. For example, if households that like older cars also like larger cars, then a newness subsidy, because it influences them to buy newer cars, would influence them to buy smaller cars.

If such correlation is not accounted for, tax and subsidy rates could be set too high or too low, and induce some households to reduce pollution by too much or by too little. In the next chapter, we present evidence that tastes for miles and vehicle characteristics are correlated.

2. Policy 5: An Alternative for Setting Uniform Rates

In order to approximate more closely the effects of an ideal emissions tax, we suggest an alternative method that more fully accounts for the technological relationships and correlation among tastes discussed above. This case is still limited to a gas tax than cannot depend on the car, and car taxes that cannot depend on miles driven, so the outcome will not perfectly match the efficient outcome of the Pigovian tax, but we seek the best possible tax rates subject to these constraints. To find the best such rates, we must find the single size and gas tax rates, and newness subsidy rate that maximize social welfare, taking as given households' demand behavior for miles, size, newness, and other goods and services. In essence, we would like to find the rates that move each household nearest to its optimal consumption of these goods. Because we are not using individual-specific taxes, only by coincidence would any one household move from its old X^o and Y^o to its optimal X' and Y'.

For this problem, the decisionmaker considers the general technological relationship between vehicle characteristics and *EPM* and *MPG*. The planner also incorporates information about the distribution across the population of vehicles and miles driven, and determines the correlation among newness, engine size, and miles.[9] The tax rates on size and gasoline and subsidy rate on newness should each be raised or lowered until the aggregate additional gain in private welfare just equals the aggregate loss from the effect on emissions. The extent to which emissions are reduced depends on the degree of responsiveness in the choice of miles, size, and newness. Thus optimal uniform tax or subsidy rates on size, newness, and gasoline depend on the elasticities of demand for these goods. But the way in which changes in size and newness affect emissions is through the technological relationships that size and newness have with emissions per mile and fuel efficiency. The functions *EPM* and *MPG* are therefore major determinants of the uniform tax rates. Correlation among preferences will also affect the optimal uniform rates.

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[9] For those readers with more background in economics, the decisionmaker maximizes the weighted sum of indirect utilities, taking as given households' demand behavior, with respect to the three tax rates. For the sake of clarity, here we consider linear second-best tax rates. Perhaps policymakers could assess nonlinear size and newness tax

Unlike the framework we use to solve for individual-specific tax rates, the mathematical model that we use to determine the general form of optimal uniform rates does not give use explicit equations for the rates. Only with data on households' vehicles and miles driven and responses to tax rates can we solve for optimal uniform rates.

IV. Conclusion

We find that the ideal Pigovian tax on emissions (Policy 1) can be replicated perfectly by a complicated gas tax (Policy 2). However, this ideal outcome requires that the gasoline tax depend on engine size, newness and *PCE*. Alternatively, the policymaker, then, attain the ideal outcome by using miles-specific vehicle tax schedules (Policy 3). If these individual-specific tax rates are too difficult or costly, they could implement uniform tax rates on gasoline, engine size, and newness. To do this, they could implement uniform rates calculated using the population averages of miles and vehicle characteristics (Policy 4). Last, policymakers could explore these technological relationships and correlation among tastes, and impose uniform taxes that account for these relationships (Policy 5). We do this in chapter 6.

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schedules fairly easily. The use on nonlinear schedules could incorporate heterogeneity by accounting for convexity or concavity of EPM and MPG, but not for the possible correlation among size, newness, and miles.

Figure 5-1: Consumer Choice Framework

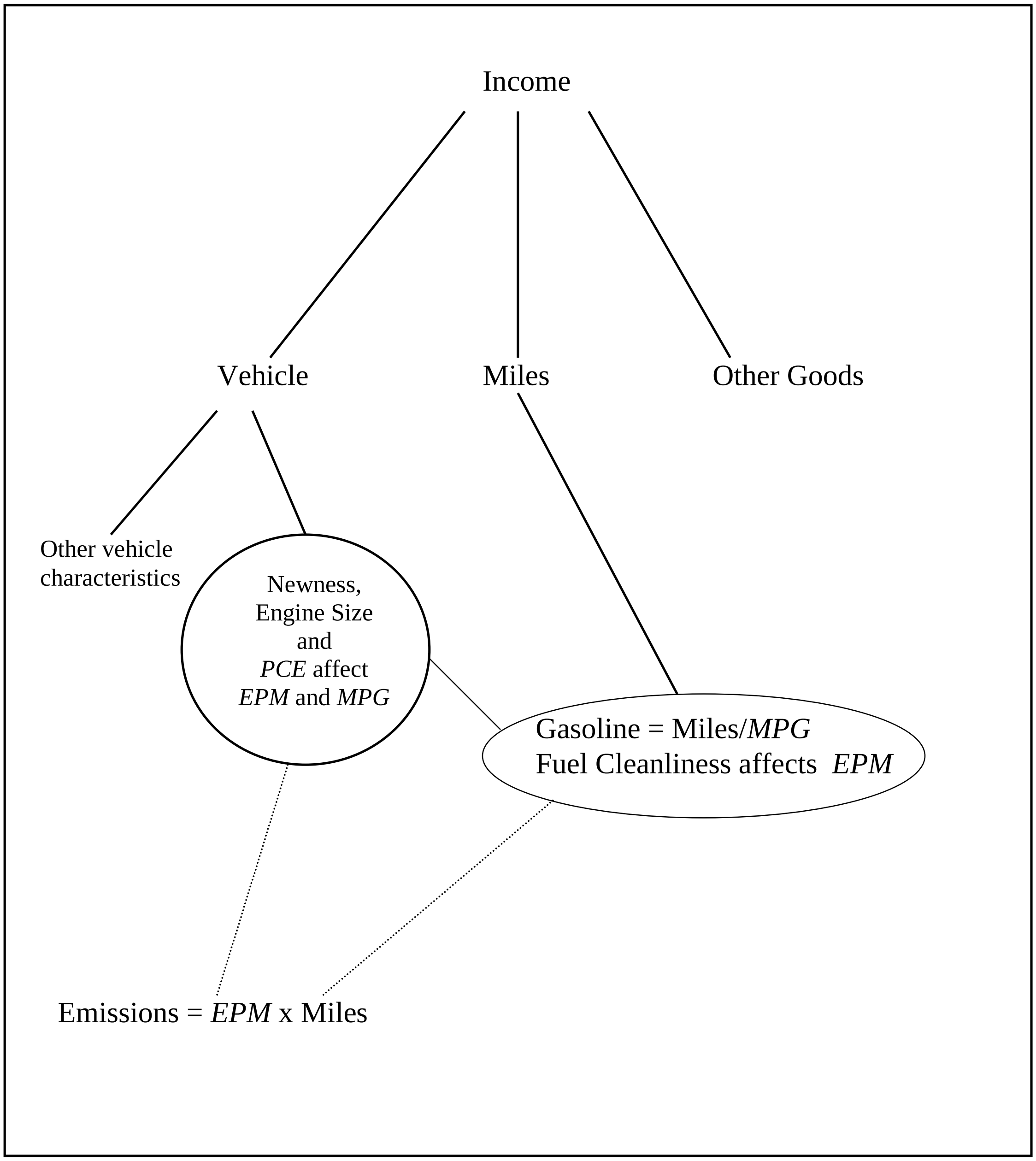

Figure 5-2

Consumption of Dirty Goods (Gasoline and Engine Size)

(Each Household has a Different Graph)

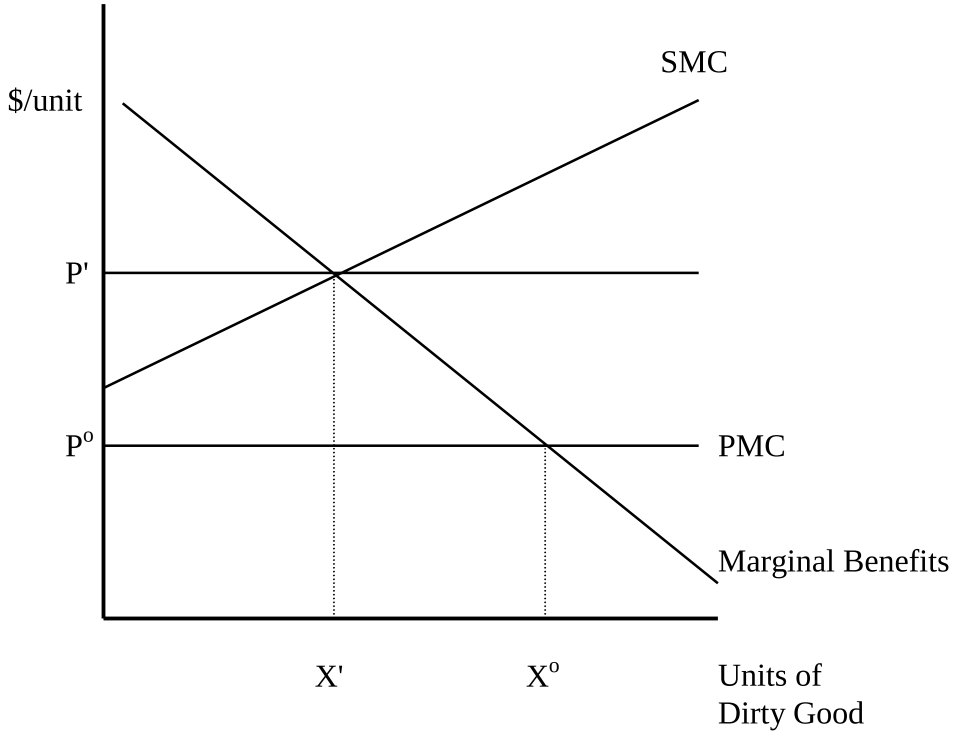

Figure 5-3

Consumption of Clean Goods (Vehicle Newness, Clean Fuel Characteristic, *PCE*)

(Each Household has a Different Graph)