1 Cars, Minivans, SUVs, Light Trucks, Snowmobiles, ATV, etc.

mobilesourcepollution.tex December 6, 2016. We have the basic theory in place for evaluating mobile-source pollution from efficiency, equity and policy perspectives. All we need to do is plug in the relevant facts about mobile source pollution (the details are what vary from one application to another).

1.1 "Stylized Facts" about mobile sources

As we go through this list, think about the implications of each for the market allocation and policies to make the allocation of pollution more efficient and/or equitable. You should have the theory under your belt to figure out how to apply the economics.

1. Mobile sources (cars, trucks, etc) are **only produced** by a small number of firms, making it relatively easy to affect new vehicles.
2. Mobile sources are numereous and ubiquitous: there are millions of them.
3. Mobile sources are mostly operated by amateurs - exceptions are trains, buses, commerical trucks and commercial airplanes.
4. Since vehicles are durable, new ones make up only a small proportion of the total fleet, so any change to new cars will take years before the full effect of the change is felt.

   Vehicle emission (5 through 12**)**
5. Vehicles produce emissions: some of which are CO_2 (carbon dioxide), NO_2 (nitrogen dioxide), CO (carbon oxide), SO_x (sulfer oxides), particulate matter, and HC (hydro-carbons)
6. Vehicles used to emit significant amounts of lead: In the U.S., gas has been lead-free for many years. Lead from gas is still a big problem in some developing countries.
7. No single vehicle, except my old snowmobile, has a significant impact on air-quality levels, but collectively they significantly affect air quality in urban areas
8. CO_2 and NO_2 are green-house (heat trapping) gases. These have the same effect on GW no matter where they emitted.
9. Practically, there is no way to reduce the CO_2 emissions per gallon of gasoline/diesel burned.[1] So, the only way to reduce CO_2 emissions from

[1] As some of my past students have pointed out to me, it is possible, in theory, to sequester CO_2, for example, in the ground or in the ocean, or in trees.

vehicles is to increase miles per gallon (fuel efficiency) and/or decrease miles driven. Vehicles are one the main sources of CO2 emissions.

10. The SOx emissions result from sulfur in gasoline. In addition to injuring people and stuff, the sulfur in gasoline damages pollution-control devices.

11. Diesel engines, relatively speaking, generate more particulate matter than do gasoline engines, but the particles tend to be bigger (bigger is better healthwise)

12. Hydrocarbons (HC) and Nitrogen Dioxide (NO_2) are precursors of ozone. NO_2 is the main cause of smog.

U.S. regulations on mobile-source pollution (13 through 20)

13. The U.S. has **ambient** air quality standards for a number of pollutants including SO_x, CO, NO_2, lead (Pb), ozone, and particulate matter.[2] (Make sure you understand the relationship between emission and the amount of the stuff in the environment.)

14. These standards are set to protect the health of the most sensitive members of society. The Health Standard (the primary standard) **is set without any consideration of benefits and costs**, so these standards on not motivated by a goal of efficiency.

15. EPA has responsibility for setting the ambient standards but the states have primary responsibility for insuring the standards are met: SIPs (state implementation plans)

16. Mobile Sources are responsible for a significant proportion of 3 *criteria pollutants*: CO, NO_2 and ozone, and CO_2 emissions.

17. There are **emissions** standards on new vehicles for many pollutants.

    These are Uniform across U.S. (except CA) . Standards are “set" to achieve ambient air quality standards (not with benefits or costs in mind). The EPA sets these standards (authority under 1990 Amend to CAA). Go to http://www.epa.gov/otaq/standards.htm the "EPA webpage for Vehicle Standards and Regulation" and then click on specific standards.

    For a history of "Milestones in Mobile Source Air Pollution Contol and Regulation" see the EPA site http://www.epa.gov/otaq/consumer/milestones.ht

18. In a number of countries (Japan, the EU and the U.S. for example), there are vehicle emissions standards on nitrogen oxides (NO_x). NO_x is the generic term for NO (nitric oxide) and NO_2 (nitrogen dioxide). These compounds are formed by burning nitrogen-bearing fuels such as oil and gas. In the atmosphere when sunlight is present, NO_x combines with

[2] Ambient standards go to how much of the stuff is allowed to be in the atmosphere. This is different from emissions. Emissions affect ambient air quality (they are the input).Ambient standards vary in two dimensions: density (e.g. ppm) and duration (e.g. hour, day, year).

organic compounds to form ozone. NO_x and ozone cause respiratory distress, impaired visilbility, degradation of vegetation and acid deposition (acid rain). Auto emisssion are a major souce, along with power plants. The U.S. has an ambient NO_x standards (.053 ppm).

19. The Obama administration proposed (Nov 2014) new ozone ambient standards.

20. There are standards on the sulfer content in gasoline. Crude oil and coal often contain sulfer which is emitted into the atmosphere as SO_2 (sulfer dioxide) when these fuels are burned. So, one way to reduce sulfer emissions from burning gasoline is to reduce the sulfer content of gasoline. Note that besides causing respiratory problem, sulfer in gasoline also gubers pollution-control devices. SO_2 "reacts with compounds in the environment to form small particles" that "penetrate deeply into the lungs. It is also a major source of acid deposition.

    See the EPA site "Sulfer Dioxide at http://www.epa.gov/airquality/sulfurdioxide/index.html

    See "Gasoline Sulfer Standards" at http://www.epa.gov/otaq/standards/fuels/gas-sulfur.htm

    and the EPA "Gasoline Sulfer Progam" and http://www.epa.gov/otaq/fuels/gasolinefuels/gasolinesulfur/
    The grey box on the page links to the specific standards.

21. The U.S. has CAFE (Corporate Average Fuel Economy) standards. E.g. new Ford cars and small trucks have to have a fleet average m.p.g. below the standard. CAFE was motivated by the energy crisis in the 70's, **not** by pollution concerns per sec. The standards doubled between 1979 and 1984. After staying at the same level for many years, fuel-efficiency strandards were just made more stringent. Fuel efficiency standard affect emissions but are not pollution standards. http://en.wikipedia.org/wiki/Corporate_Average_Fuel_Economy

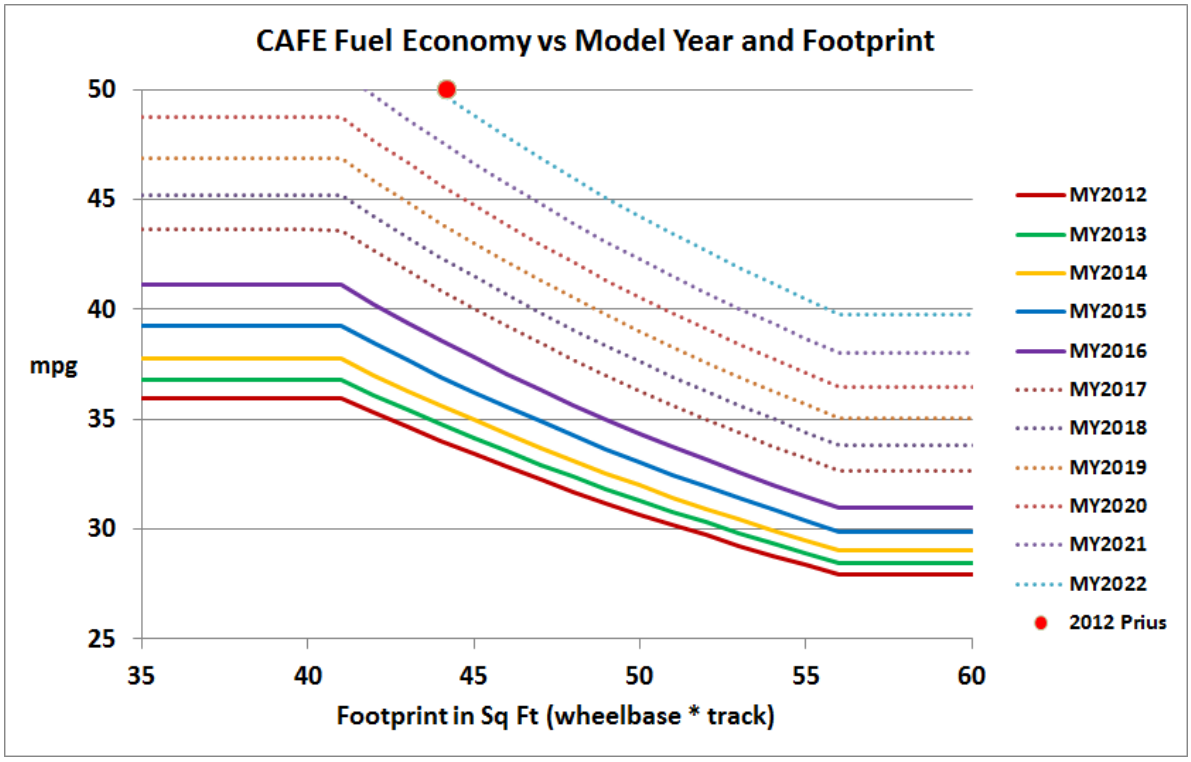
    Note how the CAFE standards depend both on the model year and on the size of the vehicle

22. There are different standards for "trucks"; they are more lack. And most SUVs are officially trucks. **SUVs are a way to avoid the standards for cars.** The market share of "light trucks" grew steadily from 9.7% in 1979 to 47% in 2001 and remained in 50% numbers up to 2011. See http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/2011_Summary_Report.pdf

    ————————————————————————

23. Vehicles miles traveled has almost tripled in the last 30 years.

24. Old cars pollute a lot more per-mile than new cars. There are two reason for this. Emission standards for new vehicles have gotten stricter over time, and emissions rates increase as the vehicle ages and is not maintained.


CAFE Fuel Economy vs Model Year and Footprint
50
45
40
35
30
25
mpg
35
40
45
50
55
60
Footprint in Sq Ft (wheelbase * track)
MY2012
MY2013
MY2014
MY2015
MY2016
MY2017
MY2018
MY2019
MY2020
MY2021
MY2022
2012 Prius

25. The cars that pollute the most per mile are typically driven by poor people.[3]

26. Colorado (the front range only) and many other urban areas have emissions testing. These are typically in non-attainment regions

27. Driving in rural areas has little impact on ambient air quality, except for CO_2 emissions.

28. Driving in urban areas impacts air quality.

29. Congestion slows traffic and increases pollution.

30. Commuting clusters emissions in the morning and evening rush hours. Sunlight is a necessary ingredient in the production of ozone, so an important consideration is whether rush hours occur when it is dark.

31. Natural gas is cheaper and cleaner than gasoline but requires larger tanks in vehicles – expensive to convert. Natural gas is good for fleets in urban areas. We are starting to see conversion. Last time I checked the U.S. Postal Service has 7400 natural-gas vans and UPS has approximately 1000. Some taxi fleets are all natural gas.

32. Hybrid vehicles (gas and electrical) are becoming increasingly available. The momentum of the car is used, for example in braking, to charge the battery. The Prius was the first big sucess story. Most manufacuters now sell a least one model of hybrid, but they still are only a small fraction of new cars sold.

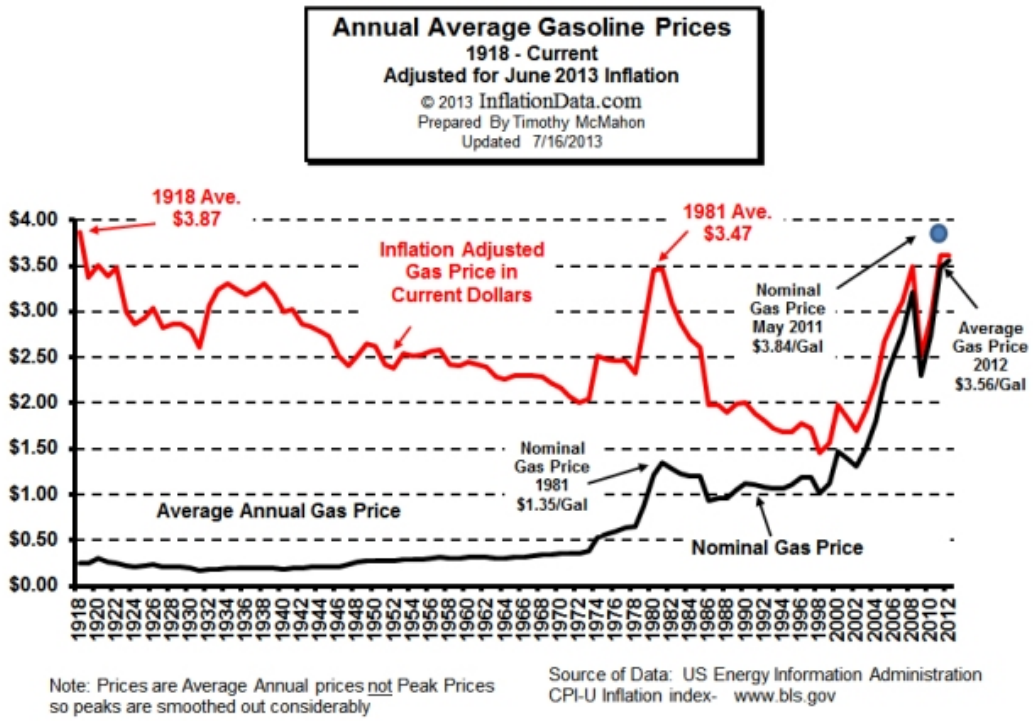
33. Electric only vehicles are common but only a small fraction of all vehicles, but are becoming available. They have limited range and lengthy recharge times, but there performance is starting to dramatically improve.

34. Producing electricity to drive electric cars produces CO2 and other pollutants. See RFF article.

35. The Second Bush Administration pushed the development of cars that will run on hydrogen fuel cells. Such vehicles are not currently economically viable. There is also the issue of where the hydrogen will come from. I had not heard much about hydrogen fuel cells in the last couple of years, but manufacturers are still working on them. See the recent NYT article on hydrogen cars.

36. Local pollution from vehicles is typically horrific in large cities in developing countries. These conditions are caused by a combination of congestion, no standards, old clunkers, 2-stroke engines and leaded gas.

[3] There are exceptions. For example, rich guys who drive around in vintage muscle cars.



37. Its is cheaper to produce cars that all have the same pollution control equipments: economies of scale (but how significant?). This is the industry argument for why it would be bad if emissions standards varied from State to State.

38. Gasoline is very cheap in the U.S. relative to the rest of the world, and relative to the U.S. in the past.

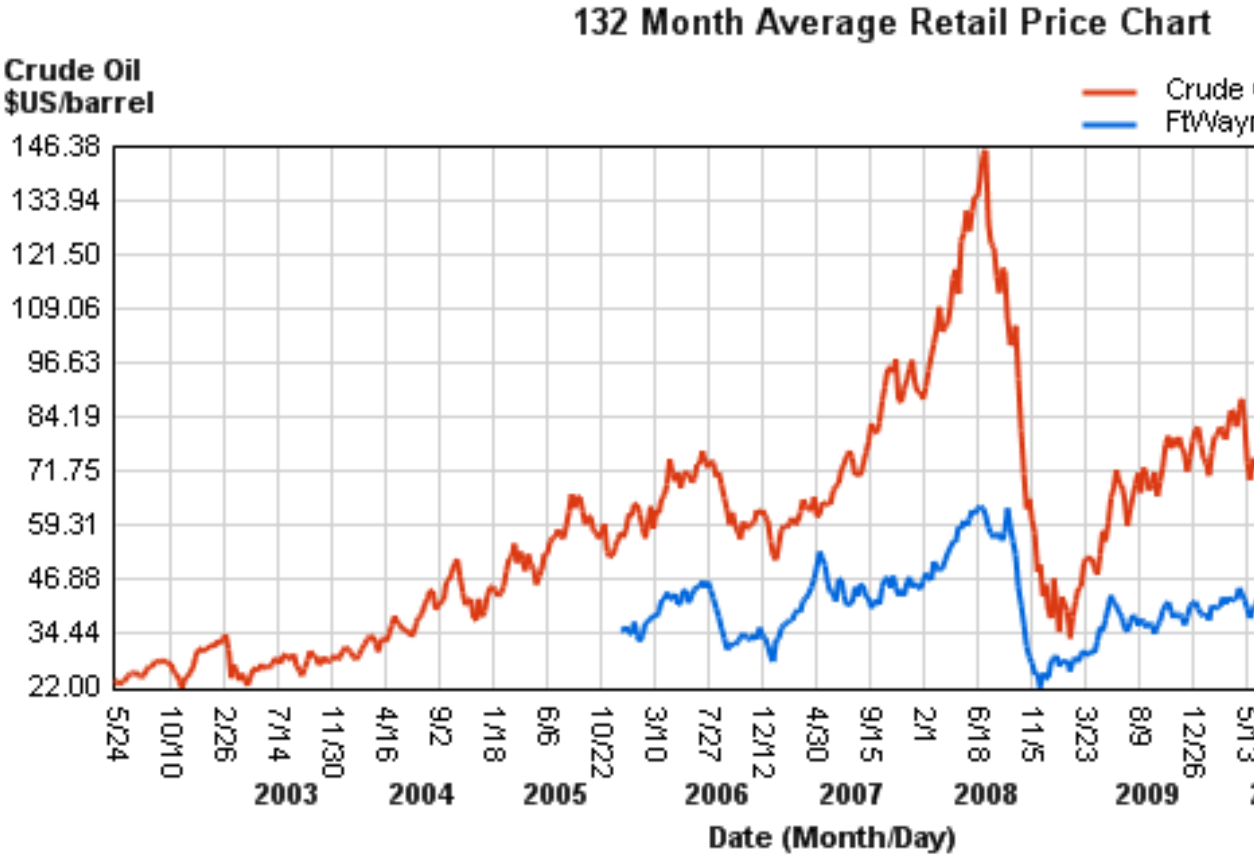
    There are great graphics about what a gallon of gas costs in different countries at http://www.bloomberg.com/visual-data/gas-prices/

    For example, Nov 30, 2014 the average price in the U.S. is $3.69 (we are ranked 51st in terms of prices, high to low).

    Norway is ranked first at $9.79. (Note that Norway as has large reserves of oil and natural gas.) Japan and Europe have much higher gas prices than the U.S.[4]

39. Gasoline prices in the U.S. are below, in real terms, their historic peak.

[4] Venezuela is the lowest at 4 cents a gallon. They are a major producer and they highly subsidize the price of gasoline for political reasons. The last time Venezuala tried to reduce the subsidies (in 1989) there were riots that killed hundreds of people.


132 Month Average Retail Price Chart
Crude Oil
$US/barrel
Crude
FtWayn
146.38
133.94
121.50
109.06
96.63
84.19
71.75
59.31
46.88
34.44
22.00
5/24
10/10
2/26
7/14
11/30
4/16
9/2
1/18
6/6
10/22
3/10
7/27
12/12
4/30
9/15
2/1
6/18
11/5
3/23
8/9
12/26
2003
2004
2005
2006
2007
2008
2009
Date (Month/Day)

40. The one-to-one relationship between CO_2 emissions and the amount of gasoline the vehicle uses has important implication for taxes and regulations.

41. There is **not** a one to one relationship between other emissions (NO_2, CO, SO_x, etc) and the amount of gasoline the vehicle uses. That is, we can affect amounts of "other" emissions per gallon of gas (abatement is possible). This has very important implications for for taxes and regulations.

42. Don't forget materials balance. For example, iwe substitute electric cars for gas-powered cars. we have to consider the pollution assocated with electricity production.

1.2 In urban areas, the unregulated market will not produce the efficient amount of exhaust emissions from society's perspective

The market will fail because drivers do not pay the full social cost of driving: driving produces negative external effects (pollution and congestion) and the market fails in making the drivers pay the full social costs associated with those external effects.

Will the unregulated market fail in unpopulated places like North Dakota? No.[5]

How should society correct these market failures? Regulation? Standards? Taxes (on what)?

In these notes, I will concentrate on the pollution externalities, but note that most policies that reduce excess pollution by reducing mileage will also reduce congestion.

[5] The exception is CO_2 emissions, but I don't want to keep saying this, so won't

1.3 Two issues from an efficiency perspective:

(1) What is the efficient level of moblie-source pollution? To answer this question, we must estimate the benefits and costs of reducing it. Note the distinction between emissions and pollution levels. This is a difficult probem in health effects and non-market valuation. As you know, non-market valuation is difficult

The mandated pollution levels in the U.S. are not based on efficiency criteria. Rather, they are based on a health criteria that was set without any consideration of costs. We can probably conclude that emissions standards that are based on an ambient standard of no negative health effects is probably to stringent from an efficiency perspective.

That given,

(2) We want to achieve the target level of mobile-source pollution (emissions or air quality) at min cost. Assume, for now, the goal is to achieve the ambient air quality standards at minimum cost and that we have a good estimate of how much pollution from vehicles needs to be reduced to achieve this goal.[6] That is, we take as given how much mobile source pollution must be reduced.

[6] Determining this is not a job for economists.

1.4 The least-cost method of achieving the desired levels of mobile-sourc pollution will likely involve some combination of the following behavioral and technical changes:

1. some driving less miles
2. increased m.p.g.
3. devices on new vehicles to reduce the amount of pollution per unit of fuel burned
4. incentives to maintain vehicles in good working order, especially pollution-control devices
5. reducing the miles driven in old clunkers
6. incentives to increase the state of technology with respect to fuel efficiency and pollution control.
7. Variation in first 6 with respect to location.

1.5 How might we achieve the goal of reducing vehicle emissions by the specified amount in the least-cost way?

Uniform emission standards for new cars?

A gas tax?

A tax based per vehicle based on the amounts of pollution produced by the vehicle?

Programs to buy and retire old clunkers?

Other?

CAFÉ standards?

Right away you should ask which of these directly regulate or tax mobile-source pollution.

If they are only an indirect way to regulate or tax mobile-source pollution it is unlikely they will achieve the redution goal in a cost-minimizing way.

1.5.1 Consider, first, uniform standards (on emissions and mpg) for new vehicles as a way to efficiently reduce mobile source emissions

What is the appeal of such standards?

Easier to impose standards on a small number of manufacturers than on drivers

Industry prefers uniform standards to non-uniform (economies of scale)
California had standards before U.S., so "grandfather clause,"
NE states? (considering new "voluntary standards")

Standards are not a tax per se, but they do increase the cost of vehicle.[7]

Are standards on new cars, alone, an efficient (min cost) way to either reduce emissions or improve ambient air quality? NO.

1. If a standard is uniform it must be too lax in some areas and too stringent in others.
2. Uniform standards for new vehicles give no incentive to keep pollution-control devices in good working order (why we have vehicle inspection programs).
3. Uniform emissions standards per mile provide no incentive to drive less.
4. No effect on older vehicles or the amount polluted by older vehicles and might cause older vehicles to remain on the road longer.

[7] One of their appeal is that the cost is indirect, so somewhat hidden.

1.5.2 How about a tax on gasoline?

1. Probably want it to have two components (a carbon component and, maybe, a sulfer component). That is a carbon tax and a sulfer tax rather than a gas tax per se.

2. A carbon component: The tax rate on CO_2 emissions should be independent of where car is driven – all CO_2 emissions contribute equally to global warming. The efficient U.S. tax rate on CO_2 emissions is likely "low".[8]

3. Sulfer component: Make the tax an increasing function of its sulfur content of the gasoline. Ideally, one would want this tax to vary as a function of where the vehicle is driven. (Note that the amount of sulfer in gas is already highly restricted, which is another way to address the issue, but many not an efficient way)

4. Consider a tax on gasoline as a way to reduce other vehicular emissions. A tax on gasoline is not the least-cost way to reduce the emissions of pollutants such as NO_x, HC and particulates because there is not a one-to-one relationship between gas consumption and the amounts of these pollutants emitted. That is, the amounts of these pollutants emitted per gallon of gasoline burned will vary significantly as a function of the type of vehicle driven, how it is driven, when it is driven, and where it is driven.

5. I would probably advocate: A gas tax based on its CO_2 content (maybe quite low) and a tax on the the sulfur content of gas if the amount of sulfur in gas is not set at some low level.

6. While a gas tax will decrease congestion and the emission of other pollutants is is not the most efficient way of achieving those goals. However, it might be better than nothing for achieving those goals. Why is the most efficienet type of taxes when it comes to congestion?

7. If the intent was simply to reduce the amount of gasoline burned, a gas tax is the way to go, but why would that be the goal? (Maybe national defense and energy independence?)

8. A gas tax or carbon tax will increase the demand for fuel-efficient vehicles.

9. A gas/carbon tax will increase the relative price of goods that use a lot of gas to produce, for example, products that are carried long distances by trucks, and taxi rides.[9]

[8] Of course, if there was a general carbon tax, this would affect the price of gasoline.
Investigate further and report some of the estimates. My recollection is that the estimates are 25 to 50 cents a gallon, but I could be remembering poorly. See the section of the course on global warming.

[9] Note that this will reduce the demand for these products, driving some of the producers of these products out of business. This is a good thing from an efficiency perspective.

1.5.3 How about CAFÉ standards as a way to increase ambient air quality?

1. Cafe standard require that the new cars a company sells in a year have an average MPG of at least X.

2. CAFE standards are not a direct tax or regulation on pollution, so not a min. cost way of reducing the pollution. They are likely not close to efficient for reducing mobile-source pollution

3. CAFÉ standards increase average m.p.g., so, will ceteris paribus, decrease CO_2 emissions per mile driven.

4. CAFE standards have no influence on the number of miles driven.

5. New more stringent standards have no affect on existing vehicles and, to the extent that the more stringent standard increases the cost of a new car, old cars will remain on the road longer.

6. CAFE standards will have conflicting impacts on "other" pollutants: to the extent they cause gas consumption to decrease, c.p. "other" pollution will decrease, but everything is not constant – there is often a tradeoff between MPG and production of other pollutants.

7. CAFÉ standards will do nothing for congestion

8. Once CAFE standards are met, manufacturers have no incentive to research improving fuel efficiency.

1.5.4 How about regulation on the amount of sulfur in gasoline?

1. We do this. See above.

2. Lead in gasoline is also regulated this way.

3. Regulating sulfer content could be efficient – the only question is whether the max. content should be uniform or vary by region (e.g. states).[10] The answer depends on whether there are economies of scale in the removal of sulfur when gasoline is refined that can only be realized at national levels of production. If regulations do vary, there is the posssible problem of buying across boundaries

4. If the sulfer content of gasoline is set a a low level, there is no need for a sulfer tax on gasoline. Alternativeley, if the tax rate on sulfer is properly set, there is no need for a standard. The latter is the more efficient way to go.

[10] Note that the sulfer content of oil and coal varys by region of origin. For example, eastern coal has more sulfer than western coal. Politicans from eastern oil and coal states do not like restrictions or taxes on sufler content.

1.5.5 Vehicle Inspection Program?

1. Motivation – to insure that pollution control devices are maintained and that car engines are kept in good working order
2. Typically only in "non-attainment" regions
3. Such a system could be used to ban from the road cars with high pollution per mile . We don't do this. There have been some experiements with buyback programs.
4. Some other countries ban old cars that pollute too much.[11]
5. Inspection programs are one way to monitor how much existing cars pollute.

[11] They are typically exported to poor countries with few enforced standards. So reduce local pollution in the banning country, but doing nothing to reduce CO2 emissions world wide.

1.5.6 Vehicle buy-back programs?

1. These programs buy and retire highly polluting old cars
2. Highly polluting old cars emit waaaaay more per mile than new cars
3. Buying highly-polluting cars, rather than banning their use, implicilty give individual the "right" to drive such vehicles.
4. Discuss my experience with buying clunkers.

1.5.7 Can we tax a specific car as a function of the specific amounts of the pollutants it emits?

1. Not exactly, but maybe close?

2. No problem with CO_2 emissions because there is a one to one relationship between gas use and CO_2 emissions, so a gas tax (or carbon tax) will work, and a gas tax is easy to administer. That said a tax on the carbon is gasoline would likely be part of a general carbon tax.

3. How about pollutants that do not have a one to one relationships between gas consumption and pollution? How might we directly tax the amount of these pollutants emitted? Tax would, ideally, be per unit of each pollutant produced in a year. For example, so many dollars for each unit of NO_2 produced. This would depend, loosely, on the specific car and how many miles it is driven–not too hard to determine.

4. For example one could base the tax on the estimated amount of each pollutant as a function of model, year, and miles driven. Pay the tax every year when the car is registered. This would not be perfect because it would not take into account how well the car is maintained or how it is driven (high speed or stop and go)

5. Or, to be more car-specific, a yearly emissions test could be used to estimate pollution per mile by type of pollution (except for CO_2): record mileage, estimate pollution per mile based on model year, model and the test, multiply mileage by these estimates to get total pollution emitted in the last year, apply tax rates at registration.

6. Deficiencies with the last proposal are there would be an incentive to "tune-up" the car right before the inspection, with no incentive to keep it maintained until the the next inspection is looming on the horizon.[12] And one is not taking account of how the car is driven.

7. CO_2 would be taxed with a carbon tax or gasoline tax.

8. The system described to here is not perfect but it is close to direct taxes on different mobile-source pollutants.[13] It could be improved as monitoring technolgy improves.

9. Except for CO_2, one would want the tax rates to vary by location, low in N. Dakota, high in Denver and L.A. There is the problem that one might live in Denver and drive to North Dakota for vacation. GPS could keep track of this but I am sure many would object to this level of monitoring by the government.

[12] Edward's Jeep.
[13] Of course it would not tax non-mobile sources of these pollutants.

10. Pollution taxes would increase the relative price of products whose production are intensive in the production of these pollutants, for example trucking firms with an old fleet would see a big increase in costs that they would pass along to their users. From an efficiency point of view, this is a good thing.

11. Such "pollution taxes," if set at the correct levels, would come close to efficiently reducing mobile-source pollution. If marginal cost of abatement is less than tax, abate (reduce emissions). If marginal cost of abatement is greater than tax, pollute and pay the tax. In equilibrium

$$tax_p = MC_{abate-pollut}$$

If everyone in a region faces the same tax rate, $MC_{abate-pollut}$will be equated across emitters.

Pollution taxes will give each of us max flexibility in how to reduce each type of emissions.[14]

Each driver can can choose their cost-minimizing combination of the following actitons:

1. can drive less
2. drive a less-polluting car
3. better maintain their car
4. drive a car with higher m.p.g.
5. buy fewer goods whose production involves the production of a lot of pollution.

Economists like to give people flexibility in achieving a goal. Why? How would you explain this desire to a non-economist.

[14] That is, they do not require that we reduce in a particular way.

If the tax rates were set correctly: There would be little need for regulations specifiying m.p.g. standards, pollution-control devices, or buying clunkers.

Consumers would demand better mileage and less pollution per mile and the market would reward manufacturers that produced cars that polluted less per mile: vehicle manufacturers would have a profit incentive produce cleaner cars, a profit incentive to improve emissions technology, and a profit incentive to increase m.p.g.[15]

People would abandon old clunkers because they would be too expensive to drive - we would not have to pay them to stop driving them.

How would one set the emissions tax at the correct level? That is, how do we determine what tax rate will reduce pollution by the desired amount? Experiment? Estimate? A tough problem.

Problems with varying tax rates by location: Individuals will have incentive to register vehicle in location with lowest tax rates (I do this. I am bad). Individuals who live in Denver will be overtaxed for the miles they drive in less-polluting areas. One possible solution is rentals for trips.

We now have the technology to know where a car has been driven. (Rental card companies use it all the time.)

High incentive to dork with odometer (enforcement issue). Dorking with odometer is now quite difficult. It was much easier in the past.[16]

Technologies now exist that are capable of **continuously monitoring the pollutants** emitted by a vehicle, and keeping a tally of each pollutant and how much was emitted in different regions. At the yearly inspection, inspection station would download the data. In theory, such a device, combined with GPS, could also keep track of how much of each pollutant was emitted in each "pollution district" and tax the pollution at different rates depending on where it occured. This method is likely not currently cost effective, but will likely be cost effective sometime soon.

[15] Note that monitoring is not without problems. Consider the Volkswagen diesels.

[16] In the olden day one could put a car on blocks and run it in reverse, making the odometer go backwards.

If miles were monitored b GPS there would be no reason to dork an odometer.

You should read/????

1.5.8 Why don't politicans, and their constituents, like pollution taxes/fees?

1. The costs of "regulations" and "standards" are more hidden, so politically more popular
2. I called them "taxes". Maybe I should have called them "pollution payments"
3. Equity implications? Maybe. More polluting cars are driven by poor people. Can equity problems be overcome with, for example, tax credits? Do politicans really care about poor people?
4. Trucking companies would spend millions lobbying and advertising against pollution payments or a gas tax, so would the oil industry.
5. A Republication advocating a "pollution payment" would have a death wish. Not quite sure why.
6. Many politicans and voters are against most forms of government intervention, or so they say. Why?

1.6 We could consider a mobile-source pollution trust (or, e.g. a CO_2 trust)

All the tax revenues from the mobile source pollution taxes, including the gas tax for CO_2 could go into a trust rather than into general tax revenues. The trust would be monitored by a government trust agency. At the end of each year the revenues collected would be equally divided amongst tax payers and paid to them as a tax credit or royalty payment.

This would make the system, on average, revenue neutral: neither increase or decrease government revenues. If you polluted less than average you would be a net gainer (get more more back than you paid in taxes) and if your polluted more than average you would be a net loser - just the kind of incentive scheme efficency requires.

Alaska does this with royalty payments from oil.