

## **Is Pay-as-You-Drive Insurance a Better Way to Reduce Gasoline than Gasoline Taxes?**

*By Ian W.H. Parry\**

Despite concerns about US dependence on a volatile world oil market, greenhouse gases from fuel combustion, and air quality effects of mobile source emissions, substantially higher federal gasoline taxes are currently a political non-starter. Any fuel conservation measures that might be more politically palatable are generally perceived as inferior to gasoline taxes on efficiency grounds. This paper challenges the latter assertion: it shows a policy that should be far more feasible than a large increase in fuel taxes can also achieve a significant reduction in fuel demand, with a dramatically larger welfare gain.

The policy is pay-as-you-drive (PAYD) insurance, which is motivated on the grounds of reducing mileage, particularly by high-risk drivers, and reducing the number of uninsured drivers by lowering premiums for low-mileage vehicles. It involves auto insurance companies switching from current, annual lump-sum premiums, to premiums levied on annual miles driven, scaled by a driver's rating factor (which varies with age, crash record, and region). By converting some of the fixed costs of vehicle ownership into costs that vary with mileage, the policy reduces the amount vehicles are driven, and thereby reduces fuel demand. And, unlike under higher fuel taxes, driving costs (fixed plus variable) for the average motorist do not increase; hence political opposition to this policy should be more muted.

To some extent, we may see a market-driven transition to PAYD over the next decade or two, given that technology for monitoring vehicle mileage is improving rapidly, and low-mileage drivers have an incentive to opt for PAYD (Todd Litman 2001). Even in the absence of externalities discussed here, tax incentives may still be warranted to hasten such a transition because individual insurance companies do not consider benefits to other companies from reduced accident risks when its own clients convert to PAYD (Aaron Edlin and Pinar Karaca-Mandic 2004).

Gasoline taxes are superior to PAYD on cost-effectiveness grounds as they exploit all behavioral responses for reducing fuel demand. They encourage motorists to drive less, manufacturers to incorporate

fuel saving technologies in new vehicles, and consumers to choose smaller, fuel-efficient vehicles. PAYD provides incentives to drive less, but not to improve fuel economy.

However, this does not account for impacts on a range of motor vehicle externalities. Estimates of combined mileage-related externalities—traffic congestion, accidents, and local emissions (regulated on a grams per mile basis)—are an order of magnitude larger than for combined fuel-related externalities—greenhouse gases and oil dependency (see below). For a given reduction in fuel demand, PAYD will reduce mileage-related externalities far more than fuel taxes, as all (rather than just a portion) of the reduction in fuel demand comes from reduced driving. We estimate that fully implementing PAYD would reduce gasoline demand by 11.4 billion gallons (9.1%) and increase social welfare by \$19.3 billion per year. The same fuel reduction could be achieved by increasing the federal gasoline tax from 18 to 45 cents per gallon, but resulting welfare gains are \$6.2 billion, just 32% of those under PAYD. We also show that PAYD is slightly more efficient than a simple tax on vehicle miles traveled (VMT) for a given fuel reduction, and even performs fairly well relative to a fully optimized VMT tax.<sup>1</sup>

## I. Analytical Model

**A. Assumptions.** Consider a static model with a large number of representative agents, each with utility:

$$(1) \quad U = u(C, M) - E_F(\bar{F}) - E_M(\bar{M}), \quad M = vm$$

Variables are expressed in per capita terms on an annualized basis, a bar denotes an economy-wide variable perceived as exogenous by individual agents,  $u(\cdot)$  is quasi-concave in its arguments, and  $E'_F, E'_M > 0$ .  $C$  is a (unit price) general consumption good,  $F$  is fuel consumption, and  $M$  is VMT, equal to the number of vehicles purchased,  $v$ , times miles per vehicle,  $m$  ( $v$  is continuously variable in the aggregate).

$E_F$  is disutility from fuel-related externalities caused by other agents; it represents (future) damages from climate change caused by greenhouse gas emissions, the uninternalized risk of macroeconomic disruption costs from oil price shocks and the “optimum tariff” from US monopsony power in the world oil market (Paul N. Leiby et al. 1997).  $E_M$  is disutility from mileage-related

externalities; it represents costs of traffic congestion, local emissions (regulated on a grams per mile basis), and traffic accidents. The latter includes, for example, injury risk to pedestrians and other road users but (for now) excludes claims on insurance companies; own driver injury risks are internalized in agents' travel decisions.

The agent's budget constraint is:

$$(2a) \quad C + v(p_v + p_m m) = I + \pi + G$$

$$(2b) \quad p_m = p_F / f + p_i + t_M + \theta(m), \quad p_F = q_F + t_F$$

$$(2c) \quad p_v = p_a + p_P(f)$$

In (2a)  $p_v$  and  $p_m$  are the (fixed) cost of owning a vehicle and the (variable) per mile driving cost respectively;  $I$ ,  $\pi$  and  $G$  are exogenous to individual agents and denote labor income, profit income, and a cash transfer from the government.

In (2b), per mile costs consist of four components.  $p_F/f$  is fuel costs where  $p_F$  is the consumer price of gasoline, equal to the producer price  $q_F$  plus a specific tax  $t_F$ , and  $f$  is fuel economy, or miles per gallon.  $p_i$  and  $t_M$  denote insurance premiums perceived on a per mile basis and a VMT tax respectively; both are initially set at zero.<sup>2</sup>  $\theta$  is maintenance costs, where  $\theta(m) > 0$ , included to ensure more than one vehicle is purchased.

In (2c) vehicle ownership costs consist of an annual lump-sum insurance premium  $p_a$ , and (annualized) vehicle purchase costs  $p_P(f)$ . Given other vehicle attributes consumers pay more for a more fuel-efficient vehicle,  $p'_P > 0$ , as this requires incorporation of technologies to improve engine efficiency and transmission, etc. Lump-sum insurance partly internalizes externalities in the vehicle purchase decision, but not in the decision of how much vehicles are driven.

Agents choose  $C$ ,  $v$ ,  $m$ , and  $f$  to maximize (1) subject to (2).

The government budget constraint, equating spending with revenues from fuel taxes, is:

$$(3) \quad G = t_F F, \quad F = M / f$$

where  $F$  is total fuel use. Higher/lower fuel tax revenues are reflected in higher/lower household transfers.<sup>3</sup>

Firms are competitive, produce goods using labor with constant returns, and provide the level of fuel economy demanded by consumers; market equilibrium equates production costs per vehicle with  $p_p(f)$ . Insurance companies are also competitive, with expected profits:

$$(4) \quad \pi = v(p_a + (p_i - x)m) \equiv 0$$

$x$  is the expected insurance claim for property damage and medical expenses per mile driven. Profits accrue to households who own firms and are zero in equilibrium.

## B. Welfare Effects from Reducing Fuel

(i) *Gasoline tax.* The welfare change (in dollars), denoted  $W$ , from a marginal increase in  $t_F$  can be expressed (all analytical derivations are available on request):

$$(5) \quad \frac{dW}{dt_F} = \left\{ t_F - \frac{E'_F}{\lambda} \right\} \frac{dF}{dp_F} + \left\{ p_a - m \frac{\tilde{E}'_M}{\lambda} \right\} \frac{dv}{dp_F} - \frac{\tilde{E}'_M}{\lambda} v \frac{dm}{dp_F}$$

Price coefficients are assumed negative,  $\lambda$  is the marginal utility of income, and  $\tilde{E}'_M = E'_M + x$  denotes marginal external mileage costs, inclusive of costs to insurance companies.

The first component in (5) is the welfare effect in the gasoline market. It is positive if the marginal external cost of fuel externalities in dollars exceeds the gasoline tax; if not, agents are overcharged for the social costs of fuel use and a reduction in fuel demand reduces efficiency. Second is the welfare effect from the reduction in vehicle demand; this is positive if the marginal external cost per vehicle  $m\tilde{E}'_M/\lambda$ , exceeds the per vehicle insurance premium. Third is the welfare gain from the reduction in mileage as agents drive vehicles less intensively in response to higher fuel costs.

We assume demand for fuel, vehicles, and miles per vehicle respond to fuel prices as follows:

$$(6) \quad \frac{F}{F_0} = \left( \frac{p_F}{p_F^0} \right)^{\eta_{FF}}, \quad \frac{m}{m_0} = \left( \frac{p_F}{p_F^0} \right)^{\beta_M \beta_m \eta_{FF}}, \quad \frac{v}{v_0} = \left( \frac{p_F}{p_F^0} \right)^{\beta_M (1-\beta_m) \eta_{FF}}$$

$\eta_{FF} < 0$  is the gasoline demand elasticity. This reflects both changes in fuel economy and in VMT; the latter reflects both reduced miles per vehicle and reduced demand for vehicles.  $\beta_M$  is the (constant) fraction of reduced gasoline that comes from reduced VMT, and  $\beta_m$  is the (constant) fraction of reduced VMT that comes from reduced miles per vehicle.

From (5) and (6) and some manipulation we obtain the welfare effect per gallon of fuel reduction:

$$(7) \quad -\frac{dW/dt_F}{dF/dt_F} = \frac{E'_F}{\lambda} - t_F + \left\{ \frac{\tilde{E}'_M}{\lambda} - \frac{p_a}{m} \right\} f\beta_M(1-\beta_m) + \frac{\tilde{E}'_M}{\lambda} f\beta_M\beta_m$$

(iii) *VMT tax*. For this policy, we convert the VMT tax into its equivalent fuel tax at initial fuel economy  $t_M^0$ , and use the same elasticities, except that, because fuel economy is unchanged, we assume fuel demand responds only to the mileage component of the fuel demand elasticity,  $\beta_M \eta_{FF}$ .

The marginal welfare effect, per gallon of fuel reduction, is:

$$(8) \quad -\frac{dW/dt_M}{dF/dt_M} = \frac{E'_F}{\lambda} - (t_F^0 + t_M f^0) + \left\{ \frac{\tilde{E}'_M}{\lambda} - \frac{p_a}{m} \right\} f^0(1-\beta_m) + \frac{\tilde{E}'_M}{\lambda} f^0\beta_m$$

There are two main differences compared with (7). First, and most important, efficiency gains from reducing mileage externalities are *not* scaled back by  $\beta_M$ , as all, rather than a fraction, of the reduction in fuel use comes from reduced driving. Second, the overall tax distortion, converted to its equivalent in the gasoline market,  $t_F^0 + t_M f^0$ , will exceed  $t_F$  in (7) for a given fuel reduction, implying a higher cost when externalities are ignored; a higher tax is required because only VMT, and not fuel economy, respond to the VMT tax.

(ii) *PAYD*. An increase in per mile insurance cost  $p_i$  is equivalent to an increase in the VMT tax  $t_M$ , except that revenues are rebated to consumers in a lower annual fee,  $p_a$ . We assume no change in vehicle demand; analogous to (8) the marginal welfare effect is:

$$(9) \quad -\frac{dW/dp_i}{dF/dp_i} = \frac{E'_F}{\lambda} - (t_F^0 + p_i f^0) + \frac{\tilde{E}'_M}{\lambda} f^0 \beta_m$$

$p_i$  will exceed  $t_M$  for a given reduction in fuel demand, given the vehicle component of the change in mileage is absent. Thus, the equivalent tax distortion for a given reduction in fuel is larger than under the VMT tax. However, the welfare gain from reduced VMT is larger because all of it comes from reduced miles per vehicle, for which none of the external costs are offset by initial insurance premiums.<sup>4</sup>

We take marginal external costs as constant. Total welfare effects for a given fuel reduction under the three policies are obtained by integrating (7)-(9).

## II. Parameters

Table 1 summarizes assumed parameter values and sources.

Following NRC (2002), we adopt values of 12 cents per gallon for carbon damages (\$50 per ton of carbon emissions) and 12 cents per gallon for oil dependency externalities (\$5 per barrel of oil). Combined externalities—24 cents per gallon—are well below the initial (federal and state) fuel tax of 40 cents per gallon, implying a welfare *loss* from the reduction in fuel use itself. Admittedly, fuel-related externalities are highly contentious; however, it is the mileage-related externalities that determine the (absolute) differences between the policies studied here.

Marginal mileage externalities sum to 12 cents per mile, or \$2.40 per gallon at initial fuel economy. Thus, mileage externalities are *ten*-times as large as fuel externalities; congestion is the most important (6.5 cents per mile), followed by accidents (4.0), and then local pollution (1.5).

The gasoline demand elasticity is  $-0.55$ , with 60% of it accounted for by long run improvements in fuel economy, and 40% from reduced VMT; of the latter, 67% comes from reduced mileage per vehicle and 33% from reduced vehicle ownership. Current lump-sum insurance payments are assumed equivalent to 6.5 cents per mile (\$1.30 per gallon).

### III. Results

If PAYD were fully implemented gasoline demand would fall by 11.4 billion gallons (9.1%). The equivalent fuel reduction could be achieved by increasing the gasoline tax by 27 cents per gallon, or a VMT tax of 3.9 cents per mile. Welfare effects under the three policies are shown in Figures 1-3.

Welfare gains from reducing gasoline are substantially higher under PAYD than under fuel taxes. For the 11.4 billion gallon decrease in fuel use, welfare gains are \$19.3 billion under PAYD, but only 32% of this amount under higher gasoline taxes. This is because welfare gains from reduced mileage are \$27.4 billion under PAYD, compared with \$9.7 billion under fuel taxes; this easily outweighs higher losses in the gasoline market under PAYD (\$8.12 billion compared with \$3.5 billion under the fuel tax).

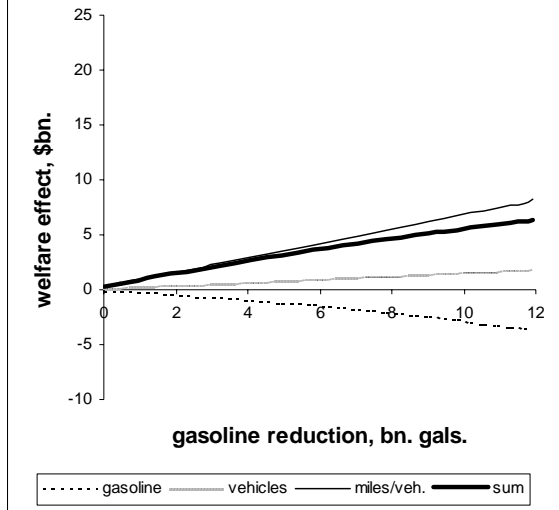
Overall, maximized welfare gains under PAYD exceed those under the equivalently scaled VMT tax by \$2.1 billion; again, larger welfare gains from reduced mileage per vehicle under PAYD more than compensate for the larger equivalent fuel tax distortion. We also compute the fully optimized VMT tax at 8.9 cents per mile, given the existing fuel tax; this reduces gasoline demand by 20.6 billion gallons. However, welfare gains from this fully optimized tax are \$22.5 billion, only moderately larger than those under PAYD.

We conclude that PAYD appears to make more sense on efficiency grounds than higher fuel taxes as a first step towards reducing conventional motor vehicle fuels. A lesson is that impacts on a broad range of motor vehicle externalities should be considered in evaluating other policy options for transportation, such as subsidies for alternative fuel vehicles and higher fuel economy standards.

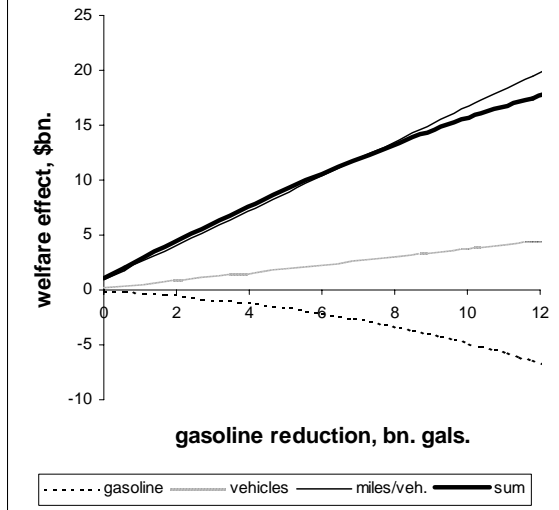
**Table 1. Parameter Values**

<b>Parameter</b>	<b>Value</b>	<b>Source</b>
Components of fuel externalities		
carbon emissions, cents/gal.	12.0	Nat. Research Council (2002)
oil dependency, cents/gal.	12.0	Nat. Research Council (2002)
sum, cents/gal.	24.0	
Components of mileage externalities		
congestion, cents/mi.	6.5	Parry et al. (2004)
accident, cents/mi.	4.0	Miller et al. (1998)
local pollution, cents/mi.	1.5	Parry et al. (2004)
sum, cents/mi.	12.0	
Fuel demand elasticity	-0.55	Parry/Small (2004)
portion due to VMT	0.4	Parry/Small (2004)
portion of VMT elast. due to mi./veh.	0.67	Johansson/Schipper (1997)
Initial gasoline tax, cents/gal.	40	Parry/Small (2004)
Initial retail gasoline price	150	Parry/Small (2004)
Initial (on road) fuel economy, mi./gal.	20	Parry/Small (2004)
Initial annual fuel consumption, bn. gals.	130	Energy Info. Admin. (2002)
Current insurance costs, cents/mi.	6.5	Litman (2001)

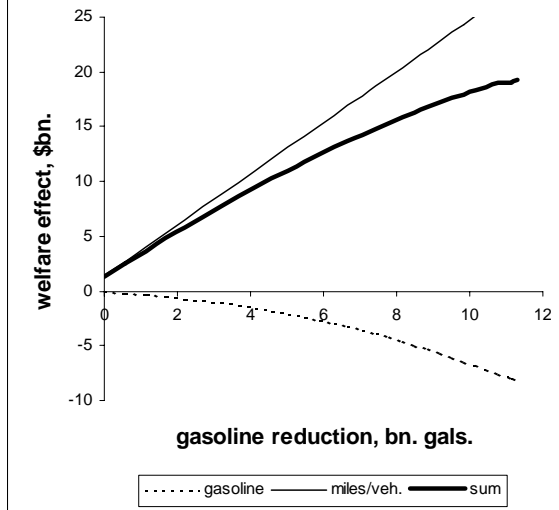
**Figure 1. Welfare Effect under Fuel Tax**



**Figure 2. Welfare Effect under VMT Tax**



**Figure 3. Welfare Effect under PAYD**



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## Footnotes

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<sup>1</sup> The discussion is related to earlier papers, by Edlin (1999) on PAYD and Ian W.H. Parry and Kenneth A. Small (2004) on fuel and VMT taxes; this paper differs by comparing welfare effects of all three policies for given fuel reductions. There are more efficient policies than PAYD to reduce mileage externalities (e.g., peak period pricing to reduce congestion), but these policies are beyond our scope.

<sup>2</sup> Current premiums give modest discounts for low-mileage, though most drivers are well above or below the threshold so the per-mile premium is effectively zero. However the more people drive, the more likely they are to crash, and face higher future premiums; by ignoring this, we moderately overstate the effectiveness of PAYD. We also abstract from vehicle registration fees, which average about \$200 per year. Incorporating them would moderately reduce efficiency gains from the VMT tax.

<sup>3</sup> If instead revenues paid for highways or cuts in other distortionary taxes, this may not greatly strengthen the case for fuel taxes vis-à-vis PAYD. Chad Shirley and Clifford Winston (2004) estimate the (average) social rate of return on highway projects is around 5%; as this is a typical discount rate used in project evaluation, this estimate suggests the social value of an additional \$1 of highway spending is approximately \$1.

Suppose instead we valued extra revenue at its dollar amount plus the efficiency gain from using it to reduce distortionary labor income taxes. However, a full assessment of fiscal interactions must account for the effect of higher driving costs on reducing real household wages and labor supply, and thereby compounding efficiency costs of labor taxes. This efficiency loss may not offset all of the gains from recycling additional fuel tax revenues if driving is a relative leisure complement (Parry and Small 2004), though it may still offset a large portion of them. Although PAYD raises no revenue for recycling, it may

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not compound efficiency costs from prior labor taxes either, as it has no first order effect on overall driving costs.

<sup>4</sup> Welfare gains from PAYD would be greater with heterogeneous agents because the reduction in driving would be more concentrated among those with greater premiums and therefore greater accident risk.