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Per-Mile Premiums for Auto Insurance

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5 Per-Mile Premiums for Auto Insurance

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... the manner in which [auto insurance] premiums are computed and paid fails miserably to bring home to the automobile user the costs he imposes in a manner that will appropriately influence his decisions.

—William Vickrey, 1968

Americans drive 2,360,000,000,000 miles each year, and the cost of auto accidents is commensurately large:[1] roughly $100 billion in accident insurance,[2] and, according to the Urban Institute (1991), an additional $320 billion in uninsured accident costs per year, far more than the cost of gasoline. (Figures are given in 1995 dollars throughout).

Every time drivers take to the road, and with each mile they drive, they expose themselves and others to the risk of accident. Surprisingly, though, most auto insurance premiums have largely lump-sum characteristics and are only weakly linked to mileage. Mileage classifications are coarse, and low-mileage discounts are extremely modest and based on self-reported estimates of future mileage that have no implicit or explicit commitment.[3] (Two noteworthy exceptions are premiums on some commercial policies[4] and a few recent pilot programs.)[5] Few drivers therefore pay or perceive a significant insurance cost from driving an extra mile, despite the substantial accident costs involved.

An ideal tort and insurance system would charge each driver the full social cost of her particular risk exposure on the marginal mile of driving. Otherwise, people will drive too much and cause too many accidents (from the vantage of economic efficiency). The extent of this potential problem is apparently severe if we consider that insurance costs almost as much as gasoline ($590 compared with $670 per year per private passenger vehicle in 1995) and that insurance costs may dramatically understate total accident costs.

In principle, insurance companies could levy a substantial charge for driving an extra mile, as new car leases do; however, this would require them to incur the cost of verifying mileage (through periodic odometer checks or by installing a monitoring and broadcasting device in vehicles). A central point of this chapter is that externalities make their incentives to do so considerably less than the social incentives. If insurance company C is able to reduce the driving of its insureds, although it will save on accident payouts, substantial "external" savings will be realized by other insurance carriers and their insureds who will get into fewer accidents with C's insureds. These externalities follow from Vickrey's observation that if two drivers get into an accident, even the safer driver is typically a "but for" cause of the accident in the sense that had the driver opted for the metro, the accident would not have occurred.[6] (see also Shavell 1987). Externalities help explain why we are only just now seeing pilot per-mile premiums programs.

Accident externalities suggest a valuable role for policy, and this chapter investigates the potential benefits of two proposals that would increase the marginal charge for driving, and consequently reduce driving and accidents. The first proposal is per-mile premiums, advocated by Litman (1997), Butler (1990), and the National Organization for Women. Under a per-mile premium system, the basic unit of exposure would shift from the car-year to the car-mile, either by requirement or by subtler policy tools, so that the total premiums of driver i would be $m_i p_i$, where m_i is the miles i travels and p_i is her per-mile rate. An individual's per-mile rate, p_i, would vary among drivers to reflect the per-mile risk of a given driver and could depend upon territory, driver age, safety records or other relevant characteristics used today for per-year rates. (In fact, the technology now used experimentally by Progressive in Texas also allows prices to vary by time of the day and by location.)[7]

The second proposal is to couple per-mile premiums with a Pigouvian tax to account for the "Vickrey" accident externality. Both these proposals differ fundamentally from the uniform per-gallon gas tax proposals of Vickrey (1968),[8] Sugarman (1993), and Tobias (1993), because under gas tax proposals, unlike per-mile premiums, the additional cost of driving would be independent of driver age, driver safety records, or in some cases of territory (all highly important indicia of risk), yet would depend upon fuel efficiency (a relatively poor risk measure).

This chapter begins by developing a simple model that relates miles driven to accidents, formalizing Vickrey's insights about the externalities of driving—this contribution is mainly pedagogical. The second contribution is to provide the first estimates of the potential benefits of per-mile premiums that take into account Vickrey's externalities as well as the resulting fact that as driving falls, so too will accident rates and per-mile premiums.[9] Third, the benefits of a per-mile premium policy are estimated coupled with a Pigouvian tax. (It's natural to consider taxing per-mile premiums to account for accident externalities once one incorporates externalities.) Finally, congestion cost reductions are included.

Nationally, the average insured cost of accidents is roughly 4 cents per mile driven, but we estimate that the marginal cost—the cost if an extra mile is driven—is much higher, roughly 7.5 cents, because of accident externalities. In high traffic-density states like New Jersey, Hawaii, or Rhode Island, we estimate that the marginal cost is roughly 15 cents. For comparison, gasoline costs roughly 6 cents per mile, so an efficient Pigouvian charge for accidents at the margin would dramatically increase the marginal cost of driving and would presumably reduce driving substantially.

Even without a Pigouvian charge to account for accident externalities, a system of per-mile premiums that shifted a fixed insurance charge to the margin would be roughly equivalent to a 70 percent hike in the gasoline price and could be expected to reduce driving nationally by 9.5 percent, and insured accident costs by $17 billion per year. After subtracting the lost driving benefits of $4.4 billion, the net accident reductions would be $12.7 billion or $75 per insured vehicle per year. The net savings would be $15.3 billion per year if per-mile premiums were taxed to account for the external effect of one person's driving on raising others' insurance premiums.

These estimates are probably a lower bound on what savings would actually be under a per-mile system, because they use state level data and assume that drivers and territories are homogeneous within a state. In a per-mile system, just as in the current per-year system, heterogeneity in accident risk would be reflected in per-mile rates that vary by territory, driver age, and driver accident record. Since the most dangerous drivers in the most dangerous territories would face the steepest rise in marginal driving cost and therefore reduce driving the most, actual benefits could be considerably larger than our estimates.

The main reason insurance companies have not switched to per-mile premiums is probably that monitoring actual mileage with yearly odometer checks appears too costly, given their potential gains, as suggested by Rea (1992) and Williamson et al. (1967, 247).[10] Our analysis suggests, however, that the gains a given insurance company could realize by switching to per-mile premiums are considerably less than the social gains. A single company and its customers might stand to gain only $31 per vehicle per year from the switch, far less than the potential social gains of $58 per insured vehicle that we estimate when we include the Vickrey externality (i.e., the reduction in others' insurance costs.) Moreover, the $31 in private gains would be temporary from an insurer's vantage and would all go to consumers once other firms match its new policies.[11] This discrepancy implies that the social gains from per-mile premiums might justify the monitoring costs (and the fixed costs of transition), even if no single insurance company could profit from the change itself.

Other external benefits could make the discrepancy between the private gains from per-mile premiums and the social gains even larger. A great deal of accident costs are uninsured or underinsured (more than half, according to the Urban Institute) and the driving reductions caused by per-mile premiums should reduce these costs just as they reduce insured accident costs.[12] Policy intervention looks more attractive still when nonaccident benefits such as congestion are taken into account. Congestion reductions raise our estimates of the benefits from per-mile premiums by $5.7 billion. This brings our estimates of total national benefits from per-mile premiums to $18.2 billion ($24.7 billion with a Pigouvian tax), or $107.5 per insured vehicle ($146.2 with a Pigouvian tax). Benefits would be higher still, if pollution costs, road maintenance costs, and other externality costs are higher than we assume here.[13]

The fact that accident and congestion externalities could make up more than two-thirds of the benefits from per-mile premiums suggests that even if monitoring costs are so large that it is rational for insurance companies to maintain the current premium structure, it is likely that per-mile premiums could still enhance efficiency in many states. Likewise, it suggests that as mileage monitoring technology becomes cheaper (e.g., global positioning system technology), insurance companies may be slower at adopting these technologies than is socially efficient.

Section 1 presents a simple model of accidents that formalizes Vickrey's insights about accident externalities and incorporates congestion. Section 2 describes the data. Section 3 simulates driving and accident reductions under per-mile premiums. Section 4 concludes and explores the policy implications of this research.

1 A Simple Model of Accidents and Congestion

A model relating driving to accidents is developed here and used to simulate the consequences of various pricing scenarios. For simplicity, an entirely symmetric model is constructed in which drivers, territory, and roads are undifferentiated and identical. The central insights continue to hold in a world where some drivers, roads, and territories are more dangerous than others, with some provisos. The relationship between aggregate accidents and aggregate miles will only hold exactly if the demand elasticity is the same across types of driving and drivers. Otherwise, accidents will be either more or less responsive to driving according to whether extra miles are driven by more or less dangerous drivers under more, or less dangerous conditions.

Attention is limited to one and two vehicle accidents, ignoring the fact that many accidents only occur because of the coincidence of three or more cars.[14] Accidents involving two or more cars are treated as if they all involve only two cars because multivehicle accidents are not separated in the accident data. Refined data would increase estimates of the benefits from the driving reductions associated with per-mile premiums because the size of accident externalities increase with the number of cars involved in collisions.

Let

m_i = miles traveled by driver i per year

M = aggregate vehicle miles traveled per year by all drivers

l = total lane miles

D = traffic density, or traffic volume = M/l

f_i = probability that i is driving at any given time

δ_1 = damages from one-vehicle accident

δ_2 = damages to each car in a two-vehicle accident

Holding speed constant, the fraction of the time that i is driving, f_i, will be proportional to the miles driven, m_i; hence $f_i = \rho m_i$, for some ρ. For convenience, imagine that the l lane miles are divided into L "locations" of equal length. An accident occurs between drivers i and j if they are in the same location and neither brakes or takes other successful evasive action. The chance that i is driving and j is in the same location is $f_i(f_j/L)$. Let q be the probability of accident conditional upon being in the same location. The expected rate of damages to i from two-car accidents with $j \neq i$ will then be

$$a_{2i,j} = \delta_2 f_i \frac{f_j}{L} q.$$

Summing over $j \neq i$ and substituting ρm_j for f_j and ρm_i for f_i yields expected damages to i from two-car accidents:

$$a_{2i} = \delta_2 \rho^2 m_i \frac{q \Sigma_{j \neq i} m_j}{L}.$$

Letting $c_2 \equiv \delta_2 \rho^2 l/L$, we have

$$a_{2i} = c_2 m_i \frac{(M - m_i)}{l},$$

or, assuming m_i is small relative to M,

$$a_{2i} \approx c_2 m_i \frac{M}{l} = c_2 m_i D.$$

Ignoring multiple-car accidents, the total expected accident damages suffered by driver i are then

$$a_i = c_1 m_i + c_2 m_i D.$$

The first term in the equation reflects the fact that a driver may be involved in an accident even if driving alone (e.g., falling asleep at night and driving into a tree), with c_1 representing the expected accident costs from driving a mile alone. The second term reflects the fact that the chance of getting into an accident with other vehicles in that mile increases as the traffic density D increases.

The linearity of this model in m_i ignores the possibility that practice and experience could bring down the per-mile risk, as well as the offsetting possibility that driving experience (which is generally a safe experience) could lead to complacency and conceit. Empirical estimates of the elasticity of an individual's accidents with respect to that individual's mileage, as surveyed in Edlin (1999), range from 0.35 to 0.92, but as Edlin (1999) discusses, this work has been limited by the scarcity of reliable microlevel data pairing mileage and accidents, and it probably yields downward biased estimates because of noisy mileage data and also because of the difficulty of controlling for the factors that cause any given driver to drive very little (which are likely related to accident propensity).[15]

Summing over each driver i yields the total accident costs:

$$A = c_1 M + c_2 MD = c_1 M + c_2 M^2/l. \tag{1}$$

Observe that the cost of two-car accidents $c_2 M^2/l$ increases with the square of total miles driven. This nonlinearity is the source of the externality effect.

The marginal total accident cost from driving an extra mile is

$$\frac{dA}{dM} = c_1 + 2c_2 D. \tag{2}$$

In contrast, the marginal cost of accidents to driver i is only

$$\frac{da_i}{dm_i} = c_1 + c_2 D. \tag{3}$$

The difference between these two costs, $c_2 D$, is the externality effect. It represents the fact that when driver i gets in an accident with another driver, driver i is typically the "but for" cause of both drivers' damages in the sense that, "but for" driver i having been driving, the accident would not have happened. (Strangely enough, it is entirely possible that both drivers are the "but for" cause of *all* damages). This model could overstate the externality effect because of accident substitution: if driver A and B collide, it is possible that driver A would have hit driver C if driver B weren't there. On the other hand, it understates the externality effect to the extent that some collisions require more than two vehicles.

A different view of the accident externality of driving is found by observing that the average cost of accidents per mile driven is:

$$\frac{A}{M} = c_1 + c_2 D. \tag{4}$$

A given driver who drives the typical mile expects to experience the average damages A/M. Yet, this driver also increases D, which means that this driver also causes the accident rate for others to rise at a rate of $(d(A/M))/(dM) = c_2(dD)/(dM) = c_2/l$. Multiplying this figure by the M vehicle miles of driving affected again yields an externality c_2D.

The basic "micro" intuition behind the accident externality is simple. If a person decides to go out driving instead of staying at home or using public transportation, she may end up in an accident, and some of the cost of the accident will not be borne by either her or her insurance company; some of the accident cost is borne by the other party to the accident or that party's insurance company. Although the average mile is not subsidized, the marginal mile is![16] The "macro" intuition is that the more people drive on the same roads, the more dangerous driving becomes. (A little introspection will probably convince most readers that crowded roadways are more dangerous than open ones; in heavy traffic, most drivers feel compelled to a constant vigilance to avoid the numerous moving hazards.)[17] A given driver or insurance company pays the average cost of accidents. The driver does not pay for the fact that driving raises the average cost of others through a crowding effect.

1.1 *Gains from Per-Mile Premiums*

The current insurance system, which is characterized (somewhat unfairly as note 3 concedes) as involving lump-sum premiums, is now compared with two alternative systems: (1) competitive per-mile premiums and (2) Pigouvian per-mile premiums. As derived above, the break-even condition for insurance companies charging per-mile premiums is

$$p = \frac{A}{M} = c_1 + c_2M/l. \tag{5}$$

This equation can be viewed as the supply curve for insurance as a function of the number of vehicle miles travelled requiring insurance. In a more sophisticated model, and in practice, rates would vary by risk class i, and break-even competitive prices would be $p_i = A_i/M_i = c_{1i} + c_{2i}M/l$.

Let the utility of each of the n drivers be quasi-linear in the consumption of nondriving goods y and quadratic in miles m:

$$V(y,m) = y + am - \frac{n}{b}m^2. \tag{6}$$

Then, the aggregate demand for vehicle miles traveled will be linear:

$$M = M_0 - bp\frac{n}{2}. \tag{7}$$

The equilibrium miles, M^*, and per-mile price, p^*, are found by solving (5) and (7). If drivers continued to drive as much under per-mile premiums as they do under per-year, that is, if $b = 0$ so that demand were completely inelastic, then competitive insurance companies would break-even by charging

$$p = c_1 + c_2M_0/l.$$

For $b > 0$, however, as driving falls in reaction to this charge, the accident rate per-mile will also fall (because there will be fewer cars on the road with whom to collide). As the per-mile accident rate falls, premiums will fall in a competitive insurance industry, as we move down the average cost curve given by (5).

Figure 5.1 depicts the situation. Let c_0 be the nonaccident costs of driving (gas, maintenance, etc.) and assume that drivers pay these costs in addition to per-mile insurance premiums p. If drivers pay per-year premiums so that $p = 0$, then they demand M_0 miles of driving. The social gain from charging per-mile accident premiums p^* in this model equals the reduction in accident costs less the lost benefits from foregone driving, the shaded region in figure 5.1. This surplus S is given by

$$S = \frac{1}{2}\left(\left.\frac{dA}{dM}\right|_{M_0} + \left.\frac{dA}{dM}\right|_{M^*}\right)(M_0 - M^*) - \frac{1}{2}p^*(M_0 - M^*). \tag{8}$$

The first term is the reduction in accident costs that results from a fall in driving from M_0 to M^*. The second is the driving benefits lost from this reduction net of the nonaccident cost savings $c_0(M_0 - M^*)$.

The marginal accident cost dA/dM is given by (2). Note that because the marginal accident cost dA/dM lies above the average cost A/M, the competitive per-mile premium $p^* = A/M$ is less than the socially optimal accident charge p^{**} which would lead to M^{**} miles being driven, as depicted in figure 5.1. Competition does not yield socially optimal accident charges because of the accident externality.

For optimal charges, the government would need to impose a Pigouvian tax of $[(dA/dM|_{M^{**}})/(A/M^{**}) - 1] \times 100$ percent on insurance premiums A/M^{**} to yield Pigouvian per-mile premiums. Pigouvian per-mile premiums could be implemented with a uniform

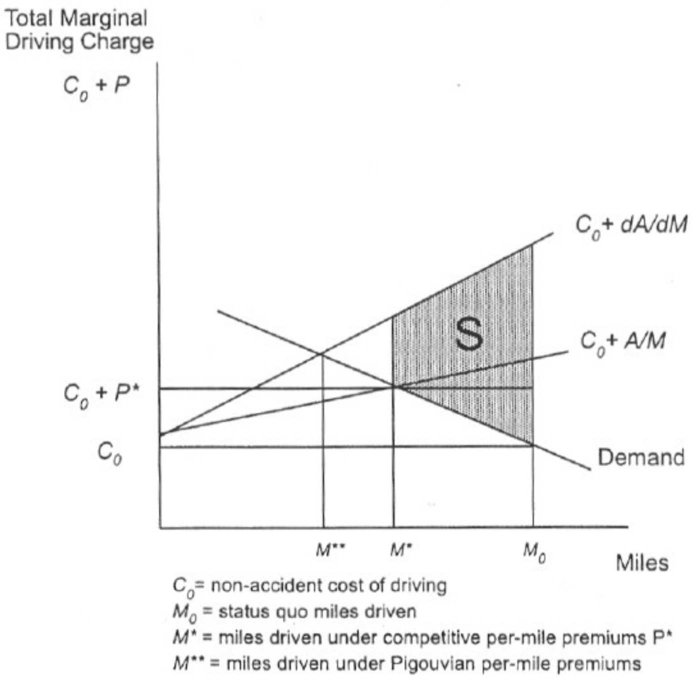

Figure 5.1
The social gains from per-mile premiums

percentage tax on competitive per-mile premiums in either a fault-based tort system or a no-fault tort system, as long as every driver stands an equal chance of being at fault. If drivers differ in fault propensity, then it will be easier to impose Pigouvian taxes in a no-fault system: In a fault-based system, by contrast, the percentage tax rate would need to vary among people, and curiously it would need to be higher for faultless drivers because they will frequently be nonnegligent despite being as much a "but for" cause of accidents as faulty drivers.

The benefit calculation assumes that the number of drivers would remain unchanged in a switch to per-mile premiums. In fact, the number of drivers would probably increase under a per-mile system because the total price of a small amount of driving (say 2,000 miles per year) would fall. Although the extra drivers, who drive relatively little, will limit driving reductions and hence accident reductions somewhat, they would probably increase the accident savings net of

lost driving benefits. The reason is that these extra drivers gain substantial driving benefits, as evidenced by their willingness to pay insurance premiums. In the case of Pigouvian per-mile premiums, the entry of these extra drivers necessarily increases the benefits from accident cost reductions net of lost driving benefits.

2 Data

As a proxy for auto accident costs, A in the model above, state-level data are used on total private passenger auto insurance premiums from the National Association of Auto Insurance Commissioners (1998, table 7). Premiums paid for comprehensive coverage are subtracted, so that we are left only with accident coverage. If the insurance industry is competitive, these figures represent the true economic measure of insured accident costs, which includes the administrative cost of the insurance industry and an ordinary return on the capital of that industry. These premium data are for private passenger vehicles, so we adjust these figures to account for commercial premiums by multiplying by 1.14, the national ratio of total premiums to noncommercial premiums.[18]

Insured accident costs do not come close to comprising all accident costs. The pain and suffering of at fault drivers is not insured, for example, and auto insurance frequently does not cover their lost wages. (In no-fault states, pain and suffering is also not compensated below certain thresholds). These omitted damages are substantial and their inclusion would raise our estimates of the cost of driving and the benefit of driving reduction significantly. Pain and suffering is often taken to be three times the economic losses from bodily injury. In addition, out of pocket costs are also not fully compensated according to Dewees, Duff, and Trebilcock (1996).

Other data come from a variety of sources. Data on the miles of lanes by state come from table HM-60, 1996 Highway Statistics, FHWA. Annual vehicle miles by state come from table VM-2, 1996 Highway Statistics, FHWA. Data on the distribution of fuel efficiency among vehicles in the current U.S. fleet, and the distribution of miles by fuel efficiency of car come from the 1994 Residential Transportation Energy Consumption Survey. Gasoline prices by state come from the Petroleum Marketing Monthly, EIA, table 31 ("all grades, sales to end users through retail outlets excluding taxes") and table EN-1 (federal and state motor gasoline taxes).

3 Policy Simulations

3.1 *Methodology*

This section estimates and compares the potential benefits of charging per-mile premiums with and without a Pigouvian tax. Competitive per-mile premiums are determined for each of the fifty states s by calibrating equations (7) and (5) with state data and gas elasticity studies and then solving them for M_s^* and p_s^*; equilibrium per-mile premiums are just sufficient to allow insurance companies to break even, exactly covering accident costs. The Pigouvian per-mile premiums simulations assume a tax on premiums to account for the externalities of accidents. Both sets of simulations assume that an individual pays premiums in proportion to the miles she drives.

The consequences of each policy option are estimated under two models of accident determination—linear and quadratic. The linear model assumes that accident costs in state s are proportional to miles driven, namely, that $A_s = c_{1s}M_s$. The coefficient c_{1s} is estimated by dividing total accident insurance premiums A_s by total miles driven M_s. The linear model takes no account of the externalities from driving, nor the related fact that as people reduce their driving, accident rates per mile should fall because there are fewer drivers on the road with whom to have an accident.

The quadratic model includes a term that is quadratic in miles as in equation (1) to account for the externality effect. The one and two-car accident coefficients are determined for the quadratic model as described in the appendix.

A linear model is estimated for two reasons. First, the efficiency savings under a linear model are the straightforward gains from more efficient contracting that a single company (with a small market share) and its customers could together expect to receive if they alone switched to per-mile pricing. (Once other firms followed suit all these gains would go to customers.) Comparing the linear model with the quadratic model, therefore, allows us to see how much of the accident savings are external to a given driver and insurance company. The second reason to be interested in the linear model results is the possibility of substantial learning-by-doing in driving. If driving more lowers an individual's accident rate so that the typical individual has an accident elasticity with respect to miles of 1/2,[19] then after accounting for the externality effect, the aggregate

elasticity of accidents with respect to miles should be approximately 1 as assumed in the linear model.

Estimates of the results of these policies naturally depend upon the price responsiveness of driving. Estimates of the price responsiveness of driving are plentiful and generally come from observed changes in the price of gasoline. Edlin (2002) provides a methodology for converting gasoline demand elasticities into elasticities with respect to per-mile charges using the fuel efficiency composition of the existing U.S. vehicle fleet.

The benchmark case here assumes that the aggregate elasticity of gasoline demand with respect to the price of gasoline is 0.15. This figure is 25 percent lower than the short-run elasticity of 0.2 that the two comprehensive surveys by Dahl and Sterner (1991 a,b) conclude is the most plausible estimate, and also substantially lower than the miles elasticity estimated by Gallini (1983). From the perspective of social policy, we should be interested in long run elasticities, which appear to be considerably larger than short run. Edlin (2002) discusses short and long run elasticity estimates more extensively. Edlin (2002) also provides details on calibrating the model of section 1 in each state, and on simulating the consequences of per-mile premiums.

3.2 *Equilibrium Per-Mile Premiums and Driving Reductions*

Table 5.1 presents estimates of equilibrium per-mile premiums and driving reductions, assuming a competitive insurance industry that sets per-mile premiums equal to the average insurance cost of accidents per mile driven in selected states. For all states, see Edlin (2002). Equilibrium per-mile premiums are quite high, exceeding the cost of gasoline in many states. Even with the modest gasoline price elasticity of 0.15 assumed here, the resulting driving reduction is substantial. The national reduction in vehicle miles traveled, $M_0 - M^*$, is approximately 10 percent in both models, and exceeds 15 percent in high-traffic states.

Reductions in driving would naturally be much larger in states that currently have high insurance costs and would thus face high per-mile premiums. Since New Jersey currently has much higher insurance costs per vehicle mile traveled (VMT) than Wyoming, for example, we estimate that equilibrium per-mile premiums would be 6.5 cents per-mile in New Jersey compared with 1.8 cents in Wyo-

Table 5.1
Per-mile premiums: Equilibrium charges and driving reductions

	$A = c_1M + c_2M^2/l$ Quadratic model		$A = c_1M$ Linear model	
Selected states	Marginal charge (cents/mile)	VMT reductions (percentage)	Marginal charge (cents/mile)	VMT reductions (percentage)
Delaware	4.4	10.9	4.9	12.1
Hawaii	6.8	15.4	7.9	18.0
Massachusetts	5.8	14.2	6.7	16.4
New Jersey	6.5	16.4	7.7	19.4
New York	5.6	13.7	6.4	15.6
Ohio	3.3	8.4	3.6	9.1
Oklahoma	2.5	6.5	2.6	6.8
Wyoming	1.8	4.4	1.8	4.6
All U.S.		9.2		10.0

Note: In 1995 dollars.

ming, and that these changes would reduce New Jersey's VMT by 16.4 percent and Wyoming's by 4.4 percent.

The driving reduction is somewhat less in the quadratic model than it is in the linear ones, because in the quadratic model, as driving is reduced, the risk of accidents also falls and with it per-mile premiums. In Massachusetts, the per-mile charge falls from 6.7 cents per mile to 5.8 cents per mile as driving is reduced. Since equilibrium per-mile premiums are lower in the quadratic model, the total driving reduction is lower than in the linear model.

Per-mile premiums estimates here have not been adjusted for uninsured drivers because data on the percentage of uninsured drivers is poor. Actual premiums would likely be higher as a result, but it wouldn't change estimates of aggregate driving reductions significantly because even though the per-mile premium would be higher for insured miles, it would be zero for uninsured miles.[20]

3.3 *Accident Cost Reductions Net of Lost Driving Benefits*

Estimates show that the driving reductions under per-mile premiums would in turn reduce insurance (and accident) costs by $17 billion in total across the United States according to the quadratic model. Even after subtracting lost driving benefits (the second term

Table 5.2
Yearly accident savings from per-mile premiums (net of lost driving benefits)

	$A = c_1M + c_2M^2/l$ Quadratic model		$A = c_1M$ Linear model	
Selected states	Total (millions of $)	Per insured vehicle ($)	Total (millions of $)	Per insured vehicle ($)
Delaware	54	106	22	43
Hawaii	132	188	57	81
Massachusetts	622	155	263	66
New Jersey	1040	198	453	86
New York	1339	139	574	60
Ohio	410	52	165	21
Oklahoma	80	34	35	15
Wyoming	6	16	3	8
All U.S.	12686	$75	5310	$31

Note: In 1995 dollars.

in equation (8)), the benefits remain substantial in both models. Nationally, these net accident savings range from $5.3 billion to $12.7 billion per year, as table 5.2 reports.

The difference between the $5.3 billion estimate under the linear model and the $12.7 billion under the quadratic model is dramatic: accounting for accident externalities raises the estimate of benefits by 150 percent. Such a large difference makes sense. If a price change for driver A causes her to drive less, much of her reduction in accident losses is offset by her lost driving benefits. In contrast, every driver with whom she might have had an accident, gains outright from the reduced probability of having an accident with A who is driving less. Taking this externality effect into account, nationally, the net gain is $75 per insured vehicle under the quadratic model, as reported in table 5.3. Since insurance companies and their customers don't take the externality benefits into account, however, their view of the gain from per-mile premiums is probably closer to the $31 of the linear model. In high traffic density states, the gain per insured vehicle is quite high—approximately $150 in Massachusetts and New York and nearly $200 in Hawaii and New Jersey in the quadratic model.

A Pigouvian accident tax has the potential to raise benefits still further. In the quadratic model, which takes account of the accident externalities, the marginal cost of accidents exceeds the average cost.

Table 5.3
U.S. benefits from other premium schedules

	Quadratic model	Linear model
Per-mile premiums		
Net accident savings		
U.S. total (billions of dollars)	12.7	5.3
Per insured vehicle (dollars)	75.0	31.4
Reduced delay costs (external)		
U.S. total (billions of dollars)	5.5	6.0
Per insured vehicle (dollars)	32.5	35.6
Total benefits		
U.S. total (billions of dollars)	18.2	11.3
Per insured vehicle (dollars)	107.5	67.0
Pigouvian tax and per-mile premiums		
Net accident savings		
U.S. total (billions of dollars)	15.3	5.3
Per insured vehicle (dollars)	90.6	31.4
Reduced delay costs (external)		
U.S. total (billions of dollars)	9.4	6.0
Per insured vehicle (dollars)	55.6	35.6
Total benefits		
U.S. total (billions of dollars)	24.7	11.3
Per insured vehicle (dollars)	146.2	67.0

Note: In 1995 dollars.

In consequence, the Pigouvian tax is substantial: an appropriate Pigouvian tax would be about 90 percent on insurance premiums in high traffic density states such as New Jersey and about 40 percent in low density states like North Dakota. On average across the United States, the Pigouvian tax would be 83 percent under the quadratic model. The Pigouvian tax makes national driving reductions 15.7 percent instead of 9.2 percent. National net accident savings grow to $15.3 billion from $12.7 billion per year as seen in table 5.3.

As the introduction points out, benefit estimates here are biased downward because we use aggregate data at the state level, thereby not taking into account the substantial heterogeneity by territory and by driver in accident costs. Per-mile premium policies would most likely be implemented so that per-mile rates varied among drivers or vehicles based upon the same territory, driving record, and other factors that are currently used to vary per-year rates. If high-risk

drivers (whether because of age, territory, or other factors) pay the highest per-mile rates, then driving reductions will be concentrated among these drivers, where they are most effective at reducing accidents.

All of these benefit estimates depend critically on driving elasticities. Driving reductions and net accident savings are higher (respectively lower) if the aggregate gas demand elasticity is higher (respectively lower) than 0.15. Nationally, net accident benefits go from $9 billion for an elasticity of 0.1 to $16 billion for an elasticity of 0.2 in the quadratic model.

Our simulations ignore the fact that more drivers will choose to become insured once they have the option of economizing on insurance premiums by only driving a few miles. Today, some of these low-mileage drivers are driving uninsured while others are not driving at all. To the extent that per-mile premiums attract new drivers, the reduction in vehicle miles traveled will not be as large as our simulations predict. Surprisingly, though, this observation does not mean that the social benefits are lower than predicted. In fact, they are probably higher. The per-year insurance system is inefficient to the extent that low-mileage drivers who would be willing to pay the true accident cost of their driving choose not to drive, because they must currently pay the accident cost of those driving many more miles. Giving them an opportunity to drive and pay by the mile creates surplus if their driving benefits exceed the social cost. (Their benefits would always exceed the social cost under Pigouvian per-mile premiums since they are choosing to pay the social cost.)

3.4 *Delay Costs from Congestion*

Congestion will fall if driving is reduced, and this constitutes one ancillary benefit of per-mile premiums and of the Pigouvian accident tax. In a fundamental respect, congestion is the counterpart to accidents. In the simplest model of congestion, congestion occurs when driver i and j would be in the same location at the same time except that one or both brakes to avoid an accident. Such a formulation undoubtedly understates the marginal cost of congestion substantially, because as two vehicles slow down they generally force others to slow down as well. A cascade of such effects becomes a traffic jam. Indeed, measured traffic flow rates as a function of the number of cars traveling suggest that during periods of congestion the marginal congestion cost of driving is often many times, up to and exceeding ten times, the average congestion experienced—at least during highly congested periods.[21]

Congestion cost savings that are external to the driving decision should also be added to the benefits from per-mile premiums. Assuming that the mile foregone is a representative mile and not a mile drawn from a particularly congested or uncongested time, the person foregoing the mile will escape the average cost of delay. This savings should not be counted, though, among our benefits from driving reductions because it is internalized. Viewed differently, each person derives no net benefit from her marginal mile of driving, because she chooses to drive more miles until driving benefits net of congestion cost just equal operating costs. Yet, as there is less traffic on the road, other drivers will experience reduced delays and this external effect should be added to our calculations. The external effect, as with accidents, equals the difference between the marginal and average cost of delay. To be conservative in our simulations, we ignore the traffic jam cascade discussed above and assume that the marginal cost of congestion is twice the average cost, so that the portion of the marginal cost that is external to the driving decision equals the average cost.

A detailed study by Schrank, Turner, and Lomax (1995) estimates that the total cost of congestion in the form of delay and increased fuel consumption in the United States exceeded $49 billion in 1992 and $31 billion in 1987 in 1995 dollars.[22] This study valued time at $8.50/hr. in 1987 and $10.50/hr. in 1992, which would appear a considerable undercounting to those who would far prefer to be at work than stuck in a traffic jam. If we project this figure to $60 billion in 1995, this amounts to an average delay cost of 2.5 cents for every mile driven. Under the assumption above the average delay cost equals the external marginal cost from congestion.

Table 5.3 gives estimates of the national portion of congestion reduction that is external and should be added to net accident benefits. In all models, estimated externalized gains from congestion reductions are large, ranging from $5.5 billion to $9.4 billion per year as seen in table 5.3.

These calculations are based upon the average cost of delay. Congestion delays are concentrated during certain peak time periods and at certain locations. It turns out that this fact simply means that the congestion reductions from per-mile pricing are concentrated

during these time periods and these locations. Our calculations are robust provided that the elasticities of demand for congested miles and noncongested miles are comparable, and that the externalized marginal cost is a constant multiple of average cost.[23] The concentration of congestion costs simply suggests that we would be even better off if driving were priced particularly high during congested periods and somewhat lower otherwise.

3.5 *Total Benefits*

Table 5.3 gives total estimated annual national benefits from competitive per-mile premiums and Pigouvian per-mile premiums. The total benefits are expressed both in aggregate and per insured vehicle. These annual benefits are quite high and suggest that charging by the mile on a national basis would be socially beneficial if verifying miles could be achieved for less than $107.50 per car each year. In some high traffic density states, per-mile premiums could be socially beneficial even if the cost of verifying miles approached $200 per vehicle. External benefits made up $13 billion of estimated benefits from per-mile premiums since net accident savings were only $5 billion under the linear model, as reported in table 5.3. The gains with a Pigouvian tax were $146 per insured vehicle nationally.

The total benefits are quite large even for the linear model where accidents are proportional to mileage. Under the linear model, the total benefits of per-mile premiums are $67 per insured vehicle. As mentioned early, this model would be roughly accurate if individual elasticities of accidents with respect to miles were 0.5, because then the externality effect would make the social elasticity roughly one, as in a linear model.

The methodology used here might overstate accident externalities because the theoretical model does not account for accident substitution (the possibility that an accident would have occurred even if one involved vehicle were not there), or understate externalities because many accidents require the coincidence of more than two cars at the same place at the same time. A potential upward bias results because c_1 and c_2 are held constant, which does does not account for the fact that as driving becomes more dangerous, drivers and states take precautionary measures. States react to higher accident rates with higher expenditures on safety by widening roads and lengthening freeway on-ramps. Drivers also make financial expenditures, buying air bags or anti-lock brakes, and nonfinancial expenditures, by paying more attention and slowing down to avoid accidents when driving in heavy traffic. All these precautionary measures mitigate the impact of extra traffic density on accidents. At the margin, if precautions are chosen optimally so that the marginal cost of precautions equals their marginal benefit, then the envelope theorem guarantees that we would still be properly capturing the sum of accident and prevention costs (i.e., we can treat prevention as being fixed). On balance, the estimation methodology appears reasonable even if rough. The regression results of Edlin and Karaca (2002) suggest that the calibration methodology in this chapter understates externalities.

A final caution is that these estimates neglect environmental gains that would result if the current price of gasoline does not adequately account for emissions, noise pollution, and road maintenance. Likewise, they would overstate gains if current gasoline taxes exceed those nonaccident noncongestion costs. Our estimates also did not account for underinsured and uninsured accident costs. Including these latter figures into estimates of eliminated accident externalities would raise the estimated benefits by several billion dollars more.

4 Conclusions and Policy Implications

In both models, the aggregate benefits of per-mile premiums are quite large. They are concentrated in states with high traffic density where accident costs and the externality effect appear particularly large. Aggregate benefits reach $11 billion nationally, or over $67 per insured vehicle even under the linear model, and are substantially larger ($18 billion) under the quadratic model. In high traffic density states like New Jersey, the benefits from reduced accident costs, net of lost driving benefits could be as high as $198 per insured vehicle, as indicated in table 5.2.

Why then are most premiums so weakly linked to actual mileage and closer to per-year than per-mile premiums? Standard contracting analysis predicts that an insurance company and its customers would not strike a deal with a lump-sum premium if an individual's accidents increase with his driving, and if vehicle miles are freely observable. By reducing or eliminating the lump-sum portion and charging the marginal claim cost for each mile of driving, the contract can be made more profitable for the insurance company and also more attractive to its customers: as individuals reduce their driving, the insurance carrier saves more in claims than customers lose driving benefits. Hence the "mystery."

The primary reason we don't see per-mile premiums is probably monitoring costs, the reason suggested by Rea (1992) and by some insurance executives. Traditionally the only reliable means of verifying mileage was thought to be bringing a vehicle to an odometer-checking station. In addition to the monitoring costs involved, a firm charging per-mile premiums would also suffer abnormally high claims from those who committed odometer fraud. The significance of monitoring costs/fraud costs as an explanation is supported by the fact that commercial policies (where the stakes are larger) are sometimes per-mile, and now that cheap technologies exist that allow mileage verification at a distance, at least two firms are now experimenting with per-mile premiums (see the introduction). Adverse selection provides another explanation that tends to close the per-mile premiums market.[24]

If monitoring costs are what limit the use of per-mile premiums policies, then to encourage their use would appear unwise because lack of use may be a good signal that the policies' benefits do not justify their costs. This chapter highlights another reason, though, why such policies are not common, a reason that suggests policy intervention could be valuable. In particular, the social gains from accident reduction as drivers reduce driving could substantially exceed the private gains (realized by drivers and insurance carriers), at least in high-traffic density states. In New Jersey, for example, estimates show that the private gains as captured by the linear model are $86 per insured vehicle as compared with social gains of $198 once external gains are included (see table 5.2). Hence, most of the benefits from switching to per-mile premiums or some other premiums schedule that reduces driving are *external*. The accident externality is surely one big reason that insurance companies have not made such a switch. If monitoring costs and other transaction costs lie in the gap between $86 and $198, then per-mile premiums would be efficient in New Jersey, but they might not materialize in a free market. Congestion reductions make the external benefits from per-mile premiums even larger, increasing the chance of market failure.

Mandating per-mile premiums as the Texas legislature recently considered and rejected might be unwise, though, even if per-mile premiums are efficient on average, because monitoring costs remain substantial and could vary across individuals. (Heterogeneity across individuals favors policy options that would allow more individual flexibility.) Even if mandates are not justified, if driving does cause substantial external accident costs as the theory and the empirical work here suggest, then some policy action could be justified.

The simplest policy option in states such as Massachusetts, which already have regular checks of automobiles for safety or emissions, would be to record odometer readings at these checks and transfer this information together with vehicle identification numbers to insurance companies. This would remove the need for special stations for odometer checking, or for installing special monitoring devices in vehicles. Private monitoring costs would also be reduced if the government increased sanctions for odometer fraud. Legislation such as the new Texas law that legalizes or otherwise facilitates switching the insurance risk exposure unit from the vehicle-year to the vehicle-mile can only help.

A second policy option would be to impose a tax on premiums sufficient to account for the accident externality of an additional driver. If insurance companies continued to have a weak mileage-premiums link, then people would at least still face efficient incentives at the margin of whether to become drivers. Moreover, insurance companies then would have increased incentives to create a strong mileage-premiums link, and drivers would face second-best incentives at the margin of deciding how many miles to drive. By making insurers pay the total social accident costs imposed by each of their drivers, a tax would give insurers the incentive to take all cost-effective measures to reduce this total cost. An externality tax would align the private incentives to incur monitoring costs and to charge per-mile premiums with the social incentives, so that insurance companies would switch premium structures to per-mile or to a schedule that better reflects accident cost whenever monitoring costs and transition costs become low enough to justify the switch. Such a tax would also make per-mile premiums higher to reflect both per-mile claim costs and the tax. The consequent driving, accident, and delay reductions would likewise be larger. An alternative to a tax that would be more difficult to administer, but perhaps easier to legislate, would be a subsidy to insurance companies that reduce their customers' driving equal to the resulting external accident cost reductions.

Another possible policy option would be to require insurance companies to offer a choice of per-mile or per-year premiums (at reasonable rates) as proposed by the National Organization for Women. A fourth option would be to facilitate the formation of an insurance clearinghouse that allowed individual per-mile premiums to be paid or billed at the pump when gasoline is purchased—again, an attempt to lower monitoring costs.

Wisdom demands, however, that enthusiasm for costly policy changes be tempered until more research is done in this area. Estimates used here are only a first cut and suffer from all the potential biases suggested and no doubt some we neglected to mention. Future research should include covariates and panel data. Simulation estimates here of the benefits from per-mile premiums and of the Pigouvian tax depend upon the size of the externality effect, the assumed linear accident/mileage profile for individuals,[25] the responsiveness of driving to price, and use of insured accident costs. Each of these areas warrants considerably more examination. For example, if the estimates of the Urban Institute (1991) are correct, and total accident costs are 4.2 times higher than the insured costs considered here, then the true benefits of premium restructuring could be much larger than estimated. Finally, we note that it would also be quite informative to break down externalities by vehicle type.

Appendix
Estimation of the Quadratic Model for Each State

To estimate a quadratic accident model for each state, we modify the model of section 1, assuming that each state's idiosyncratic errors ε_s enter multiplicatively as follows:

$$\frac{A_s}{M_s} = (c_1 + c_2 D_s)(1 + \varepsilon_s). \tag{9}$$

$$= c_{1s} + c_{2s} D_s, \tag{10}$$

where, $c_{1s} = c_1(1 + \varepsilon_s), c_{2s} = c_2(1 + \varepsilon_s)$ and where s indexes states.

We utilize national data on the percentage of accidents involving multiple cars. Assume that national accident costs are given by

$$A = c_1 M + c_2 MD,$$

where the costs of one- and two-car accidents are, respectively,

$$A_1 = c_1 M$$

and

$$A_2 = c_2 MD.$$

Let $\bar{a}$ be the average damage per insured vehicle from an accident, so that two-vehicle accidents have total damages of $2\bar{a}$ and one-vehicle accidents have damages $\bar{a}$. Let r denote the proportion of accidents that involve two vehicles. (Nationally, 71 percent of crashes were multiple-vehicle crashes in 1996, and we assume that multicar accidents involve only two cars, since we don't have data on the number of cars in multicar accidents and since this assumption makes our benefit estimate conservative.)[26]

If N is the total number of accidents in a state we have

$$A = N(1-r)\bar{a} + 2Nr\bar{a},$$

so that

$$N\bar{a} = \frac{A}{1+r}.$$

This implies that the total cost of one-car accidents is

$$A_1 = \frac{(1-r)}{1+r}A,$$

and similarly for two-car accidents

$$A_2 = \frac{2r}{1+r}A.$$

The one and two-car accident coefficients can then be determined from the formulas:

$$\hat{c}_1 = \frac{A_1}{M} = \frac{(1-r)A}{1+r}\frac{1}{M}$$

and

$$\hat{c}_2 = \frac{A_2}{M^2}l = \frac{2r}{1+r}A\frac{l}{M^2}.$$

Using the observed national data on accident costs (A), miles traveled (M), and lane miles (l), we estimate that the one-vehicle coefficient $\hat{c}_1$ is roughly .007 dollars per-mile, while $\hat{c}_2$ is 1.1×10^{-7} dollars per-mile squared per lane mile. This means that roughly 18 percent of costs are attributed to one-car accidents.

We find the state-specific coefficients for one and two vehicle accidents as follows:

$$\hat{c}_{1s} = \hat{c}_1(1+\hat{\varepsilon}_s)$$

$$\hat{c}_{2s} = \hat{c}_2(1+\hat{\varepsilon}_s)$$

$$\hat{\varepsilon}_s = \frac{A_s}{\hat{c}_1 M_s + \hat{c}_2 M_s D_s} - 1.$$

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Notes

1. U.S. Department of Commerce (1997, table 1030). Figure for 1994.

2. After subtracting comprehensive insurance coverage, which covers fire, theft, vandalism and other incidents unrelated to the amount of driving, the remaining premiums for private passenger vehicles totaled $84 billion in 1995 in 1995 dollars. See National Association of Insurance Commissioners (1997). In additon, commercial premiums are approximately 15 percent of premiums for private passenger vehicles. Insurance Information Institute (1998, 22).

3. For example, State Farm distinguishes drivers based upon whether they report an estimated annual mileage of under or over 7,500 miles. Drivers who estimate annual

mileages of under 7,500 miles receive 15 percent discounts (5 percent in Massachusetts). The 15 percent discount is modest given that those who drive less than 7,500 miles per year drive an average of 3,600 miles compared to 13,000 miles for those who drive over 7,500 per year, according to author's calculations from the 1994 Residential Transportation Energy Consumption Survey of the Department of Energy, Energy Information Administration. The implied elasticity of accident costs with respect to miles is 0.05, an order of magnitude below what the evidence suggests is the private or social elasticity of accident costs. The link between driving and premiums may be attenuated in part because there is significant noise in self-reported estimates of future mileage, estimates whose accuracy does not affect insurance pay-outs.

Insurance companies also classify based upon the distance of a commute to work. These categories, however, are also coarse. State Farm, for example, classifies cars based upon whether they are used for commuting less than 20 miles per week, in between 20 and 100 miles per week, or over 100 miles per week.

Finally, miles driven are indirectly factored into premiums through experience rating, so that premiums rise with accidents. To the extent that insurance companies offer customers banking services (a loan upon accident), miles are priced in the form of higher future premiums. People certainly take experience rating into account when deciding whether to report an accident, but it seems doubtful that they do so when deciding how much to drive. Our estimates assume that they do not.

4. For private and public livery, taxicabs, and buses, because "rates are high and because there is no risk when the car is not in operation, a system of rating has been devised on an earnings basis per $100 of gross receipts or on a mileage basis" (Bickelhaupt 1983, 613). For details on per-mile commercial insurance, see "Commercial Automobile Supplementary Rating Procedures," Insurance Services Office.

5. One experiment is in Texas and another in the U.K. See *Wall Street Journal* (1999), or Carnahan (2000) for information on the Texas pilot program run by Progressive Corporation and ⟨*http://news.bbc.co.uk/hi/englishbusiness/newsid-1831000/1831181.stm*⟩, ⟨*http://www.norwich-union.co.uk*⟩ for information on Norwich-Union's program in the U.K.

6. Likely exceptions include accidents where a driver plows into a long line of cars.

7. See *Wall Street Journal* (1999).

8. Vickrey's first suggestion was that auto insurance be bundled with tires hoping that the wear on a tire would be roughly proportional to the amount it is driven. He worried about moral hazard (using a tire until it was threadbare), but concluded that this problem would be limited if refunds were issued in proportion to the amount of tread remaining.

9. Externalities turn out to increase the benefit estimates by 140 percent, over what one would calculate in a linear model of accidents (i.e., a model without externalities) as studied by Litman (1987) and Rea (1992).

10. Monitoring costs are cited as the principal reason by actuaries I have interviewed (see also Nelson 1990).

11. In a competitive industry, insurance companies cannot profit from a coordinated change because the efficiency gains would be competed away in lower prices.

12. See, for example, Dewees, Duff, and Trebilcock (1996) for evidence of substantial undercompensation. See also the estimates of the Urban Institute (1991).

13. We assume in this article that existing gasoline taxes of 20–40 cents per gallon account for these costs. Many estimates, however, suggest that these costs may be much higher. Delucchi (1997) estimates that the pollution costs of motor vehicles in terms of extra mortality and morbidity are $26.5 to 461.9 billion per year in the United States.

14. For example, one car may stop suddenly causing the car behind to switch lanes to avoid a collision—the accident occurs only if another car is unluckily in the adjacent lane.

15. For an example of such a downward bias, consider Hu et al. (1998) who study an elderly population. Omitted bad health variables seem likely to be positively correlated with worse driving and probably with less driving as well. Mileage data in that study also come from surveys and seem highly susceptible to measurement error.

16. Another way to derive our formula for accidents, in which two-vehicle accidents are proportional to the square of miles driven, is to begin with the premise that the marginal cost of a mile of driving equals the expected cost of accidents to both parties that will occur during that mile: $dA_{2-car}/dM = 2(A_{2-car}/M)$. The unique solution to this differential equation, in which the elasticity of accidents with respect to miles is 2, is $A_{2-car} = c_2M^2$.

17. This vigilance no doubt works to offset the dangers we perceive but seems unlikely to completely counter balance them. Note also that the cost of stress and tension that we experience in traffic are partly accident avoidance costs and should properly be included in a full measure of accident externality costs.

18. See p. 22 in the Insurance Information Institute 1998 Fact Book.

19. See, for example, the estimates in Hu et al. (1998) that were discussed in Edlin (1999).

20. Let u be the fraction of uninsured drivers and $\hat{p}$ be our estimate of true per-mile premiums. If premium $\hat{p}/(1-u)$ is charged on $(1-u)$ percent of miles, then the aggregate mile reduction is identical to our estimate given linear demand. Some revenue shortfall could be expected because priced miles fall by a larger percentage than in our estimate. This is approximately offset, however, by the fact that insured accident losses could be expected to fall by more than we estimate, because driving reductions would be concentrated in the insured population.

21. Author's calculation based upon traffic flow tables. GAO, "Traffic Congestion: Trends, Measures, and Effects," GAO/PEMD-90-1, November 1989, p. 39.

22. My summation for the fifty urban areas they studied. See table A-9, p. 13, and table A-15, p. 19, in Shrank, Turner and Lomax (1995). See also Delucchi (1997), who estimates congestion costs at $22.5 to 99.3 billion.

23. To understand why, consider a model with two types of miles: A, B. Let the initial quantities of driving these miles be a, b, and let C_a, C_b be the total cost of delay during driving of types A, B, respectively. Then, the average cost of delay is $c = (C_a + C_b)/(a+b)$, and the average cost of delay during driving of the two types is $c_a = C_a/a, c_b = C_b/b$. The externalized marginal congestion costs are likewise c_a, c_b. Observe that if a uniform per mile price p is charged for both types of miles, the congestion savings will be $p\varepsilon/g[ac_a + bc_b] = p\varepsilon/g(C_a + C_b)$, where g is the initial gas cost per

mile of driving, and ε is the elasticity of miles with respect to the price of gasoline. This is equivalent to what we would calculate if we treated the two types of miles equivalently, with c as the externalized marginal cost of miles. Then we would estimate the congestion reduction as: $p\varepsilon/g[a+b]c = p\varepsilon/g(C_a + C_b)$.

24. Adverse selection is another reason that a given insurance company may not want to switch to per-mile premiums on its own. Even if the insurance company knows the average miles driven per year by drivers in a given risk pool, it does not (currently) know the miles that given individuals drive. If it charges a per-mile premium equal to the current yearly premium for the pool divided by the average number of miles driven by drivers in the pool, it will lose money. Those who drive more miles than the average will leave the pool for a firm charging per-year rates and those who drive less miles will stay with this insurance company. The remaining drivers are adversely selected, because low mileage drivers in any given per-year risk class with a given accident experience level will tend to be worse drivers than high mileage drivers in the same risk class. (Long-run historical accident costs divided by miles driven would be a sensible measure of per-mile risk.) This adverse selection means that the insurance company will have to charge a relatively high per-mile price to break even, given the selection problem and the possibility that high-mileage drivers can choose to pay fixed annual premiums with other insurance companies. In principle, the insurance company could probably find a sufficiently high per-mile price that would increase profits. One could understand, however, the hesitancy of a marketing director to propose to his CEO that the insurance company change its pricing structure in a way that would make its prices less attractive than other insurance companies' to a large percentage (probably more than half) of its current customers.

25. Note that our estimates of the size of the accident externality effect are largely independent of the shape of the typical individual's accident profile, because these estimates are based upon cross-state comparisons of the effects of different traffic density levels on insurance premiums normalized by the amount of driving done. If an individual's elasticity of accident costs with respect to miles is closer to 1/2 instead of 1, as assumed here, then the elasticity of total (social) accident costs with respect to that individual's driving should be roughly 1, because of the externality effect. This observation suggests that if an individual's accidents are that unresponsive to driving, then the linear model should roughly predict the social gains from switching to per-mile premiums.

26. The statistic 71 percent is found by taking the ratio of the number of multiple vehicle crashes to total crashes in table 27, U.S. Department of Transportation (1997). This figure understates the number of accidents that involve multiple vehicles because if a single vehicle crashes into a fixed object, for example, that is a single vehicle crash even if the vehicle swerved to avoid another car.

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6 Capital Adequacy Regulation: In Search of a Rationale

Franklin Allen and Douglas Gale

1 The Flight from Theory

Financial crises have become a popular academic subject since the recent events in Asia, Russia, and elsewhere. Of course, financial crises are nothing new; they are part of the long and colorful history of the development of the financial system. They are also an important part of the history of central banking. Central banks were originally established for a wide variety of reasons, such as enhancing the payments system and raising money to help governments finance wars. They later took on the prevention and control of financial crises as one of their central functions. The Bank of England perfected the technique in the nineteenth century. The U.S. Federal Reserve System, founded in the early twentieth century, was a slow learner and only mastered the technique in the 1930s. (A more detailed discussion of the history of central banking is contained in chapter 2 of Allen and Gale 2000a).

For the most part, the development of central banking and financial regulation has been an essentially empirical process, a matter of trial and error driven by the exigencies of history rather than formal theory. An episode that illustrates the character of this process is the Great Depression in the United States. The financial collapse in the United States was widespread and deeply disruptive. It led to substantial changes, many of which shape our current regulatory framework. The SEC was established to regulate financial markets. Investment and commercial banking were segregated by the Glass-Steagall Act (subsequently repealed and replaced by the Gramm-Leach-Bliley Act of 1999). The Federal Reserve Board revised its operating procedures in the light of its failure to prevent a financial