ISSN 1064-6647

# Journal of Actuarial Practice

Volume 1, No. 1, 1993

REPRINT



516

# Cost-Based Pricing of Individual Automobile Risk Transfer: Car-Mile Exposure Unit Analysis

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## Abstract

Every mile traveled by a car transfers risk to its insurer. This paper posits that the product of a cents-per-mile rate based on class experience and the miles recorded on the car's odometer appropriately earns prepaid premium while the car is driven. Operation of a practical car-mile system is described briefly. To test the competing idea that driver-record pricing responds to known large differences in risk transfer, a model used to validate claim free discounts is reexamined with the car-mile as the measure of individual cost. Driver-record pricing is found to inflate car-year price-to-cost differences. Consequences of accident rate variability for a car-mile system are reviewed. The per mile cost of individual risk transfer is a class property because of the random nature of accidents. Driver-record pricing attempted on a per mile basis would amplify differences within classes.

Key words and phrases: *Per mile insurance, accident rate, risk classification, driver record model, merit rating*

## 1 Introduction

Cost-based pricing of individual risk is a key ratemaking principle promulgated by the Casualty Actuarial Society (CAS). The principle states that "A rate provides for the costs associated with an individual risk transfer;" see CAS (1993). The question for automobile insurance is how the cost of individual driving risk should be measured. When a car is not being driven, its owner has no risk to transfer for driving coverage (for all losses as a direct consequence of the car's being driven) so the cost to its insurer is zero. Every mile a car is driven adds to its risk of accident; the total cost of risk transfer increases mile by mile. Both conditions point to adoption of the *car-mile* (as opposed to the car-year that currently is used) as the unit of

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risk transfer, that is, the exposure unit. Conversion of class rates from dollars per car-year to cents per car-mile for driving coverages would be required by a one sentence amendment to rate regulatory law proposed in several states.

The purpose of this paper is to demonstrate that the car-mile exposure unit is essential to cost-based pricing of individual risk transfer. The effect of driver-record pricing on individuals is analyzed with the car-mile unit as the objective measure of cost.

## 2 Car-Mile Exposure Unit

The entire entry on the exposure unit in the CAS statement of ratemaking principles is: "The determination of an appropriate unit or premium basis is essential. It is desirable that the exposure unit vary with the hazard and be practical and verifiable." The currently accepted assessment of the car-mile exposure unit for automobile insurance seems to have been established by Dorweiler (1929). Regarding the variation-with-hazard requirement, Dorweiler states: "The mileage exposure medium is superior to the car-year medium in yielding an exposure that varies with the hazard, as it responds more to the actual usage of the car." Note that Dorweiler's phrase "responds more" obscures the fact that the car-year *does not respond* to actual use of the car. In addition, suspension of coverage during periods of no use requires administrative intervention. Dorweiler further states that "[t]he devices and records necessary for the introduction of [the car-mile] medium make it impractical under present conditions," and that while the car-year "measures the exposure prospectively, the [car-mile] require[s] a final adjustment which would be determined retrospectively."

Despite Dorweiler's assessment of superiority of the car-mile exposure unit over the car-year unit in a fundamental characteristic and his qualified judgment concerning its practicality, no substantive actuarial reassessment has been published. Bouska (1989) updates Dorweiler's paper and notes without comment that conversion to the car-mile unit has been advocated by the National Organization for Women. In a discussion of Bouska's paper, Diamantoukos (1991) observes only that the car-mile exposure unit is "perhaps a theoretically superior one in some respects" to the car-year unit.

The National Organization for Women completed a 1992 study[1] for Pennsylvania legislators on operation of a car-mile system which

[1] National Organization for Women. *Operation of an Audited-Mile/Year Automobile Insurance System Under Pennsylvania Law.* Washington, DC: NOW, 1992, reprinted in

suggests that such a system would follow the odometer-limit and non-tampering conditions used in mechanical breakdown insurance policies, but otherwise would not differ much from current practice. The study follows transactions involving an example car, including a midyear sale, for four policy years. Premium payment in advance would be required to keep insurance protection in force. The premium for driving coverage at car-mile rates is prepaid in mile amounts and at times chosen by the car owner. Administrative expense and a premium for nondriving coverages are based on yearly rates and are prepaid at each policy-year renewal. Premium would be earned by the car's insurer by the day for nondriving coverages, as is currently done for all coverages, and by the mile recorded on the odometer for driving coverages. The car's insurance ID card displays the odometer-mile and date limits at which protection lapses pending further premium prepayment.

Policy renewal under this plan would be conditional on taking the car to a garage designated by the company for an annual odometer audit. The odometer would be inspected and read, and tamper-evident seals would be applied at the initial audit. Theft of insurance protection is controlled because tampering with the odometer—already a federal crime—automatically voids the policy. Driving with the cable unhooked does not steal insurance protection, because tampering usually would be detected after an accident, and tampering voids protection. The cents per car-mile rate would depend on coverage and the car's classification as appropriate by territory, use, driver, and other categories.

## 3 Driver-Record Pricing

Advertisements such as those promising "good rates for good drivers" lead consumers to believe that accidents can be avoided and that the important condition in individual risk of accident is how a car is driven, not how it much it is driven. This belief is encouraged through the use of merit ratings by automobile insurers to raise or lower individual prices at policy renewal time.

The actuarial literature has neglected to examine the effect of driver-record pricing on individual price-to-cost ratios where the claim rate average for the class is taken as the price and defined individual claim rates are taken as the costs of hypothetical individuals composing the class. Recent studies of driver records have

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*The Casualty Actuarial Society Forum* (Summer 1993): 307-338. This study is available from NOW, 1000 16th Street, NW, Suite 700, Washington, DC 20036.

focused on general questions of variation in individual risk without reference to pricing or cost. For example, Mahler (1991) examines the state accident records of drivers for variation in individual risk over time (14 years), but does not discuss how the information could be applied to pricing automobile risk transfer. An earlier actuarial study done for insurance regulators, however, provides information on individual price-to-cost effects.

A widely circulated 1979 report on risk classification by insurance company actuaries on the industry Advisory Committee to the National Association of Insurance Commissioners contains a section on driver-record pricing. The report describes the issue of pricing individual risk transfer: "Many accidents are the result of chance. The problem becomes—how can insurers identify the 'bad' drivers from the 'good' drivers who were unlucky?" The impossibility of solving this problem through driver records, although downplayed in the report, is illustrated with a compound Poisson model composed of specified numbers of drivers defined to have uniform high and low annual rates of accident involvement.

In a subsequent study of driver-record pricing, Butler and Butler (1989) analyze the high and low accident rate model in terms of the car-mile exposure unit. They value the price-to-cost ratio for individual cars in terms of cents per mile and conclude that pricing based on accident, claim, or traffic violation records greatly increases the existing overpricing for unlucky owners of cars driven less than the annual average for their risk class.

Continuing justification for driver-record pricing, however, relies on the fact that cars whose drivers have had recent accidents (or traffic convictions) average more accidents in a subsequent year than do cars identically classified whose drivers have not had a recent accident. A simplified explanation for this fact—in terms of a uniform claim rate per mile—is presented below through reinterpretation of a classic model for a claim free discount plan. Assumption of a cents-per-mile cost for all cars of the model provides a base for analyzing the price-to-cost effects of driver-record pricing on individual cars. This article also considers the variation in claim rates per mile and its consequences for classification and driver-record pricing under a car-mile system in place of the assumed uniform claim rate per mile.

## 4 Bailey & Simon Model for Claim-Record Experience

The CAS paper "An Actuarial Note on the Credibility of Experience of a Single Private Passenger Car," by Bailey and Simon

(1959) is the chief reference on the CAS examination syllabus which shows and models the application of driver-record pricing to insurance for individual cars. Familiarity with its method of calculating Poisson models is required for questions on the CAS exam on advanced ratemaking; see Murdza (1992).

Bailey and Simon examine the Canadian liability claims experience of about 4 million insured car-years. The claim rate of the undivided class for each of five classes defined by car use and driver type is compared with the rates calculated for four subclasses created by sorting the records according to how many full years have elapsed since the last claim was incurred by the car's drivers.

The relative effects of sorting cars by the prior claim records of their drivers are similar for all five classes and are not affected significantly by a correction for territorial class differences. The experience for the largest Canadian class, Class 1, is shown in Table 1. The recalculated rate relative to the claim rate for the undivided class was 9 percent lower for the three year claim free subclass and progressively higher with decreasing time since the last prior claim.

**TABLE 1**
**1957-1959 Canadian Automobile Claim Data by Prior Claim Records***

Class 1
Pleasure—No Male Operator Under 25

| | Class (undivided) | Years Since Last Prior Claim 3+ | 2 | 1 | 0 |
|---|---|---|---|---|---|
| Number of Claims Incurred | 288,019 | 217,151 | 13,792 | 19,346 | 37,730 |
| Car-Years Insured | 3,325,714 | 2,757,520 | 130,706 | 163,544 | 273,944 |
| Claims Per Car-Year | 0.087 | 0.079 | 0.105 | 0.118 | 0.138 |

* Source: Bailey and Simon (1959); claim rate calculated

As part of their examination of the statistical justification for claim free discounts, Bailey and Simon structure a model that reproduces the decrease in the claim rate observed in the Canadian data. The model comprises cars with three annual amounts of risk transfer representing a fourfold range in annual claim rates: 100,000 cars with a uniform risk transfer rate of 0.05 claims per car-year (Amount I); 100,000 cars with a uniform rate of 0.10 claims per car-year (Amount II); and 50,000 cars with a uniform rate of 0.20 claims per car-year

(Amount III). The average claim rate of the model class is 0.10 claims per car-year. Bailey and Simon calculate the number of cars that would be claim free with a Poisson distribution after three years and combine them into a claim free subclass for each of the defined risk transfer rates. They calculate that the average claim rate for the new mix of the three defined rates would be 8 percent less than the class average. A subclass reduction in claim rates requires an offsetting claim-rate increase, however, to maintain the overall class average.

Because the present study concerns how all cars are affected individually by the pricing of risk transfer, the Bailey and Simon model calculations are extended here to include the subclasses with more recent prior claims. The results are compared with the Canadian experience in Figure 1. (Table 2 shows the calculated distribution of cars with the three defined risk transfer rates among the four claim-record subclasses.)

The extended model reproduces the general features of the Canadian claim data. (Bailey and Simon point out that further adjustment of model parameters would achieve more detailed agreement of the model with the Canadian data. For the present purposes, however, such adjustment would add to complexity but not to understanding.) If claim rates are taken as a measure of relative insurance prices:

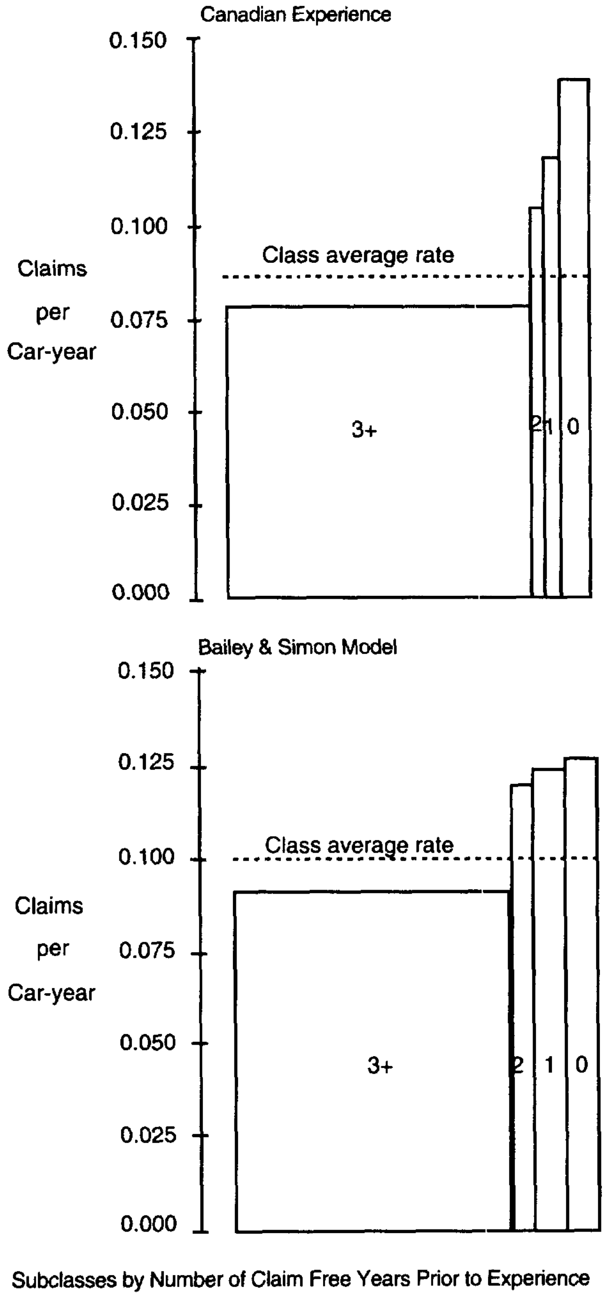
- The price level for the claim free majority of cars decreases below the rate that the undivided class would pay; and
- This relatively small decrease is balanced by sharp price increases for the minority subclasses with recent claims.

The Bailey and Simon model, by reproducing empirical claim record insurance experience, shows the large variation in individual risk transfer that exists within automobile insurance price classes. Individuals in the same class are charged different prices for the same amount of risk transfer. The Amount I cars (0.05 claims per car-year) are charged four pure premiums and Amount II cars (0.10 claims per car-year) are charged two pure premiums for the same amount of risk transfer that costs the Amount III cars (0.20 claims per car-year) only one year's pure premium.

## 5 Risk Transfer and Miles Driven

Bailey and Simon (1960) consider reasons for the large variation in annual risk transfer within single price classes as indicated by the

**Figure 1—Claim Rates of Prior-Claim Subclasses**



Canadian claim record experience and posited in the Bailey and Simon 1959 model for the experience. They note that driver-record and class plans are "quite ineffective in separating the better risks from the poorer risks," and conclude that:

> [W]e have reached the point where we may state that the still unanalyzed cause (or causes) of variation among individual risks: (1) has a wide dispersion, (2) varies significantly from year to year for an individual risk, and (3) is measured only to a limited extent by the class plan and the merit rating plan. Annual mileage, which has long been felt to be an important measure of hazard, fits all these requirements better than any other single cause.

The first characteristic—dispersion of cars by annual miles driven—is corroborated by the U. S. Department of Transportation's nationwide personal transportation surveys. In 1977 one in five household cars was driven less than 3,000 miles, and one in ten was driven more than 20,000 miles; see Butler, Butler, and Williams (1988, p. 376).

The second characteristic—significant individual year-to-year variation in miles driven—is one that can be measured only by the car's odometer. Nevertheless, Bailey and Simon do not note a need for the car-mile exposure measure, but seem to view mileage as a lump sum class definition from which experienced car-year cost averages are used prospectively to set base price multipliers.

The third characteristic implies that variation in risk transfer amounts among individual cars resulting from differences in miles driven can be measured by class and driver-record plans. Modern class plans continue to show narrow distributions of cars by base price multiplier, in contrast to the range in miles driven; see Butler, Butler, and Williams (1988).

## 6 Bailey & Simon Model With Uniform Claim Rate Per Mile

Within-class variation in individual amounts of risk transfer per year can be seen as variation in the product of a rate variable and an exposure variable for each car; that is, variation in the product of a hypothetical average claim rate per mile for a car over the course of a year and the number of miles the car is driven. The current practice of charging annual rates for risk transfer implicitly assumes that the two variables cannot be resolved. In a car-mile system, however, the value of the exposure variable is recorded by each car's odometer. The following analysis of the Bailey and Simon model assumes that all of the model cars share the same average risk-transfer rate, 0.00001 claims per mile. (The effect of presumed within-class differences in individual average claim rates per mile is considered later.) The model differences in annual risk transfer amount, therefore, are measured by the exposure variable.

The adopted claim rate per mile defines the miles per year driven for the model's three risk amounts. For Amount I cars, 0.05 claims per year means 5,000 miles exposure per year; for Amount II cars, 0.10 claims per year means 10,000 miles exposure per year; and for Amount III cars, 0.20 claims per year means 20,000 miles exposure per year. The total risk transferred at the end of 20,000 miles traveled is the same for all cars.

**TABLE 2**
**Model Distribution of Mile-Amount Cars by Claim-Record Subclass**

| Amount of Risk Transfer | Miles/Year (Each Car) | Class (Undivided) | Years Since Last Claim 3+* | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| | | | Number of Cars | | | |
| I | 5,000 | 100,000 | 86,071 | 4,413 | 4,639 | 4,877 |
| II | 10,000 | 100,000 | 74,082 | 7,791 | 8,611 | 9,516 |
| III | 20,000 | 50,000 | 27,441 | 6,075 | 7,421 | 9,063 |
| Total cars | | 250,000 | 187,594 | 18,279 | 20,671 | 23,456 |
| Avg. Miles per Car-Year | | 10,000 | 9,169 | 12,118 | 12,468 | 12,824 |
| Avg. Claims per Car-Year at 0.00001 Claims per Car-Mile | | 0.1000 | 0.0917 | 0.1218 | 0.1247 | 0.1282 |

* Number of cars in subclass from Bailey and Simon (1959)

Bailey and Simon use their model to examine the mix of risks in the claim free subclass. The present study extends the analysis to obtain distributions of cars transferring the three risk amounts in the other three claim-record subclasses, as shown in Table 2. (As only the most recent claim is recognized by the plan, the claim-record distribution of the cars is calculated working back in time with a declining balance of claim free cars eligible to have a claim that counts. For example, of the 100,000 Amount I cars eligible in the 0 year, 4,877 have claims by the Poisson distribution at a 0.05 rate. The claim free balance of 95,123 cars similarly is reduced in past year 1 and so on for three years.) The miles-per-car-year average for each subclass is determined by the mix of Amount I, II, and III cars.

Although the number of cars transferring each risk amount (I, II, and III) increases with claim recency (from 2 to 1 to 0 years since the last claim), the number of highest mile cars (20,000 miles) increases most rapidly. Therefore, the average miles driven is highest (12,824 miles) in the most recent claim subclass (0 years). The average of the claim free subclass (3+ years) concurrently decreases from the class average of 10,000 miles to 9,169 miles.

## 7 Accidents as Random Sampling

If it is assumed that each class has uniform average claim rates per mile, automobile accidents in the Bailey and Simon model can be envisioned as a random sampling of the class population on the road. Accidents can sample only what is exposed. (Bias in the accident sampling of real car-mile class populations that results from differences in the average driving conditions encountered by individual cars is examined later in the paper.) Cars driven many miles and cars driven few miles are included in the random accident sample of the car-miles driven by the cars in the class. Because cars driven more than the class average put more miles on the road, they are overrepresented in the accident sample. Cars driven less than average are underrepresented in this sample relative to their proportion in the class. The average miles per car of the recent claim subclasses are increased through this random sampling process. The preferential selection of cars driven more miles into the recent claim subclasses also concurrently lowers (slightly) the average miles per car of the large remaining population of cars without accidents. Because of their greater average number of miles of exposure, therefore, the recent claim subclasses average more claims in a subsequent year than does the claim free subclass. All of the recent claim subclasses, however, also contain cars driven less than the class average.

## 8 Price-to-Cost Accuracy for Individual Risk Transfer

The miles-driven interpretation of the Bailey and Simon model provides a cost measure in car-miles for the three individual amounts of risk transferred. A price-to-cost relationship can be established for the three risk transfer amounts (I, II, and III) in the undivided class and in each of the four driver-record subclasses, a total of 15 relationships applied to the 15 groupings of cars in Table 2. (An equivalent 15 price-to-cost ratios would result from dividing the model's average claim rates per year at the five class and subclass prices by the three defined annual claim rates at the individual costs. Without being referenced to an objective standard such as odometer miles for measuring individual cost, however, the ratios would be without practical significance.)

To picture the price-to-cost transfer comparisons, assume a class-average cost of $10,000 per claim. This claim cost (severity) multiplied by the assumed model rate of 0.00001 claims per mile produces a cost of 10 cents per mile pure premium for the class. Because the average amount driven per year for the class is 10,000 miles, the 10 cents-per-mile cost makes the class cost (pure premium) $1,000 per car-year.

Despite the range in miles driven, it is assumed that all of the cars stay in the same dollars-per-year class (as the Bailey and Simon model implicitly assumes). This would have been the case for the Canadian experience under the class plans of the time and is true now for a large number of cars. Current discounts for estimated future mileage less than 7,500 or 8,000 miles in some company class plans are not used or have been discontinued by other automobile insurers as intrinsically lacking in objectivity. (Because the discount difference between 5,000 and 20,000 estimated future miles is usually about 15 percent, the adjustment would not affect the results of the analysis significantly.)

Without claim-record pricing, all individuals pay the $1,000 per year pure premium for the class, the same premium that Amount II cars would pay at 10 cents a mile. At a $1,000 annual rate, however, the 20,000 mile Amount III cars pay 5 cents a mile, while the 5,000 mile Amount I cars pay 20 cents a mile, as shown by Figure 2.

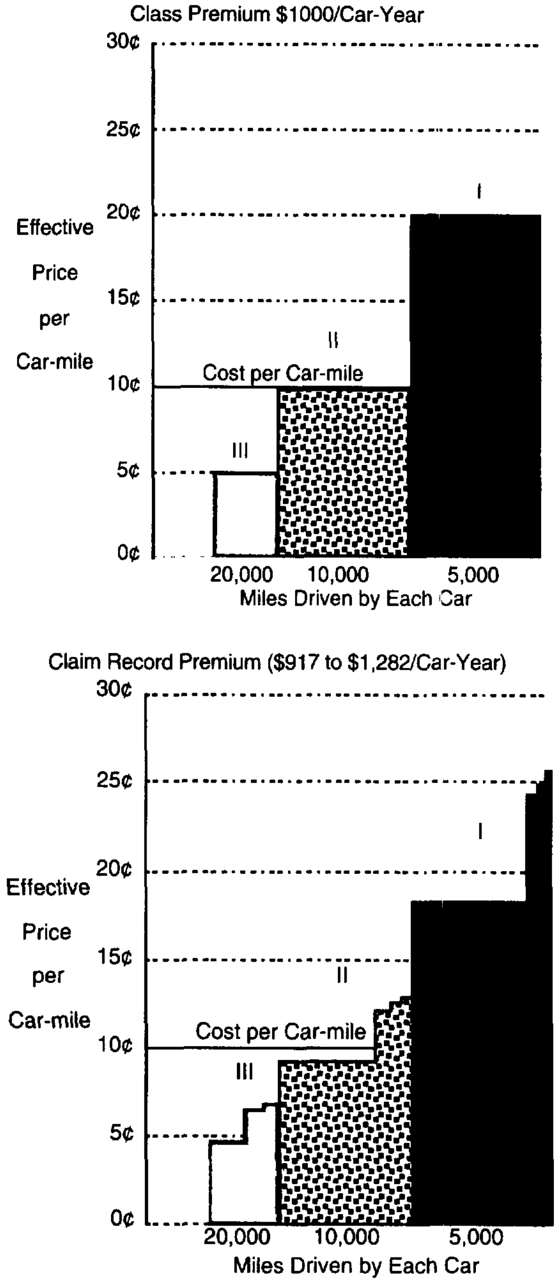
When the model class is subdivided on the basis of claim records, the proportions of cars at the three mile amounts are changed in the four subclasses created. These new mile averages multiplied by the assumed rate of 0.00001 claims per mile produce four new pure premiums for the claim-record subclasses: $917 for the claim free subclass and $1,212, $1,247, and $1,282 for the progressively more recent claims subclasses. These four annual premiums divided by the three mile amounts in each subclass produce the 12 new prices per mile for the model cars shown in Figure 2. The effects on the cars at the three mile amounts are different.

The effect of claim-record pricing on the risk transfer Amount II cars, which are individually driven 10,000 miles per year, is most telling. Without subclassification, all Amount II cars pay 10 cents a mile for insurance. With subclassification, most of them receive a 1 cent reduction in the cost per mile. Some cars in the class which have had a recent claim, however, pay 2 cents to 3 cents more per mile (Figure 2). Claim-record subclassification transforms pricing that is cost-based by definition for all Amount II individual cars to pricing that is not accurate for any cars.

It could be argued that improved price-to-cost accuracy is needed most for the model car risk transfer amounts that differ most from the class average. Without claim-record subclassification, the cars at the 5,000 mile amount pay 20 cents a mile, 10 cents a mile more than the class average price. In the claim free subclass such cars receive a 2 cent per mile reduction in price. This reduction, however, is much smaller than the 4 cents to 5 cents a mile below the class average price that the cars at Amount III (20,000 miles) pay regardless of their claim-record subclass. Furthermore, provision of this 2-cents-per-mile downward adjustment for the cars at Amount I is gained at great cost to the Amount I cars with recent claims. For these individuals, the 20-cent-a-mile amount they pay without claim-recency pricing is increased 4 cents to 6 cents a mile in the recent claims subclasses. This increase equals the entire per mile price paid by the cars at Amount III regardless of their claim-record subclass. The only negative effect for Amount III cars of pricing on claim record is that some lose a small part of their per mile subsidy (Figure 2).

Statistically, a decrease in the average cost per mile paid by Amount I cars from 20 cents to 19.3 cents coupled with an increase in the average cost per mile paid by Amount III cars from 5 cents to 5.3 cents is evidenced in a 6 percent decrease in variance of price-to-cost ratios from the three ratios of the undivided class to the twelve ratios of the driver-record subclasses. The reduced variance, however, should not mask the disparate cost of the improved statistics on individuals that is evident in Figure 2. Driver-record pricing increases the range in price-to-cost ratios paid by individuals in the same class 40 percent, from a spread of 15 cents a mile before driver-record pricing to 21 cents a mile between the lowest value for Amount III cars and the highest for Amount I cars. Operating at random on individuals, the so-called improvement increases the underpricing of risk transfer for some cars already underpriced and the overpricing of risk transfer for some cars already overpriced.

**Figure 2**
**Effect of Model Annual Premiums on Car-Mile Prices**



If the pricing unit were converted from car-year to car-mile so that all of the car-owners in the model class paid the same 10 cents per mile rate, however, each owner would pay only for the on-the-road protection the car consumed, while total premium received by insurers would remain the same. A car driven the model class average of 10,000 miles would experience no change in the $1,000 premium with insurance charged at car-mile rates, provided its mile amount did not change. A car driven 4,780 miles would pay $478, while a car driven 21,240 miles would pay $2,124.

## 9 Variation In Claim Rates Per Mile

The large differences in the type of risk environment that cars can encounter are indicated by comparing statistics for accident severities and per mile accident rates between interstate highways and city streets or between day and night driving on the same road. For example, the injury rates per million vehicle-miles of travel ranged from 0.36 on rural interstates to 3.0 on local urban roads in 1991; see Federal Highway Administration (1992). In principle, therefore, the diverse individual mixtures of car use and driving environment make it inevitable that changes in class definition would result in different claim costs per mile for new classes.

Accident rates per vehicle mile depend not only on traffic engineering classification of accidents experienced under roadway or other relevant conditions during some time period, but also on determination of the number of vehicle-miles of exposure to risk that produced the classified accidents. The same relationship holds for automobile insurance. Only if car-miles of exposure are determined can the number and cost of claims incurred within a certain time period by a certain class of cars provide any quantitative information on the expected risk transfer cost of each mile that cars in the class will travel in a subsequent rating period.

As an example of the effect of classifiable per mile differences within a business-use class of cars with adult drivers, assume two types of car use by sales representatives. With reference to the government injury rates given above, assume that one type of use covers the whole state and averages 0.25 claims per million car-miles (statewide cars), while the other covers only a metropolitan area and averages one claim per million car-miles (metro cars). Any lower average cost per claim by the metro cars resulting from lower speed urban accidents would narrow the effect on the claim cost per mile of the 4:1 claim-rate difference. Separately classifying the statewide and metro cars, provided there were enough car-miles of each usage type for statistical reliability, would show the differences in car-mile cost.

## 10 Accidents as Biased Random Sampling

The analogy used above for viewing accidents as a process of sampling car-miles on the road can be extended to presumed variations within classes in per mile accident rates. To the extent that cars are not classified by driver age and experience according to the known per mile differences in accident involvement for these categories, the accident random sampling of class car-mile populations would be biased toward the cars driven by inexperienced drivers and by drivers near the beginning and end of the driver age range. Further, owing to differences in driving conditions by time and place, the accident random sample of car-miles would be biased to the cars used more under conditions of higher risk per mile. The accident samples, however, also will contain cars used on average under conditions of lower risk per mile. For example, with a Poisson distribution of claims at the rates given for the hypothetical business use cars, 18 percent of the metro cars will incur claims in 200,000 miles of driving, but so will 4.9 percent of the statewide cars.

## 11 Driver-Record Pricing on a Car-Mile Basis

Like the current driver-record pricing on a car-year basis, driver-record pricing under a car-mile exposure unit system would have an apparent justification in cost. The inevitable bias in an accident sample assures that the subclass of cars defined as incurring a claim in the most-recent-miles-traveled interval—within the most recent 50,000 miles, for example—will average more accidents per mile in a following miles-traveled interval than the class average. Applying a recent claim surcharge to the cents-per-mile class price, however, would constitute a deliberate, random, and unjustifiable increase in what is paid per mile by the recent claim cars with lower than average claim rates compared to what they would pay if they were classified separately. Furthermore, the higher per mile charges for the recent claim cars with significantly higher than average claim rates per mile still would be less than what they would pay if they were classified separately.

Because both the claim free and recent claim subclasses of a class are mixtures of cars with above average and below average claim rates per mile, any action to separate them must be through class redefinition applied to the whole class.

## 12 Conclusion

CAS introduces its ratemaking principles with the specification that "[r]atemaking is prospective because the property and casualty insurance rate must be developed prior to the transfer of risk." In a car-mile system, evaluation of the cost per mile to be used in a prospective class rate can be done only on the basis of claim experience for a group of cars referenced to the group's total measured car-miles of exposure that produced the claims.

What cannot be known prospectively, because it is controlled by individual car owners, is the amount of risk that will be transferred through operation of each car. Although risk transfer is paid in advance at a class rate per mile, protection is not consumed (premium is not earned by the insurer) until the risk is transferred, mile after mile, by driving. Conversely, premiums charged at car-year rates invert this cost-based relationship by charging less per mile for each mile of protection consumed, a contradiction of cost-based pricing. The assumption that this contradiction is unavoidable on practical grounds is not neutral. It favors all owners of cars driven more miles per year than the average for their class.

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# Discussion of Patrick Butler's "Cost-Based Pricing of Individual Automobile Risk Transfer: Car-Mile Exposure Unit Analysis"

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Aside from its hyperacademic title, Patrick Butler's paper on mileage and merit rating of automobile insurance policies provides a nice twist to an old model and a reasonably compelling theoretical argument for the use of mileage as a rating variable. Yet one basic real world truth runs counter to Dr. Butler's view: automobile insurance companies generally do not use mileage as a rating variable, except in the broadest of categories. This is despite the fact that Dorweiler's justification for the use of mileage has been around for more than 60 years.

Because it generally is conceded that classification schemes have become more refined over time in response to competition, why haven't insurers already gone down the path to which Dr. Butler points? I can suppose two reasons: (1) competition doesn't really work; or (2) competition does work and the competitive market finds the use of mileage to be wanting in some respect. In my opinion, the second reason is more likely to be true.

Assuming this second reason is correct, then either the demand for or the supply of mileage rating is too low for it to be used more than it is. On the demand side, it is possible that insurance company customers don't like the notion of having their odometers inspected or of adding an uncertain level of premiums to their already complicated lives; after all, the purpose of insurance is to replace uncertain losses with certain, not uncertain, premiums. On the supply side, the costs of administering a system such as that proposed by Dr. Butler simply

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may outweigh the benefits; I am unaware of any administrative cost studies that would illuminate the answer to this particular question.

Beyond pointing out this basic conflict between theory and practice, I would like to make the following observations on Dr. Butler's analysis:

- While there is likely to be at least some correlation between variation in mileage and variation in claim frequency within a class, the Butler analysis essentially assumes a perfect correlation, disregarding the legion of unmeasurable factors that could account for as much variation as does mileage; Dr. Butler's numerical results should be tempered considerably, therefore, before being used in the real world;
- Dr. Butler is clearly in the right when he notes that the per mile expected risk transfer cost only can be determined if real car-miles of exposure are determined. Any study based on mileage data reported by either insurers or insureds is subject to question. In the former case, this may be due to insurer indifference in reporting correct statistical data when no premium effect is involved. In the latter case, this may be due to insureds' incentive to cheat. Here in Massachusetts, where I currently am employed, we have found that nearly 30% of policies have estimated future annual mileage of zero recorded; on the other hand, nearly 50% of policies have estimated future annual mileage of magnitudes too high to qualify for any rate discount, making it likely that these estimates are unaffected by cheating;
- Again, here in Massachusetts, we have found some evidence of a relationship between annual mileage estimates (which are based on questionable data, as explained above) and merit rating classification under the merit rating scheme used here; in particular, the higher rated (worse) drivers do tend to have higher mileage estimates, in keeping with Dr. Butler's thesis; and
- Finally, Dr. Butler's point (in his section 11) that "Applying a recent claim surcharge to the cents-per-mile class price, however, would constitute a deliberate, random, and unjustifiable increase" seems to argue for the complete elimination of merit rating, which the paper does not justify. As anyone who has listened to a radio talk show can attest, at least some part of the driving public demands merit rating as a way of punishing those perceived as offenders (unless, of course, the caller is one of those on the receiving end of a surcharge, in which case he or she would look on Dr. Butler's article quite favorably). Talk show callers aside, the potential relationship between merit rating classification and other unmeasured variables (aside from mileage) cannot be dismissed based solely on this article, nor can the virtually-impossible-to-measure deterrence effects of a merit rating scheme.

In summary, Dr. Butler's article, while not quite supportive of all of his conclusions, does make plain the problem of random incidence.

The principle that "cars driven more than class-average miles are over represented in the accident sample" is one that I expect many practicing actuaries frequently forget. I recall an analogous phenomenon from an undergraduate probability class; if one surveys subway riders at random and asks how many days per month they ride the subway, the average answer will be too high an estimate of the population mean because the survey-taker more likely will encounter persons who are frequently on the subway. Of course, if we all rode the subway every day, the incidence problem would go away, as would much of the need for cars and the corresponding mileage and merit rating issues. If Dr. Butler is not starting his own insurance company soon, perhaps he can devote some time to the advocacy of better public transportation systems, thereby reducing the problem he has illustrated so nicely.

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## Richard G. Woll*

The purpose of this paper, according to Patrick Butler, is to "demonstrate that the car-mile exposure unit is essential to cost-based pricing of individual risk transfer." On the basis of his demonstration, Dr. Butler advocates changing the exposure basis for private passenger automobile insurance from a car-year basis to a per mile basis. Current auto insurance prices are based on a contract that runs for a fixed period of time, usually a half year. He argues that the basis for the insurance contract for most coverages should be changed to miles driven.

Dr. Butler's demonstration consists of creating a simplified model where there are three types of insurance customers. The first type of customer drives 5,000 miles per year. The second drives 10,000 miles per year, and the third drives 20,000 miles per year. He assumes that the risk process for each customer is Poisson with a frequency of

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one accident per 100,000 miles. For illustrative purposes, he assumes that each claim costs $10,000. He then uses this information to generate the dollars of loss experienced by each customer. This allows him to evaluate the effect of what he calls *claim record* pricing. This means establishing prices on the basis of prior claim records. He concludes that claim record pricing does not match prices to costs as well as charging on the basis of miles driven. He also concludes from this that "the car-mile exposure unit is essential to cost-based pricing of individual risk transfer."

Insurance companies currently recognize differences in miles driven by the use of class factors. Dr. Butler argues, however, that:

> Modern class plans continue to show very narrow distributions of cars by base price multiplier in contrast to the range in the miles driven (Butler, Butler, and Williams, 1988).

Basing insurance prices on the number of miles driven makes intuitive sense. It is obvious that the difference in rates between two drivers, *other things being equal,* should be proportional to the difference in the miles they drive. The cost of insuring different auto customers, however, depends not only on how much they drive, but on other factors such as *how well* they drive, *where* they drive, and *what* kind of car they drive.

In addition, the relationship between the number of miles a customers drives and insurance claims is complex. Dr. Butler seems to assume that customers who drive more than other customers have proportionately more losses. That is, he expects a customer who drives 10,000 miles to have twice the losses of a customer who drives 5,000 miles. Allstate's data, however, present a more complicated picture. Figure 1 shows the relationship between the number of PD[1] claims per mile and the number of miles driven annually by a customer. It uses information about the 1991 PD claim experience of Allstate customers in California.[2]

Figure 1 shows the number of PD claims per mile going from 3.5 claims per 100,000 miles for persons who drive about 1,000 miles per year down to 0.3 claims per 100,000 miles for persons driving 30,000 miles or more. This is in sharp contrast to the constant number of

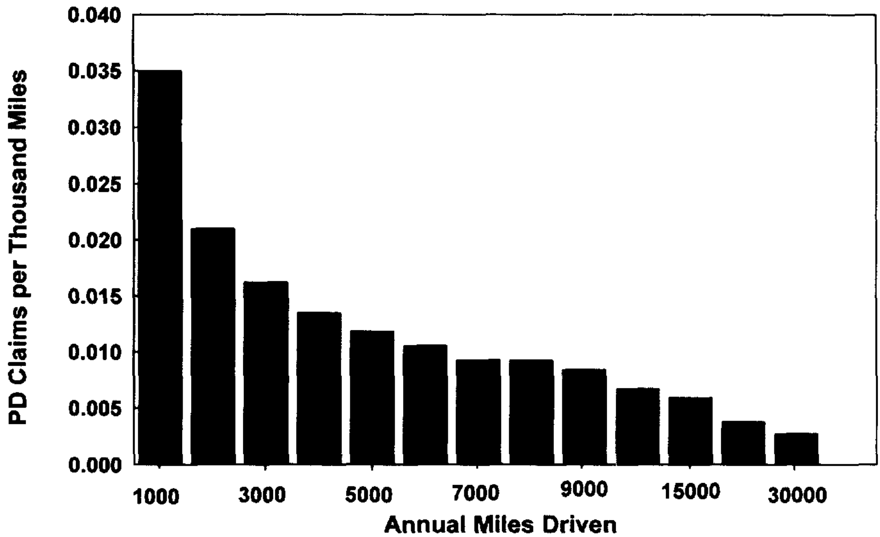
[1] PD (property damage liability) claim frequency is used because it generally has been found to be the best indicator of underlying accident frequency.

[2] Because of the passage of Proposition 103 in California which mandated the use of mileage in rating automobile policies, Allstate sent questionnaires to all its customers to get mileage data. Allstate already had collected mileage information on its customers, but the questionnaire helped to confirm the information.

claims per 100,000 miles assumed in Dr. Butler's analysis. This results in customers who drive about 1,000 miles per year having a claim frequency of 3.5 claims per year per 100 insured cars while those who drive over 30,000 miles have a claim frequency of about 8.0—a relationship of 2.25 to one, rather than the 30+ to one under Dr. Butler's assumptions.

When we turn our attention to other risk factors, we find that mileage is a relatively unimportant source of difference between customers compared to territory and years of driving experience.

**Figure 1**
**PD Claims per Mile by Annual Mileage**
**Allstate 1991 California Experience**




The effectiveness of any auto insurance risk assessment system depends on the extent to which it matches insurance prices to insurance costs. Dr. Butler has demonstrated that the use of mileage as an exposure base in a theoretical world, where all differences in loss experience come from differences in the number of miles driven, is more effective than the use of claim record pricing. He has not demonstrated anything with respect to actual insurance experience.

The effectiveness of automobile insurance risk assessments systems was discussed extensively many years ago. A study by the Stanford Research Institute (SRI) in 1976 entitled *The Role of Risk Classifications in Property and Casualty Insurance: A Study of the Risk*

*Assessment Process* developed a means for evaluating risk assessment systems by measuring the variance of expected losses of the partitions each system produces.[3]

The most efficient risk assessment system is the one that divides insurance customers into groups with the largest variance in expected losses. We also can evaluate the relative importance of various risk classification factors by measuring the percentage of the total variance each factor explains.

Dr. Butler seems to argue that the primary contributor to the variance of expected losses in the real world is the difference in the number of miles that each customer drives. There is no evidence presented by Dr. Butler, or by anyone else, to show that this is the case. The major case made for mileage in the paper is the repeated observation that insurance risk is transferred, mile after mile, by driving.

Using the SRI approach, the Allstate Research and Planning Center recently conducted a study of risk classification factors in California. The study covered most of the factors customarily used by most companies with the exception of vehicle characteristics. Allstate has collected data on the mileage driven by each customer since 1981, so the study was able to include mileage. Mileage, years licensed, and territory explained over 90 percent of the variance of the classification data included in the study for liability coverages (bodily injury liability, property damage liability, medical payments, and uninsured motorists). Over 55 percent of the total variance, however, was explained by territorial differences. Years licensed explained almost 23 percent of the variance, and mileage explained about 14 percent.

The picture was somewhat different for collision coverage. Territory, mileage, and years licensed again explained over 90 percent of the variance, but mileage explained over 33 percent of the total variance, years licensed explained about 30 percent, and territory explained about 26 percent.

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[3] The SRI report states "First, we define a measure of efficiency. Our probabilistic model for actual losses separates the random element of actual losses from the predictable element, the expected loss, that is, claim likelihood and expected claim severity. A perfectly efficient risk assessment process would be one that estimates exactly individuals' expected losses. A process with zero efficiency would not resolve any of the initial expected loss uncertainty. A process with intermediate efficiency will be characterized by the average fraction of the initial *expected* loss uncertainty it resolves" (emphasis added).

The report continues that: "We find it convenient to use variance to measure uncertainty because of [its] additive property ... In words, the expected loss variance in an entire population is equal to the sum of the average expected loss variance within each class and of the variance of the rates (average expected losses) among classes" (SRI, Supplement, p. 200).

Insurance customers with less than one year of experience have the highest losses per car. Losses per car decline each subsequent year. Thus, persons with more years of driving experience have improved loss experience. This, in turn, suggests that an important element in the transfer of insurance risk is *how* the customer drives. Territory rates, of course, depend on *where* insurance customers drive.

The Allstate study indicates clearly that *how much* its customers drive is only part of the overall variance of systematic risk. It is more important than the other two factors for collision insurance, but still accounts for only about one third of the total variance. It plays even a smaller role in liability insurance, the major part of auto insurance costs.

Thus, we do not believe that Dr. Butler has been able "to demonstrate that the car-mile exposure unit is essential to cost-based pricing of individual risk transfer."

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# Author's Reply to Discussion

The discussions by Messrs. Ruy A. Cardoso and Richard G. Woll question different points in the paper and raise other important issues concerning automobile insurance exposure units that are outside the immediate scope of the paper. Responding to these questions not only calls for expanded consideration of points discussed in the paper, but also requires examination of further consequences of conversion to the car-mile exposure unit and of retaining the car-year unit. The efforts of Mr. Cardoso and Mr. Woll in providing this opportunity and challenge are appreciated greatly.

## Reply to Discussion By Ruy A. Cardoso

Mr. Cardoso's major argument against conversion to the car-mile exposure unit can be paraphrased as follows: if the car-mile were judged superior to the car-year by Dorweiler in 1929 and has not been adopted or even studied since then (over 60 years), then the car-mile unit must have some unidentified fatal flaw. Specific flaws suggested by Mr. Cardoso are (1) the technical failure of future mileage as a classification variable, (2) the irrelevancy of exposure measurement because competition prevents overpricing, and (3) customer resistance to odometer auditing. Upon examining these suggested flaws, however, one finds evidence that the true fatal flaw that has prevented the use of the car-mile unit is seen only from the perspective of automobile insurers. Adoption of the car-mile unit as an objective standard for measuring transfer of on-the-road risk would curtail price competition severely for larger-premium consumers with broad insurance needs. It also would end the subsidy for this competition currently paid by consumers transferring less than class average risk per car-year.

Mr. Cardoso's criticism of mileage as a flawed classification variable—i.e., usable only in broadest categories, insurer indifference to integrity of data, incentive to cheat—agrees with company rate hearing testimony previously published; see Butler, Butler, and Williams (1988, p. 388). The problem with this critique is that it misses the point: the subject discussed by the current paper, as well as by the 1929 Dorweiler study, is *not classification variables but exposure units*. It is necessary, therefore, to clarify the difference between variables chosen to define price classes and the price unit chosen as the unit of purchase to which prices refer.

Gasoline purchase provides a ready analogy to distinguish classification variables from the price unit. Gasoline usually is available in twelve different price classes. The pricing variables that distinguish these classes are three octane levels, self service or full service, and cash or credit payment; thus, $3 \times 2 \times 2 = 12$ prices. Yet the gasoline gallon is the unit of purchase common to all of the price classes. In auto insurance, price classes are defined by variables such as territory, driver characteristics, and use of car. Distinct from such class definition variables is the *price unit*, currently the car-year, but which would be the car-mile after conversion to the car-mile exposure unit. Although classification variables and the price unit have distinct functions, the choices of which to use for assessing the cost of risk transfer are influenced strongly by auto insurance price competition.

In suggesting that competition currently prevents insurance overpricing of cars driven less than average, Mr. Cardoso apparently is taking the well-known fact that competition lowers auto insurance prices for marketing targets and extrapolating it to the public relations dictum that competition precludes overpricing. There is plentiful evidence, however, that insurers' price competition for customers with more risk to insure has, as its complementary effect, the overpricing of customers with less risk to insure (what Bailey (1960) calls "skimming the cream"). This effect was described in 1911 by the New York State Legislature's Merritt Committee Report (p. 41) in its examination of the need for regulation of fire insurance pricing:

> In a state of open competition the rates adjust themselves not to the hazards but largely to the strength of the insured so that the man of influence, whose patronage is desired, will get his insurance too cheaply, as against the small man who is not in a position to drive a sharp bargain. That is, competition results in discrimination.

Automobile rate hearing records contain admissions that costs are shifted from higher mileage customers to lower mileage customers and from men to women in response to price competition; see Butler, Butler, and Williams (1988, p. 405). For example, in 1982 State Farm testified to the Pennsylvania Insurance Department that in order to keep the price down for its higher mileage customers, the company keeps its low mileage discount to about half the size it should be. State Farm stated:

> We're already very competitive on the [lower mileage] class, and we're generally tight on a competitive standpoint on [the higher mileage] class, and if we widen the differential, we're going to hurt ourselves very substantially on the [higher mileage] class of business.

Later in the hearing the State Farm actuary explained:

> We like to follow the statistics where we can. The rating law talks about rates which are not excessive, inadequate or unfairly discriminatory, but your rating [law] also talks about doing nothing to prohibit competition in the marketplace, and as a matter of fact, we simply can't—we just can't always follow the statistical indications.

Auto insurers not only keep price differences between risk classes smaller than cost differences to compete for members of the more costly class, but also merge higher and lower risk classes or do not divide classes where such groups are distinguishable. In the latter case, for example, competition for adult men's business explains why nearly all cars in the adult driver classes are unisex-rated despite government mileage statistics, backed by accident involvement data, that show that men's average risk per year is about twice women's average risk per year. The same accident involvement data are said to require sex-divided prices for youth classes. Rate-hearing testimony also shows that men's prices may be lowered contrary to experienced cost to allow agents to establish good relations with young men who are desirable as future sales targets.

Just as competition works to flatten rather than sharpen class differences, resistance to any real measure of exposure differences within classes also expresses competitive concern for the "man of influence" at the expense of the "small man." The capacity for miles of driving is dependent on income level, which generally determines the ability to buy gasoline and own reliable cars. Because the car-year price unit is the status quo for insurance, the result of choosing this price unit as opposed to one that responds to individual cost can be examined by analogous conversion of the price unit for gasoline from the gallon to the car-year. That is, what would the consequences be for customers if gasoline were sold like auto insurance?

With gasoline sold by the car-year, everybody with cars in the same class would pay a dollars per car-year price based on the cost per car of supplying gasoline for that class in previous years and adjusted for expected change in gasoline cost and, as currently done for auto insurance, any trend toward increased or decreased driving. Payment in advance for a car-year's worth of gasoline would allow customers to draw gasoline as needed from the class pool. Sale of gasoline by the car-year, however, would lead to problems analogous to the affordability breakdown that occurs in areas where the car-year price of auto insurance is high.

With gasoline prices set to cover the anticipated car-year average cost of each class, above average users of gasoline would experience a decrease in their gasoline expense paid by an increase in gasoline expense for below average users. Once accustomed to the benefits of unmetered gasoline, the above average user would object to any expense and accountability that using meters on gasoline pumps would entail, as Mr. Cardoso observed would occur with the use of odometers to earn insurance premiums. If the increase in annual gasoline cost per car were to force some below average users to give up cars, however, class average gallons per car-year would rise. A rise in average consumption would raise the cost of gasoline per car-year and would force still more below average users to give up their cars, causing the gasoline cost per car-year to rise even more. This death spiral effect that results when prices are not tied to a unit of individual consumption first would become apparent where the annual prices are highest, as is happening currently with auto insurance in some urban areas.

Surcharging the yearly gasoline bill of every tenth customer in a class so that the other nine can receive a customer retention discount would be analogous to the randomness of auto insurance merit rating. (Although Mr. Cardoso defends merit rating as having possible deterrence effects, customer retention is an obvious purpose. If discounts for claim free years were really risk-related, eligibility would transfer between companies. Customers generally are puzzled to discover that it does not.) With gasoline sold by the gallon instead of the car-year, however, the classification variables that set prices are certain, objective, obviously related to a cost that can be evaluated by customers, and not easily manipulated to price discriminate between customers. From the auto insurers' viewpoint, the real fatal flaw in car-mile pricing is that it would inhibit cost shifting within classes by making the cost of individual risk transfer as understandable and controllable as the gasoline cost of automobile operation.

The public demand for driver-record pricing voiced on call-in radio talk shows to which Mr. Cardoso refers is a political response based on the only information available to consumers. Charged by the car-year, auto insurance is experienced as a flat tax on car ownership at prices based on group characteristics. By appearing to take the *individual* into account, driver-record pricing competes, as the paper notes, with the idea of making the car-mile the price unit for individual risk transfer.

## Reply to Discussion By Richard G. Woll

Two sentences early in Mr. Woll's discussion transform what purports to be a critique of the paper's subject—the car-mile as the price unit for individual risk transfer—into a critique of a topic that the paper does not address—the problematic estimated future mileage discount classes with the car-year as the price unit. (These discounts are used by some insurers, but were rejected as inherently unenforceable by other insurers after several decades' use; see Butler, Butler, and Williams (1988, p. 388)). "It is obvious," Mr. Woll states, "that the difference in rates between any two drivers, *other things being equal,* should be proportional to the difference in the miles they drive. The cost of insuring different auto customers, however, depends not only on how much they drive but on other factors such as *how well* they drive, *where* they drive, and *what* kind of car they drive."

While the qualifying phrase "other things being equal" in the first sentence could refer to the purpose of classifications such as those cited in the second sentence, the word "however" in the second sentence suggests a rebuttal of the first. Together they seem to imply that the amount driven is not a measurement but a factor, i.e. a classification variable arguably related to risk, as are driver experience, garaging territory, and car type. For the remainder of the discussion, Mr. Woll criticizes the car-mile exposure unit as if it were a mileage classification variable (which it is not) to be compared with other car-year classification variables as has been done in his research at Allstate.

The basic premise of the paper is that the car-mile must work in conjunction with risk classification as the exposure unit to measure the cost of individual risk transfer. The abstract states that odometer miles multiply "a cents-per-mile rate based on class experience" and that the "per mile cost of individual risk transfer is a class property." The essential relationship of individual exposure measurement to risk classification is emphasized in every section. It is from this perspective that the main issues raised by Mr. Woll will be addressed. These issues are within-class proportionality of cost to miles driven; observed decreasing claim rates per mile with increasing annual mileage; and car-mile costs by territory classification.

The question of proportionality of cost to miles driven is raised by Mr. Woll's observation that Dr. Butler "expects a customer who drives 10,000 miles to have twice the losses of a customer who drives 5,000 miles." This correctly represents how the car-mile unit works if the cars driven different distances are classified identically (and have the same coverage).

The proportionality assumed by the current car-year system, ostensibly for administrative convenience, is that within-class cost is proportional to the time period the car is insured in units of car-years. This assumption produces widely divergent per mile costs for cars identically classified. Table 1 illustrates this using Mr. Woll's 5,000 and 10,000 miles per car-year example. The cars driven the two distances per year are garaged in the same territory and are classified identically by driver (adult unisex) and use (pleasure with limited commuting to work). The premium and per mile costs of 10,000 miles of coverage driven at 5,000 miles per car-year under two arrangements are compared with the cost of driving 10,000 miles in one car-year. Three different premiums are paid for 10,000 car-miles of exposure.

**TABLE 1**
**Within-Class Variation in Cost of 10,000 Miles Coverage**

| How 10,000 Miles are Driven | Territorial Base Price per Car-Year* | Discount** | Discount-Adjusted Class Multiplier | Premium Paid for 10,000 Car-Miles | Cost per Mile for Owner |
|---|---|---|---|---|---|
| 1 Car in 2 Years | $500 | Mileage | 1.00 | $1000 | 10.0¢ |
| 2 Cars in 1 Year | $500 | Mileage Multicar | 0.85 | $850 | 8.5¢ |
| 1 Car in 1 Year | $500 | None | 1.15 | $575 | 5.8¢ |

* Assumed value
** Deductions from the class multiplier: -0.15 for estimated future mileage less than 7500 miles; -0.15 for two or more cars on policy. From the Pennsylvania manual of State Farm Mutual Automobile Insurance, effective 5/15/92

Table 1 shows that factors not directly related to risk, such as number of cars in a household and how intensively they are used within time periods, determine large differences in what is charged per mile of exposure to risk of loss for cars in the same territory and driver risk class.

The requirement endorsed by Mr. Woll that the number of price units should be proportional to expected losses, other risk factors being equal, leads to the absurd conclusion that insurers currently expect a customer who drives 10,000 miles over two years or in two cars in one year to have approximately twice the losses as a customer driving one car the same distance in one year.

Mr. Woll raises the issue of decreasing claims per mile with increasing annual mileage by presenting Allstate study data in his Figure 1. By raising this relationship as an objection to the car-mile as a price unit, Mr. Woll implies that the same cents-per-mile price would be applied to all cars and therefore would overcharge the owners of cars driven more intensively in a year relative to owners of cars driven much less in a year. This objection, however, ignores the fact that cents-per-mile prices would depend on each car's risk classification.

As in prior studies with similar results, the results shown in Mr. Woll's Figure 1 are obtained with data that either are unclassified or are classified only by driver sex; see Butler, Butler, and Williams (1988, p. 266). As a consequence, drivers at the extremes of the age range, who have considerably higher than average accident rates per mile and also average much less driving, would be over represented at lower mileages without classification by driver age. (The paper points out that car-miles of exposure randomly sampled by accidents would be biased toward the cars of such driver groups.) Concurrently, the higher mileage data would be biased to cars used predominantly on limited access highways with lower accident rates per mile. As Mr. Woll points out, it is not just miles driven that determine risk transfer cost, but territory, driver, and use of car, all of which require risk classification for evaluation. Conversion of class prices from dollars-per-year to cents-per-mile demonstrates this essential relationship.

Table 2 compares the conversions of two existing car-use classes to cents-per-mile prices. All that is necessary for the conversion is an average mileage value for the class. At averages assumed for the two classes, the difference in the cents-per-mile class prices shown in the table approximate the threefold decrease in per mile claim rates with the fivefold increase in intensity of car use from 5,000 miles to 25,000 miles per year shown by the Allstate data in Mr. Woll's Figure 1.

**TABLE 2**
**Car-Mile Prices For Two Use Classes**

| Class | Territory Car-Year Base Price* | Multiplier** | Car-Year Price | Average Miles per Car-Year* | Calculated Price per Car-Mile |
|---|---|---|---|---|---|
| Pleasure | $500 | .95 | $475 | 5,000 | 9.5 ¢ |
| Business | $500 | 1.40 | $700 | 25,000 | 2.8 ¢ |

* Assumed values
** Adult unisex driver class. Multipliers from the California manual of State Farm Mutual Automobile Insurance, effective 1/15/91

What determines per-mile risk for a car is not the number of miles it is driven within an arbitrary time period (one year), but the average conditions under which the driving is done. Although intensity of car use may correlate with driver age and car use, classification is essential to determine the cost of insurance coverage per car-mile for any set of driving conditions. The car-mile unit for measuring the cost of risk transfer is also essential to meaningful territorial classification.

As though the car-mile were a classification variable, Mr. Woll states that "[W]e find that mileage is a relatively unimportant source of difference between customers compared to territory." An example shows, however, that classification by territory depends on the car-mile exposure unit—as distinct from mileage classification—to have meaning for individual risk transfer. Table 3 shows the dollars per car-year prices for a high priced territory and a low priced territory in California for cars in the same driver and use class. The ratio of high to low prices per car-year is 4.4, presumably representing the greater traffic density in Los Angeles and other differences in conditions and costs. The cents-per-mile costs for car owners also is shown in both territories at three mileage amounts.

**TABLE 3**
**Car-Mile Costs by Territory and Miles Driven**

| California Territory | Car-Year Price for High Annual Mileage* | Car-Mile Cost to Owner by Miles Car is Driven in Year: 3,000** | 12,000 | 20,000 |
|---|---|---|---|---|
| 13 Northern Counties | $265 | 7.6¢ | 2.2¢ | 1.3¢ |
| Los Angeles City | $1172 | 33.7¢ | 9.8¢ | 5.9¢ |

* State Farm manual effective 1-15-91. Minimum coverage, adult unisex driver and car use profile from California Insurance Dept.'s 1990 Auto Premium Survey
** Discount for estimated future mileage less than 7,500 miles applied

If it is assumed that the average exposure for the class in both territories in Table 3 is 12,000 miles per car-year, conversion to the car-mile unit means that all of the northern counties cars would be paying 2.2 cents a mile and all of the Los Angeles cars in the class would be paying nearly 10 cents a mile, thus preserving the difference in territorial risk transfer costs.

In contrast to the differences between territories in cents-per-mile costs at class average mileages, the northern counties owners of cars driven 3,000 miles in a year pay more than seven cents a mile while owners of Los Angeles cars driven 20,000 miles in a year pay less than six cents a mile. The meaning of difference in risk by territory is lost if more is paid per mile for individual cars in territories with low traffic densities than is paid per mile for individual cars in territories with the highest traffic densities.

Mr. Woll devotes a considerable portion of his critique to discussing his study of statistical measures for comparing classifications of car-year data, citing evaluation methods developed by the Stanford Research Institute (SRI). Although the SRI study (1976) did not evaluate the car-mile unit as an alternative to the car-year unit, a major finding from its empirical study of nine years of individual driver accident records establishes strong limitations on the ability of classification by year to distinguish the cost of individual driving risk. The study corroborates that the most powerful class separation is driver sex, with men's average accident likelihood per year about twice the women's average. Despite this large class difference, however, the distributions of individual accident likelihoods per year for men and women completely overlapped, with 13% of women having likelihoods greater than men's average and 28% of men having likelihoods less than women's average. These overlapping distributions and averages show characteristics that are similar to the distributions of men's and women's annual mileages in relation to the approximately 2:1 difference in their average miles driven. Eleven percent of women exceed men's average mileage, and 24% of men drive less than women's average mileage; see Butler, Butler, and Williams (1988, p. 396). Individual miles of driving cannot be predicted from experienced class averages, by driver sex, or in any other way. (See the paper for the characteristics of individual mileage listed by Bailey and Simon.) The miles that individual cars are driven, however, are recorded on their odometers as the measure of individual risk transferred. The expected cents-per-mile cost of risk transfer depends on statistically reliable actual class experience.

Mr. Woll's discussion of the car-mile price unit as if it were a classification variable has provided an opportunity to show why the car-mile exposure unit is essential to meaningful classification for individual risk transfer. Dollars-per-year prices for example risk classes that purport to distinguish differences in risk by territory, driver, and car use show large individual variability in cents-per-car-mile costs for reasons not directly related to risk. Therefore, not only is the car-mile exposure unit essential for cost-based pricing of individual risk transfer, but its use is essential in order for risk classification variables (factors) to have meaning for individual risk.

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