

Federal Reserve Bank of Minneapolis
Research Department Staff Report 139

April 1991

WHY IS AUTOMOBILE INSURANCE
IN PHILADELPHIA SO DAMN EXPENSIVE?

Eric Smith

University of Essex

Randall Wright

Federal Reserve Bank of Minneapolis
and University of Pennsylvania

ABSTRACT

We document and attempt to explain the observation that automobile insurance premiums vary dramatically across local markets. We argue high premiums can be attributed to the large numbers of uninsured motorists in some cities, while at the same time, the uninsured motorists can be attributed to high premiums. We construct a simple noncooperative equilibrium model, where limited liability can generate inefficient equilibria with uninsured drivers and high, yet actuarially fair, premiums. For certain parameterizations, an optimal full insurance equilibrium and inefficient high price equilibria with uninsured drivers exist simultaneously, consistent with the observed price variability across seemingly similar cities.

Financial support from the National Science Foundation is gratefully acknowledged. We also thank seminar participants at Pennsylvania, Stanford Business School, London School of Economics, the Rand Corporation, Williams College, the NBER Summer Institute, and the Canadian Economic Theory Conference at UBC for their input. Four referees also made several suggestions that improved the paper substantially. These individuals are not responsible for the results or opinions in the paper.

The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

I. Introduction

This paper presents an analysis of the automobile insurance market. Interest in this topic, while far from new, has certainly intensified recently. Beginning with Proposition 103 in California, and since spreading to Pennsylvania, New Jersey and elsewhere, some dramatic and controversial policies are currently being debated and implemented.¹ Public concern over auto insurance and the prospect of these and other policy interventions would seem to warrant an extended economic analysis.

The main issue is price; but the problem is paradoxical, in that premiums are exorbitant in some places and very much lower in others. According to the Insurance Information Institute (1989), "Although there are a few places where auto insurance affordability problems are truly a statewide phenomenon, it is more commonly a problem in particular cities, or even in particular neighborhoods. ... It is a problem in Miami, but not in Jacksonville, in Los Angeles but far less so in San Diego and San Jose. The problem is severe for many insureds in Baltimore, Boston, Chicago, Cleveland, Detroit, Newark, New York City, and Philadelphia. Yet it is far less extreme for most drivers, for example, in Columbus, Dallas, Houston, Indianapolis, Memphis, Milwaukee, Nashville, and Seattle" (p. 3). We document this in Table 1, which presents premiums for four sample policies,

1. California's Proposition 103 includes: (i) 20% reductions, and a temporary freeze, in premiums below their November 1987 level; (ii) restrictions on the use of geographic rate setting; (iii) mandatory 20% discounts for good drivers; (iv) restrictions on insurers' ability to cancel or not renew policies (see *The Los Angeles Times*, May 5, 1989, pp. 1, 28, 30 31). In Pennsylvania, a law was passed July 1, 1990 requiring companies to roll back rates as much as 22%, and some additional proposals under debate include various forms of no-fault insurance, and having a single insurer underwrite all policies in Philadelphia (see *The Philadelphia Inquirer*, Feb. 6, 1990, *The Wall Street Journal*, Feb. 22, 1990, p. A16 and *The New York Times*, Sept. 3, 1990, p.10).

as well as some other information, for twenty-seven local markets across the country.²

As an example, consider a 45 year-old married male with a clean record, driving a 1987 Chevrolet Caprice (Sample Premium A - see the notes to the table for more details). He would pay \$516 annually in Milwaukee and \$570 in Columbus, compared with \$1679 in Philadelphia and \$1925 in Los Angeles. For a couple with two teenage sons, owning the same Chevy as well as a 1982 Buick LeSabre (Sample Premium C), the cost is \$1803 in Milwaukee and \$1944 in Columbus, as compared with \$5513 in Philadelphia and \$6394 in Los Angeles. Although these cities are extreme, the overall variability in premiums in the table is remarkable. We add that this is cannot simply be attributed to differences in regulations or other factors across states, since statewide average premiums (not shown) vary much less, as do premiums across cities in the same state in Table 1. To illustrate this further, Table 2 presents sample premiums from another data source for six cities within Pennsylvania.

How could rates vary so much across cities? Several potential explanatory variables suggest themselves immediately.³ It is obvious that

2. We constructed the premium data from three sources: the publication "Auto Insurance Issues," by the Insurance Information Institute (1989), and two data sets provided to us by the AETna and State Farm insurance companies. Our three samples did not overlap perfectly, so we combined them (adjusting for differences in means in the samples) to get one observation on each policy for each city. The demographic and theft data are from the Statistical Abstract of the United States. We constructed the variable UM/BI, which is the ratio of uninsured motorist to bodily injury liability claims, by combining data from two sources: the AIRAC publication "Uninsured Motorists" and the ISO-NAII publication "Factors Affecting Urban Auto Insurance Premiums" (again adjusting for differences in means). We chose the cities in the sample because they are ones for which we were able to get the information on UM/BI, which is an important variable in what follows.

3. High repair, medical, legal, and other costs contribute to high premiums, of course; but it is unlikely that these factors could differ enough across cities to explain the observed variability (although we did not have the

population density, also reported in Table 1, should be important since it is an indicator of accident frequency. Also, one would think that high vehicle theft rates add to the cost of insurance, although we point out that Philadelphia's theft rate is rather low in both Tables 1 and 2. Without denying all relevance for these factors, we wish to focus on another factor here - the uninsured driver problem. Table 3 presents indemnities (dollars of insured loss per auto between 1983 and 1987) on several types of coverage for a subsample of our cities for which we had data.⁴ Observe that the indemnity for uninsured motorist (UM) coverage in Philadelphia is \$110, much higher than any other city in the sample. This is also over 10 times the Pennsylvania state average. A complimentary piece of information in Table 2 is that the UM claim frequency in Philadelphia is 20 times greater than Pittsburgh.

Our thesis is that the high price of auto insurance can be attributed (at least in part) to the large number of uninsured drivers in some localities, while at the same time, the large number of uninsured motorists

data to check this carefully). We also think it is unlikely that excess profits due to collusion among insurers can explain this variability, since the same companies serve many of our cities and it is difficult to imagine them colluding in one local market but not another. In any case, on the suggestion of a referee, we compared the ratios of premiums to idemnities, which proxies for profits, across cities. The correlation between this measure of profitability and price was $-.16$, which tends to support our view that price variability is not the result of variability in profits.

4. The types of coverage are as follows. BI (bodily injury liability) and PD (property damage liability) cover losses inflicted on third parties. PIP (personal injury protection) covers medical payments, lost wages, and so on, for the insured. COMP (comprehensive) covers damages caused by theft, fire, vandalism, etc. UM (uninsured, and underinsured, motorist coverage) pays for damages that you would be entitled to receive, less any sums that you actually do receive, from the owner or operator of an uninsured vehicle. We did not have data on collision coverage, which pays damages to a car resulting from colliding with another vehicle, a telephone pole, etc. A textbook such as Rejda (1986) provides more details.

can be attributed (at least in part) to the high premiums. The basic idea is simple. When an uninsured or underinsured driver causes a loss, the damaged party is forced to collect from his own policy. Hence, his insurance company must charge a higher premium in order to earn a given rate of return, and this premium can be high enough to make driving without insurance the best option for some drivers. A key assumption below will be limited liability, or a bankruptcy constraint. Without this constraint, the unique equilibrium has all drivers fully insured; but limited liability introduces a non-convexity for low wealth (although not for high wealth) individuals that potentially allows equilibria with some uninsured drivers, and high, yet actuarially, fair premiums. Our model predicts that, given two similar cities, one can end up in an equilibrium with high numbers of uninsured drivers and high premiums, while the other can end up with lower premiums and few uninsured drivers. Both accident frequency and income distribution variables are important in determining which outcome is more likely to occur.

Table 1 also provides estimates of the fraction of uninsured drivers in each city. These estimates are constructed by dividing the number of UM claims by the number of BI liability claims. This is, more accurately, a measure of the number of accidents caused by uninsured motorists, but it is the standard way of estimating the fraction of uninsured drivers in the industry (see AIRAC, 1989). For example, in Philadelphia a surprising 38% of motorists are uninsured.⁵ In Figure 1, we plot the price of each policy

5. This compares with a Pennsylvania state average of 16%, and a national average of 13%. It has also been estimated that 30% of the registered cars in Philadelphia are uninsured (see *The Wall Street Journal*, Feb. 22, 1990), but this underestimates the fraction of all cars that are uninsured because a greater proportion of uninsured cars are unregistered, due to the fact that it is illegal to register without insurance in the Pennsylvania.

against the fraction of uninsured drivers; we also indicate which cities are high or low density and high or low income (high income is greater than \$9909. per capita while high density is greater than 6,800 people per square mile). Observe how five localities seem to lie to the northeast of the others: Philadelphia, Los Angeles, Miami, the Miami Suburbs (actually, Dade county excluding Miami and Miami Beach), and Detroit, although there is some reason to suspect that UM/BI overestimates the fraction of uninsured drivers in Detroit, due to a Michigan state law that makes it easier to file a UM claim than a BI claim. All of these localities are high density, and all are low income, except Los Angeles. However, a few very wealthy denizens of LA raise average income and hide the fact that the city does have a sizable low income population. It appears that in the data, as well as in our model, high density and a large number of low wealth drivers are necessary for markets to end up in equilibria with high prices and high UM/BI ratios.

The rest of the paper is organized as follows. In the Section II we present our basic model, and prove the existence of an equilibrium. In Section III we analyze welfare implications. We show that equilibria with uninsured drivers are inefficient, and are Pareto dominated by full insurance. For certain parameterizations, the model displays a coordination failure, in that both an efficient full insurance equilibrium and inefficient high price equilibria with uninsured drivers exist simultaneously. In Section IV we discuss some of the recent policy measures in light of our theoretical model. In Section V we conclude.⁶

6. A model that is in certain respects similar to ours is contained in Keeton and Kwerel (1984), who also refer to some earlier literature. Their analysis differs from ours in several important aspects, however, some of which will be discussed below. A different literature related to automobile insurance tries to model price dispersion across insurers within a given local market as a search equilibrium; see Dahlby and West (1986).

II. The Theoretical Model

There is a continuum of agents, called *drivers*, with a total population normalized to unity. Each driver has the same von Neumann - Morgenstern utility function $U(\cdot)$, that is twice continuously differentiable with $U' > 0$ and $U'' < 0$. During the period under consideration, each driver is involved in an accident with probability $\pi > 0$, and no accident with probability $1-\pi > 0$. For simplicity, an accident in our model always involves two drivers drawn at random from the population, and results in a loss of L for each, or a total loss of $2L$. In any accident, one of the drivers is unambiguously and costlessly found to be *at fault*, each with equal probability. Thus, for a given individual, with probability $\pi/2$ he is hit and with probability $\pi/2$ he hits someone else. Drivers are homogeneous except possibly for their initial wealth, x . We assume $x \geq L$, but otherwise wealth can be arbitrarily distributed across agents for now.⁷

A driver who is at fault in an accident is responsible, up to the extent of limited liability, for the total loss of $2L$, and must compensate the victim either from his insurance or from his own wealth. If he has insufficient resources to compensate the other driver, he pays what he has and ends up with zero final wealth. When this limited liability constraint is binding, the victim suffers a loss as well, and he can make a claim against his own policy. We do *not* assume that uninsured motorist coverage can be purchased separately, but that it is bundled together with a general automobile insurance package. Although in some (not all) states it is possible to buy insurance without UM coverage, the relevant consideration is

7. The analysis below assumes a particularly simple wealth distribution, but some preliminary results are actually easier to develop without specifying this distribution at all.

that it is impossible to buy UM coverage without liability. For this and several other reasons, we think that it is better to assume that all types of coverage are bundled together.⁸

We want to capture strategic interaction in the automobile insurance market as a simple game. A pure strategy is an amount of coverage, $q \in [0,1]$, and a mixed strategy is a probability distribution over pure strategies.⁹ The price per unit of coverage is denoted by p , and will be determined below as part of the equilibrium. Insurance pays on all damages the policy holder causes plus any loss he suffers from being hit by a driver with resources insufficient to compensate him. For example, suppose driver A with wealth x and coverage q hits driver B. Then A's insurance pays him q times $2L$, leaving him with $x' = x - pq - L + 2Lq$ dollars, and from this he must reimburse B. If x' is less than L , however, A pays what he can and B makes a claim against his own policy for $L - x'$. When choosing his strategy, each driver takes as given the price p and the strategies of others. The amount of coverage purchased by other drivers will be represented by Q , where Q can

8. Keeton and Kwerel (1984) assume (unrealistically, they admit) that UM coverage can be purchased separately from liability. In this case, there is even a greater potential for market failure, as agents who can purchase UM coverage alone have even less incentive to acquire liability coverage. As suggested by Keeton and Kwerel, this may help explain why UM coverage cannot be purchased without liability in the real world. Nevertheless, we will show that there is *still* a potential for market failure when coverage must be bundled, and that this market failure interacts with premiums in a way that is consistent with the empirical observations discussed in the introduction. Further, in reality there is substantial interaction and subsidization across types of coverage, and the presence of uninsured drivers will affect the cost of medical and collision as well as uninsured motorist coverage. All of these considerations, as well as simplicity, suggest that our assumption is a good one for the purposes at hand.

9. Later, we also discuss the case where q is restricted to $\{0,1\}$ - i.e., either no insurance or full insurance. That model is slightly simpler to analyze, but some interesting insights come out of the more general case. The reason we need to consider mixed strategies is that pure strategy symmetric equilibria do not always exist.

differ across agents because of their initial wealth or because they are using mixed strategies.

We now derive the expected utility of a driver with initial wealth x and coverage q . With probability $1-\pi$, he is not involved in an accident and enjoys final wealth $x-pq$. With probability $\pi/2$, he hits someone and is left with final wealth $\max\{x-pq-2L(1-q), 0\}$, which cannot be less than zero due to the limited liability constraint. Finally, with probability $\pi/2$, he gets hit, implying final wealth $x-pq-(1-q)(L-R)$, where R is the amount he recovers from the other driver, and is random because the other driver's wealth X and coverage Q are random. If $X-pQ-L+2LQ \geq L$, the at-fault driver fully compensates and $R = L$; otherwise, the at-fault driver goes bankrupt and $R = X-pQ-L+2LQ$. Hence,

$$L - R = L - \min\{L, X-pQ-L+2LQ\} = \max\{0, -X+pQ+2L(1-Q)\}.$$

Combining terms, expected utility can be written

$$\begin{aligned} v(q, Q, p) = & (1-\pi)U(w-pq) + \frac{\pi}{2}U[\max\{w-pq-2L(1-q), 0\}] \\ & + \frac{\pi}{2}EU[w-pq-(1-q)\max\{2L(1-Q)-X+pQ, 0\}], \end{aligned}$$

where E denotes the expectation over X and Q .

The next step is to determine the actuarially fair insurance premium by equating revenue and expected indemnities. This readily yields the implicit pricing formula

$$p = \frac{\pi}{2}(2L) + \frac{\pi}{2}E(L-R) = \pi L + E\max\{0, -X+pQ+2L(1-Q)\},$$

where, again, E is the expectation over X and Q . The first term on the right-hand side is the part of the premium due to the possibility of causing an accident, while the second term is the part due to the possibility of being hit by an uninsured or underinsured driver. Let $p = p(Q)$ be the solution to this equation. Notice that p is minimized by setting $Q = 1$ for all drivers, which implies $p = \pi L$, and is maximized by setting $Q = 0$ for all drivers, which implies $p > \pi L$ as long as there is positive probability that $X < 2L$. Inserting p into $v(\cdot)$ yields the *payoff function*

$$V(q, Q) = v[q, Q, p(Q)].$$

Let $q' = (2L-x)/(2L-p)$ be the amount of coverage at which the limited liability constraint is just binding for an individual with wealth x – i.e., the point at which $x - pq' - 2L(1-q') = 0$. For any driver with wealth $x \geq 2L$, limited liability is never a relevant consideration, even with $q = 0$. On the other hand, if $x < 2L$, then $q < q'$ implies limited liability will bind whenever at fault. These considerations imply the payoff functions satisfy the conditions in the following lemma and illustrated in Figure 2 (the proof follows directly from differentiation and is left to the reader).

LEMMA 1: Fix Q and therefore $p = p(Q)$. Then we have:

(a) For $x \geq 2L$ (high wealth drivers), $V(q, Q)$ is strictly concave in q on $[0, 1]$ and has a maximum at $q = 1$.

(b) For $x < 2L$ (low wealth drivers), $V(q, Q)$ is strictly concave in q on $[0, q']$ and has a local maximum at some $q_0 \in [0, q')$, and is also strictly concave in q on $[q', 1]$ and has another local maximum at $q = 1$.

REMARK: The local maximizer q_0 may be strictly positive or zero, although it is possible to give sufficient conditions under which $q_0 = 0$ (see below). Also note that, if p is sufficiently high, a low wealth driver may not be able to afford $q = 1$, and in this case we can show that q_0 is in fact the global maximizer subject to the budget constraint $pq \leq x$.

Part (a) of Lemma 1 tells us that a high wealth driver's global maximum occurs at $q = 1$, irrespective of Q , and therefore full insurance is his dominant strategy. This immediately implies the following result:

THEOREM 1: If $x \geq 2L$ then $q = 1$ is a dominant strategy. If $x \geq 2L$ for all agents then full insurance is a dominant strategy equilibrium, and therefore the unique Nash equilibrium. In this equilibrium, $p = \pi L$.

This indicates the sense in which low wealth agents are important: if all drivers have enough wealth so that limited liability is never binding, then the only equilibrium has no uninsured drivers and a low price. Hence, from now on, we assume that there is some positive fraction of the population θ that each have wealth $x = w$, where $L \leq w < 2L$. The rest of the population each have wealth $x \geq 2L$, and since they will always use their dominant strategy, we can concentrate on the low wealth drivers. As indicated by part (b) of Lemma 1, low wealth drivers choose $q = 1$ if $V(1, Q) > V(q_0, Q)$, they choose $q = q_0 < 1$ if $V(1, Q) < V(q_0, Q)$, or they may randomize if $V(1, Q) = V(q_0, Q)$. The important part of this observation is that these agents, if they randomize at all, will only randomize between the two points q_0 and 1. Hence, although a mixed strategy is generally any probability distribution over $[0, 1]$, any mixed strategy that a low wealth driver might

choose can be summarized here by the pair (q_0, ϕ) , where q_0 is the maximizer of V subject to $q < q'$, and ϕ is the probability assigned to $q = 1$.¹⁰

We now prove that there always exists a symmetric Nash equilibrium in mixed strategies. However, rather than having each agent randomize by choosing a probability ϕ of choosing $q = 1$, it would be equivalent to have a fraction ϕ of the low wealth drivers choose $q = 1$, while the remainder $1-\phi$ choose $q = q_0$. Hence, our proof can alternatively be interpreted as establishing the existence of an equilibrium in pure but non-symmetric strategies.

THEOREM 2: There always exists a symmetric mixed strategy equilibrium, or equivalently, a non-symmetric pure strategy equilibrium.

PROOF: Suppose that the $1-\theta$ high wealth drivers choose their dominant strategy of $Q = 1$, while the θ low wealth drivers choose $Q = 1$ with probability ϕ and $Q = Q_0 < 1$ with probability $1-\phi$, and consider the best response problem of a typical low wealth agent. With some simplification, his payoff function can be written

$$V = \phi u(w-p) + (1-\phi)[\phi v(q_0, 1, p) + (1-\phi)v(q_0, Q_0, p)],$$

where p is given by $p = \pi L + .5\pi\theta(1-\phi)\max\{2L(1-Q_0)-w+pQ_0, 0\}$, or

$$p = \pi \cdot \max\left\{L, \frac{2L + \theta(1-\phi)[2L(1-Q_0) - w]}{2 - \pi\theta Q_0(1-\phi)}\right\}.$$

10. The key thing here is that strategies can be represented by a pair of numbers belonging to $[0,1] \times [0,1]$, a convex, compact subset of \mathbb{R}^2 . This makes the necessary fixed point argument relatively straightforward.

A symmetric Nash equilibrium is a fixed point of the correspondence $\rho: [0,1]^2 \rightarrow [0,1]^2$, defined by letting $(q_0, \varphi) = \rho(Q_0, \Phi)$ maximize V . Now ρ is non-empty by the Wierstrauss Theorem and upper semi-continuous by the Theorem of the Maximum. It is convex valued, because $\rho(Q_0, \Phi)$ will either be the point $(q_0, 0)$ or the point $(q_0, 1)$ or the set $\{q = q_0, 0 \leq \varphi \leq 1\}$, all of which are convex. By Kakutani's Theorem, ρ has a fixed point. Q.E.D.

III. Analysis of Equilibria

In the previous section we established the existence of equilibrium. There are two possible types of equilibria: when $q = 1$ for all agents, we have $p = \pi L$ and we say that we are in a low price equilibrium with full insurance; when $q < 1$ for a positive fraction of the low wealth drivers we have $p > \pi L$ and we say that we are in a high price equilibrium with incomplete coverage. Below we will provide examples demonstrating that both are possible, and that for some parameterizations both exist simultaneously. Prior to this, we establish some basic welfare results: full insurance for all drivers is Pareto optimal, whether or not it is an equilibrium; high price equilibria are Pareto dominated by full insurance; and multiple equilibria can be Pareto ranked when they coexist.

THEOREM 3: Full insurance ($q = 1$ for all drivers) is Pareto optimal.

PROOF: Since agents are risk averse, any optimal allocation x' must provide them with nonstochastic final wealth, so there is no loss in generality to restricting attention to nonstochastic allocations. To be feasible, the sum of final wealth over agents cannot exceed the sum of initial wealth minus the aggregate loss, $\int x' \leq \int x - \pi L$. The full insurance allocation is $x' = x$

- πL . For an allocation x'' to Pareto dominate this, it must satisfy $x'' \geq x'$ for all agents with strict inequality for some set of agents with positive measure. This implies $\int x'' > \int x' = \int x - \pi L$ and violates feasibility. Q.E.D.

THEOREM 4: Any equilibrium with incomplete insurance, and therefore $p > \pi L$, is not Pareto optimal, and can be dominated by full insurance, at least if we have access to lump sum taxes and transfers.

PROOF: In any equilibrium, high wealth drivers set $q = 1$, while low wealth drivers set $q = 1$ with probability ϕ and $q = q_0 < 1$ with probability $1-\phi$. Consider an equilibrium with $\phi < 1$ and $p > \pi L$. If $\phi > 0$, then low wealth drivers get the same payoff from $q = q_0$ and $q = 1$, and that payoff equals $U(w-p)$. As this is strictly less than $U(w-\pi L)$, they strictly prefer $q = 1$ at the full insurance price πL . High wealth drivers also obviously prefer a lower price. Therefore, all mixed strategy equilibria are Pareto inferior to full insurance at the lower price.

The case of a pure strategy high price equilibrium, $\phi = 0$, is more complicated. Let $v(q) \equiv V(q, q)$ be expected utility for low wealth drivers when they *all* choose q ,

$$v(q) = [1-.5\pi(1+\theta)]U(w-pq) + .5\pi U[\max\{w-pq-2L(1-q), 0\}] \\ + .5\pi\theta U[w-pq-(1-q)\max\{2L(1-q)+pq-w, 0\}],$$

where $p = p(Q)$. Suppose they all choose $q = q_0 < 1$. By Lemma 1, $q_0 < q' = (2L-w)/(2L-p)$, which implies that the second term is $.5\pi U(0)$, and also that $p = [2\pi L + \pi\theta(2L(1-q)-w)]/(2-\pi\theta q)$.

Now consider a transfer $T = (p-\pi L)(1-\theta)/\theta$ to each low wealth driver,

financed by a lump sum tax of $p - \pi L$ on each high income driver. By construction, high income drivers are indifferent between paying p or paying πL plus the tax. If we impose $q = 1$ on all low wealth drivers, after simplification their final wealth can be computed to be

$$x' = [1 - .5\pi(1+\theta)](w - pq) + .5\pi\theta\{w - pq - (1-q)[2L(1-q) + pq - w]\}.$$

After some algebra, Jensen's inequality implies $v(q) < U(x')$. Hence, low income drivers strictly prefer $q = 1$ along with this tax - transfer scheme to the equilibrium with $\varphi = 0$. Q.E.D.

Several comments are in order concerning these results. First, note that because high wealth drivers are always fully insured, the presence of underinsured drivers is essentially a lump sum transfer away from them - that is, p rises, but because it is still actuarially fair, high wealth drivers still choose $q = 1$. Inefficiency arises in an equilibrium with $\varphi < 1$ because low wealth drivers take socially unnecessary risks. Second, note that all mixed strategy (or non-symmetric) equilibria are Pareto dominated by full insurance without the need for any transfers, while pure strategy equilibria with $q = q_0$ for all low wealth drivers can only be dominated in general with transfers. Finally, note that Theorem 4 says full insurance dominates any high price - incomplete coverage equilibrium (assuming the necessary transfers are made), even if full insurance is not an equilibrium itself. In other words, low wealth drivers would want *mandatory* full insurance at the low price imposed on them collectively, even if they would individually choose $q = q_0 < 1$ at this price.

THEOREM 5: Pure and mixed strategy equilibria are inversely Pareto ranked by price. If full insurance is an equilibrium, then it Pareto dominates all other equilibria.

PROOF: Suppose there are two pure strategy equilibria, one with $q = q_0$ for all low wealth drivers and price p_0 , and another with $q = q_1$ and price p_1 . From the actuarial pricing formula, $q_1 > q_0$ implies $p_1 < p_0$. Therefore,

$$v(q_0, q_0, p_0) < v(q_0, q_1, p_1) \leq v(q_1, q_1, p_1).$$

The first inequality follows because a given driver is better off when others have more insurance and also when the price is lower, while the second follows by the assumption that q_1 is an equilibrium, and hence a best response. This shows that low wealth drivers prefer q_1 and p_1 to q_0 and p_0 . As high wealth drivers obviously also prefer the low price equilibrium, it Pareto dominates the high price equilibrium.

A very similar argument establishes that any mixed strategy equilibrium with price $p > \pi L$ is dominated by a full insurance equilibrium with price πL , and that any two mixed strategy equilibria also can be ranked inversely by price. Hence, if full insurance is an equilibrium then it dominates all other equilibria. This completes the proof. Q.E.D.

We emphasize that there are two distinct types of "bad" outcomes that are possible in the model. First, there could be multiple equilibria, and we could get stuck in an inefficient high price equilibrium with underinsured drivers even though the low price - full insurance outcome is also an equilibrium. This is a *coordination failure*, in the sense that all

low wealth drivers would be happy to choose $q = 1$ if only p were lower, and p would indeed be lower if only they would all choose $q = 1$.

Second, it may be that full insurance is not an equilibrium at all, and low wealth drivers would not choose $q = 1$ even at the low price. In this case, everyone agrees that they would all be better off if they all had complete coverage, but there is no way to get low wealth drivers to voluntarily purchase full insurance at an actuarially fair price. Although both outcomes are inefficient, the phenomena of multiple equilibria is perhaps especially interesting here, in that it may help to explain the large observed differences in premiums across seemingly similar cities.

To pursue this further, it is useful to decompose the effect of underinsured drivers on individual payoffs into two components - a *risk effect* and a *price effect*. The risk effect captures the impact of a change in the coverage of low wealth drivers, say Q_L , holding p constant (which affects expected utility because it increases your loss when hit by a low wealth driver). The price effect captures the impact of a change in p holding Q_L constant. The total impact of Q_L on expected utility is

$$\frac{\partial v[q, Q, p(Q)]}{\partial Q_L} = \frac{\partial v(q, Q, p)}{\partial Q_L} + \frac{\partial v(q, Q, p)}{\partial p} \frac{\partial p(Q)}{\partial Q_L}$$

At $q = 0$, the price effect is zero (because you are uninsured) while the risk effect is positive. At $q = 1$, the risk effect is zero (because you are fully insured) while the price effect is positive. Hence, the risk effect rotates the payoff function around $V(0, Q)$ while the price effect rotates it around $V(1, Q)$, as shown in Figure 3.

In Figure 3, $q = 0$ is the best response when $Q_L = 0$; i.e., $V(q, Q)$ is maximized by choosing to buy no insurance when other low wealth drivers buy

no insurance and p is at its equilibrium value. Thus, no insurance for all low wealth drivers is an equilibrium. Now consider changing Q_L from 0 to 1. The pure price effect rotates the payoff function around its intercept, and if it is sufficiently strong then $V(q,Q)$ will end up being maximized at $q = 1$. The risk effect, however, counteracts this by rotating the payoff function around its intersection with the vertical line through $q = 1$. If the payoff function is maximized at $q = 1$ after both rotations, as shown in the figure, then full insurance is also an equilibrium. Hence, for multiple equilibria to exist, it is necessary that the price effect is large and the risk effect is small.¹¹

We now demonstrate by an explicit example that multiple equilibria can actually arise. First, we make a simplifying assumption, by restricting q to be either 0 or 1 (either no insurance or full insurance).¹² Consider the constant relative risk aversion utility function, $U(x) = x^{(1-\alpha)}/(1-\alpha)$, and for simplicity set $w = L = \theta = 1$. It is not hard to show $V(0,0) \geq V(1,0)$, which means no insurance is an equilibrium, if and only if $\alpha \leq \alpha_0$, and $V(1,1) \geq V(0,1)$, which means full insurance is an equilibrium, if and only if $\alpha \geq \alpha_1$, where $\alpha_0 = 1 - \ln(1-\pi)/\ln(1-3\pi/2)$ and $\alpha_1 = 1 - \ln(1-\pi/2)/\ln(1-\pi)$. In Figure 4, the locus satisfying $\alpha = \alpha_1$ and the locus satisfying $\alpha = \alpha_0$ are plotted in (π, α) space. For all points above the α_1 curve there exists an

11. In the language used by Cooper and John (1988), the price effect entails a *strategic complementarity*: when more low wealth drivers buy insurance the price falls and this encourages more low wealth drivers to buy insurance. The risk effect works the other way, however: when more low wealth drivers buy insurance there is less need to be insured. Multiplicity requires the net effect to be positive and large.

12. The restriction of q to be either 0 or 1 would actually be innocuous if $\partial V/\partial q \leq 0$ at $q = 0$. A sufficient condition on parameters and the utility function for this to hold is given in the working paper version (Smith and Wright 1989).

equilibrium with $q = 1$ and $p = \pi L$, while for all points below the α_0 curve there exists an equilibrium with $q = 0$ and $p > \pi L$. In the shaded region, both exist simultaneously. For a given α , the $q = 0$ equilibrium is more likely to occur when π is large. Also, multiple equilibria require both π and α to be large.

IV. Policy Implications

In this section, we consider some recent policy proposals in light of our model. Automobile insurance reform has emerged as a central issue recently, as discussed in the introduction, and the suggestions differ widely. Some commentators appeal to the efficiency of free markets and call for less regulation or greater competition, while others seek stricter control and legislated pricing. Others advocate a change in the institutional and legal structure of the market, including a move to no-fault insurance or a move to have one monopoly carrier. The theory presented above has implication for all of these issues.

Concerning efficiency in laissez-faire, our model demonstrates clearly the possibility of market failure in the market for automobile insurance. High price equilibria with uninsured or underinsured drivers can exist and they are not optimal. Additionally, the existence of multiple Pareto ranked equilibria demonstrates the possibility of a coordination failure. In this case, it may well be that policy makers should focus simply on achieving lower premiums, and price rollbacks like those legislated recently in California and Pennsylvania may be all that is required. As long as full insurance is an equilibrium, it is self-enforcing once achieved, and further measures are unnecessary. When full insurance is not an equilibrium, however, rolling back premiums will not eliminate underinsured drivers,

since low wealth individuals would not purchase full coverage even at the low price. In this case, rollbacks will only cause insurers to lose money.

Of course, the enforcement of mandatory full insurance would eliminate the inefficiency.¹³ However, our results indicate that the enforcement of mandatory insurance will need to be coupled with transfer payments to low wealth drivers if we want to guarantee that it will Pareto dominate a high price equilibrium. This is consistent with the view of some people, who are reluctant to impose or enforce mandatory insurance laws because they amount to "forcing many low-income drivers to choose between paying for food or shelter and buying auto insurance" (see *The Los Angeles Times*, Sept. 2, 1990, p.A30). Of course, this equity argument is not necessarily valid. We have shown that it is possible that forcing low wealth individuals to buy insurance can, in and of itself, reduce premiums - perhaps, although not necessarily, to a level these same low wealth individuals are willing to pay.

In addition to mandatory insurance laws, another institution designed to combat uninsured driver problems is the so-called "involuntary" insurance market or "assigned risk" plan. When individuals cannot get insurance in the normal market at a reasonable price (e.g., because they are high risks), the state assigns them to insurers. Premiums are higher for such drivers,

13. Existing regulations in over half the states have some form of mandatory insurance while the rest have some form of financial responsibility law, although the minimum liability limits are typically very low. In any case, legislating against the problem does not necessarily make it go away. The *Journal of American Insurance* (1982) reviews mandatory insurance laws, and summarizes the evidence as follows: "the sad fact is that while requiring everyone to buy auto liability insurance coverage may look great on paper, it just doesn't seem to work in the real world. In states where these laws have been tried, they have proven both difficult and costly to enforce. ... And they don't seem to be doing much to get uninsured drivers off the road." (p. 20).

but not high enough to avoid substantial underwriting losses in the involuntary market, and other drivers end up subsidizing them. Although we abstracted from differential risks, our model does have individuals who cannot find insurance they find affordable at actuarially fair rates. Consider the case where low wealth drivers choose $q < 1$ when $Q = 1$ and $p = \pi L$ (so that full insurance is not an equilibrium). There will always be some \bar{p} between 0 and πL such that they will voluntarily become fully insured, but it will involve an underwriting loss of $\pi L - \bar{p}$ per low wealth driver. Nevertheless, if their number is small relative to high wealth drivers, the latter will be willing to subsidize them rather than end up in a high price - incomplete insurance equilibrium. This rationalizes a policy of subsidized rates for low wealth in addition to high risk drivers.

Another policy option, and one that is often favored by the insurance industry, is no-fault insurance. In a no-fault system each party in an accident collects from his own insurer, and in a *pure* no-fault system injured parties have no right to sue.¹⁴ Arguments for no-fault usually revolve around transaction costs, especially the cost of litigation. Arguments against no-fault typically concern incentive effects. In our model there is a new argument in favor of no-fault. Under such a system, each driver is responsible for only his own loss, which eliminates the impact of limited liability. It can be shown that full insurance at the low price is the unique equilibrium under a pure no-fault system; with partial no-fault, there would still be a possibility of market failure, but

14. In the literature, pure no-fault means only medical expenses and lost wages are covered, and not property damage or pain and suffering. Since 1971 about half of the states adopted some form of no-fault law (although several have since been repealed). However, none have been pure systems, and individuals always maintain some right to sue.

presumably it would be reduced. Of course, we have abstracted from many of the issues relevant to the no-fault debate, including both incentive effects and transaction costs, but these implications of our model still seem relevant.

Finally, some proposals call for one large insurer to cover the entire market in cities like Philadelphia (recall footnote 1), and the model here suggests that this also has some merit. Since high price equilibria are suboptimal, economic rents are available. Suppose that instead of simply setting actuarially fair premiums, an enterprising insurer tries offering a lower p in order to capture these rents. Further, suppose that by beating the going rate, he captures a fraction z of the market, where for simplicity z is independent of the difference in prices.¹⁵ One can show that for z near 1 the strategy of lowering p will increase profit, while for sufficiently small z , any p other than the equilibrium premium generates negative profit. Thus, a single insurer will be able to circumvent the coordination failure if and only if he is sufficiently large. A monopoly supplier introduces standard problems, and may require regulation; but in the presence of a multiple equilibria of the type studied here, there is at least one reason for recommending one large rather than many small carriers.

The bottom line is that several of the policy recommendations that have been under consideration recently can be rationalized here. Legislated price roll-backs, subsidized involuntary insurance markets, and monopoly suppliers can all be Pareto improving policies in this model. Perhaps on the surface mandatory insurance laws seem the most straightforward idea, but

15. The variable z is meant to proxy for various factors that prevent an immediate and complete capture of the market; these include search and advertising costs, customer-brand loyalty, and so on.

we reiterate that these are costly to enforce and are typically less than completely successful. Additionally, they do not necessarily result in a Pareto improvement over high price equilibria without transfer payments to low wealth drivers. If a single policy recommendation was to be made, it appears that a pure no-fault system looks best from the perspective of our model, because it eliminates the externality entirely. We would prefer to be somewhat cautious, however, about recommending any policy, as the model has abstracted from many considerations that may be relevant.¹⁶

V. Conclusion

In this paper, we have demonstrated the possibility of market failure in the automobile insurance market, in the sense of inefficient equilibria with uninsured or underinsured drivers. We have also demonstrated the possibility of a coordination failure, in the sense of multiple, Pareto ranked equilibria. The model does not predict that the automobile insurance market always ends up in an inefficient equilibrium; this is as it should be, since many cities have reasonable premiums and few uninsured drivers. But we are not simply saying that "anything can happen" either. The framework does indicate factors that tend to make the inefficient outcomes more or less likely. Theorem 1 suggests that cities with mostly high wealth individuals will be immune to uninsured driver problems.¹⁷ The example in Section III suggests that the accident frequency has to be sufficiently high

16. To quote P.J. O'Rourke's *Holidays in Hell*, "Half the world's suffering is caused by earnest messages contained in grand theories bearing no relation to reality - Marxism and No-Fault Insurance, to name two."

17. Not surprisingly, uninsured drivers do tend to be low wealth individuals. See AIRAC (1989) and *The Journal of American Insurance* (1982).

for a high price equilibrium to exist. Hence, we expect that cities with high income and low density are unlikely to end up in a bad equilibrium. We refer again to Figure 1, which shows that low income and high density are necessary, but not sufficient, for a city to appear in the northeast part of the chart.

How much of the high premiums observed in these cities can be reasonably attributed to uninsured drivers? Unfortunately, one cannot simply look at UM premiums for the answer. In Philadelphia, for example, basic UM typically costs only around 10% of the total premium, but this does not reflect the true actuarial cost, as each \$1 of UM premiums results in \$1.33 of losses that must be covered by other parts of the policy. More significantly, UM coverage typically applies only to bodily injury and not property damage. Damage to one's car is covered by collision, which is paid regardless of fault - if you cause the accident your insurer pays you, while if you get hit, you can collect from your own insurer, who will then attempt to collect from the at fault party or his insurer. The presence of uninsured motorists therefore undoubtedly increases collision premiums. A similar argument applies to personal injury or medical protection as well.

Hence, the true impact of the uninsured on the cost of automobile insurance will exceed the 10% of the premium that goes to UM coverage. If we assume that uninsured drivers have roughly the same effect on the cost of personal injury and collision coverage that they have on the overall premium, then we can use the data in Table 3 to form an estimate of this effect (as a practical matter, ignoring personal injury protection and collision losses is our only alternative, since we have only sketchy data on the former and none on the latter). If we divide the indemnity for UM coverage by the sum of the indemnities for BI, PD, COMP and UM coverage,

this provides an estimate of the fraction of these losses that are due to uninsured motorists and, under our maintained hypothesis, also an estimate of the total effect. For 12 of the 15 cities in the table, the estimate is no greater than 10%. For Los Angeles, the estimate is 11%, for Miami, it is 19%, and for Philadelphia it is 22%. Interestingly, the recent Pennsylvania legislation discussed in Section I rolled back rates exactly 22%. Perhaps they got it right.

REFERENCES

- All-Industry Research Advisory Council (AIRAC), *Uninsured Motorists*, 1989.
- Cooper, Russell, and John, Andrew, "Coordinating Coordination Failures in Keynesian Models," *Quarterly Journal of Economics*, 1988, 103, 441-64.
- Dahlby, Bev and Douglas S. West, "Price Dispersion in an Automobile Insurance Market," *Journal of Political Economy*, 1986, 94, 418-38.
- Insurance Information Institute (III), *Auto Insurance Issues*, 1989.
- Insurance Services Office, Inc., and National Association of Independent Insurers (ISO-NAII), *Factors Affecting Urban Auto Insurance Costs*, 1988.
- Journal of American Insurance, "Compulsory Auto Insurance: How Well Does It Work?" Summer 1982, 20-23.
- Keeton, William R., and Kwerel, Evan, "Externalities in Automobile Insurance and the Underinsured Driver Problem," *Journal of Law and Economics*, April 1984, 27, 149-179.
- National Association of Independent Insurers (NAII), *Pennsylvania Fact Book*, 1989.
- Rejda, George E., *Principles of Insurance*, 2nd ed. Glenview, Illinois: Scott, Foresman and Company, 1986.
- Smith, Eric and Wright, Randall, "Why is Automobile Insurance in Philadelphia so Damn Expensive?" University of Pennsylvania CARESS Working Paper 89-16, 1989.

TABLE 1: CITY DATA

City	Pop	Thefts	Income	UM/BI	Sample Premiums			
					A	B	C	D
Baltimore	9.4	976	8647	.236	953	2572	3211	1316
Chicago	13.2	1315	9642	.175	1204	3446	4122	2052
Chicago Sub	13.2	---	9642	.108	749	2199	2726	1152
Cleveland	6.8	1917	8018	.228	907	2567	3043	1523
Cleveland Sub	6.8	---	8018	.150	635	1808	2187	972
Columbus	3.0	626	9909	.109	570	1637	1944	885
Detroit	8.0	2732	8852	.287	1627	2540	5803	3019
Jacksonville	0.8	807	10466	.156	594	1585	---	842
Kansas City	1.4	---	11153	.205	742	2183	2686	1182
Kansas City Sub	1.4	---	11153	.150	548	1630	1978	894
Los Angeles	7.0	1709	12084	.253	1925	5038	6394	2697
Miami	10.9	2093	8904	.399	1365	3325	4552	1777
Miami Sub	10.9	---	8904	.450	1169	2963	4182	1464
Milwaukee	6.3	945	9765	.144	516	1507	1803	789
New Orleans	2.8	---	8975	.182	1129	3151	4590	1626
New York	24.1	1313	11188	.097	1417	3565	4433	2317
Phoenix	2.3	632	11363	.136	1100	3199	4142	1572
Philadelphia	12.1	929	8807	.383	1679	4081	5513	2338
Phila. Sub	12.1	---	8807	.222	836	1846	2585	1151
Pittsburg	7.0	1837	9998	.134	687	1539	2079	1056
Pittsburg Sub	7.0	---	9998	.110	601	1343	1873	881
San Diego	3.1	1744	11766	.153	869	2439	3069	1326
San Francisco	16.1	1006	13575	.146	1451	4009	4978	2304
San Jose	4.2	472	12583	.115	960	2707	3364	1452
Seattle	5.8	1011	12919	.089	720	2033	2432	1103
St Louis	6.9	---	8799	.197	1027	2887	3704	1705
St Louis Sub	6.9	---	8799	.103	589	1652	2149	899

Notes:

For Pop = population per square mile (thousands) and Income = income per capita, the suburb variables are set equal to the respective city variables. Thefts = thefts/100,000 cars and UM/BI = ratio of UM to BI liability claims.

Policy A: married male age 45 drives 1987 Chevrolet Caprice.

Policy B: single male age 19 drives 1987 Chevrolet Caprice.

Policy C: two car family - married male age 50 and single male age 19 drive 1987 Chevrolet Caprice, married female age 50 and single male age 17 drive 1982 Buick LeSabre.

Policy D: married male age 45 drives 1988 BMW 325E 4 Door.

Each policy is for less than 10 miles to work and 8,000 miles annually, a clean record, and the following limits: BI/PD = 50/100/25; UM = 15/20; Collision = 250; Comprehensive = 250; MED/PIP = (BASIC)

TABLE 2: CITY DATA - PENNSYLVANIA

City	Thefts	UM Claims	Sample Premiums	
			Adult	19 yr old
Philadelphia	929	1200	1688	5060
Pittsburg	1837	60	659	2058
Harrisburg	655	50	492	1575
Reading	411	30	497	1587
Erie	289	---	571	1810
Johnstown	---	---	500	1588

Notes:

Thefts = thefts/100,000 cars.

Sample premiums are averages over three major state insurers. For Philadelphia, the rates have also been averaged over city's three territories.

Policies are both for males driving a 1987 Chevrolet Caprice less than 10 miles to work with a clean record, with the following limits: BI/PD = 50/100/25; UM = (BASIC); Collision = 250; Comprehensive = 250; MED/PIP = (BASIC).

Source: National Association of Independent Insurers, *Pennsylvania Fact Book*, 1989.

TABLE 3: INDEMNITIES (FIVE YEAR LOSS COSTS)

City	BI	PD	PIP	COMP	UM
Baltimore	221(2.37)	78(1.47)	91(2.52)	32(1.27)	36(3.17)
Chicago	89(1.77)	46(1.11)	---	82(2.06)	24(3.55)
Cleveland	70(1.85)	45(1.15)	---	87(2.19)	19(3.32)
Columbus	39(1.03)	46(1.16)	---	25(0.84)	6(1.10)
Detroit	34(1.42)	169(1.38)	100(1.63)	168(2.48)	12(4.01)
Jacksonville	28(0.63)	45(1.02)	31(0.88)	20(0.73)	7(0.49)
Los Angeles	302(2.31)	94(1.40)	---	84(1.96)	60(3.64)
Miami	84(1.89)	54(1.23)	59(1.67)	61(2.24)	46(3.20)
Milwaukee	73(1.71)	43(1.32)	---	33(1.10)	13(2.94)
New York	114(2.00)	64(1.20)	76(1.63)	166(3.23)	10(3.56)
Philadelphia	247(4.66)	54(1.26)	276(4.18)	87(2.59)	110(10.6)
San Diego	103(0.78)	46(0.87)	---	37(0.88)	8(0.55)
San Francisco	127(0.95)	66(1.23)	---	50(1.16)	15(0.98)
San Jose	90(0.68)	57(1.06)	---	35(0.83)	8(0.54)
Seattle	65(1.15)	53(1.34)	18(0.89)	24(1.02)	8(1.04)

Notes:

The policies are defined as follows: BI = bodily injury liability, PD = property damage liability, PIP = personal injury protection, COMP = comprehensive, UM = uninsured motorist coverage. We did not have data on collision coverage.

Numbers in parentheses are loss costs divided by state averages.

Detroit's PD loss cost is for Michigan's broadened collision coverage.

Source: Insurance Services Office, Inc., and National Association of Independent Insurers (ISO-NAII) *Factors Affecting Urban Auto Insurance Costs*, 1988.

Figure 1a: PREMIUMS VS UNINSURED

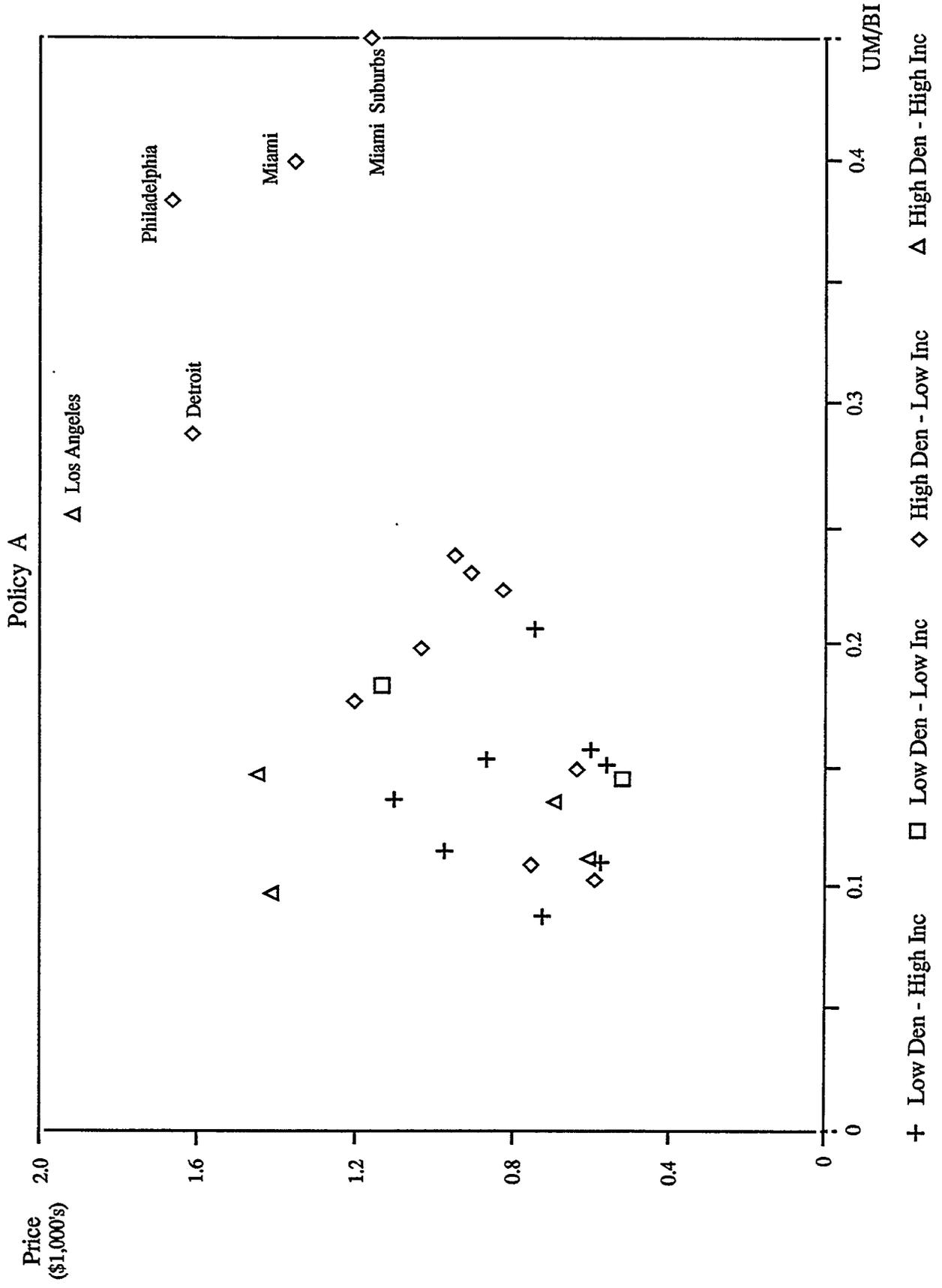


Figure 1b: PREMIUMS VS UNINSURED

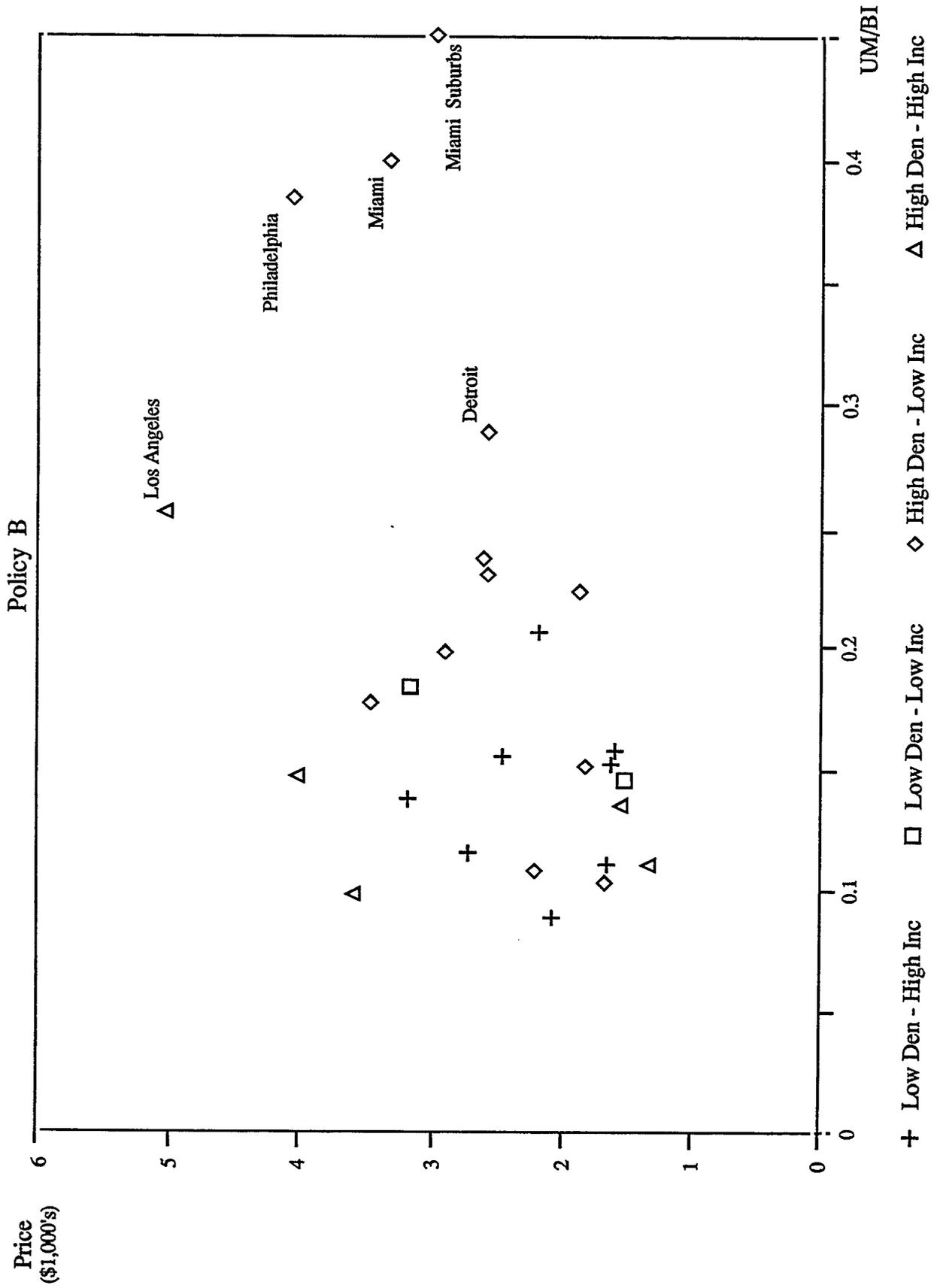


Figure 1c: PREMIUMS VS UNINSURED

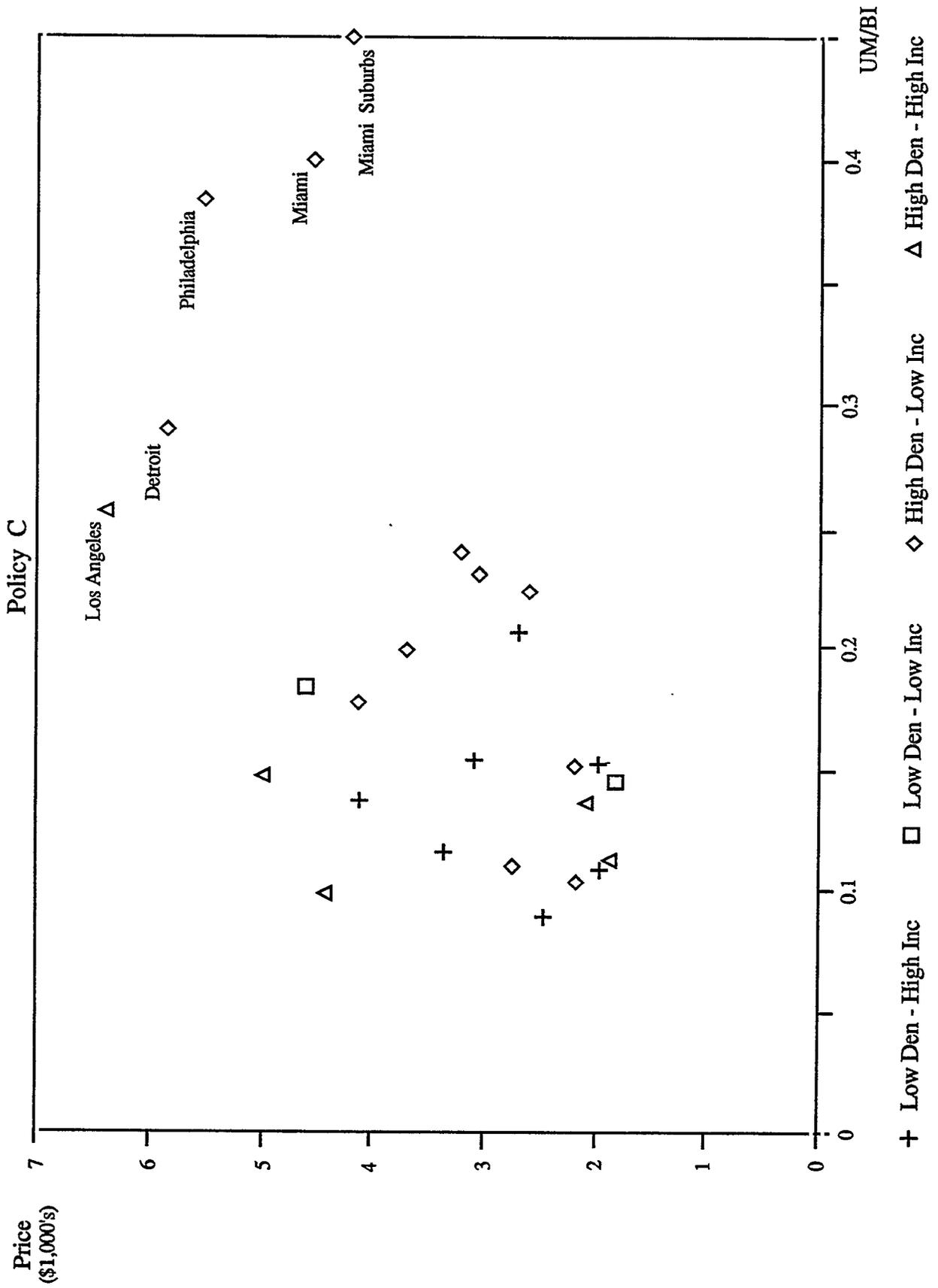
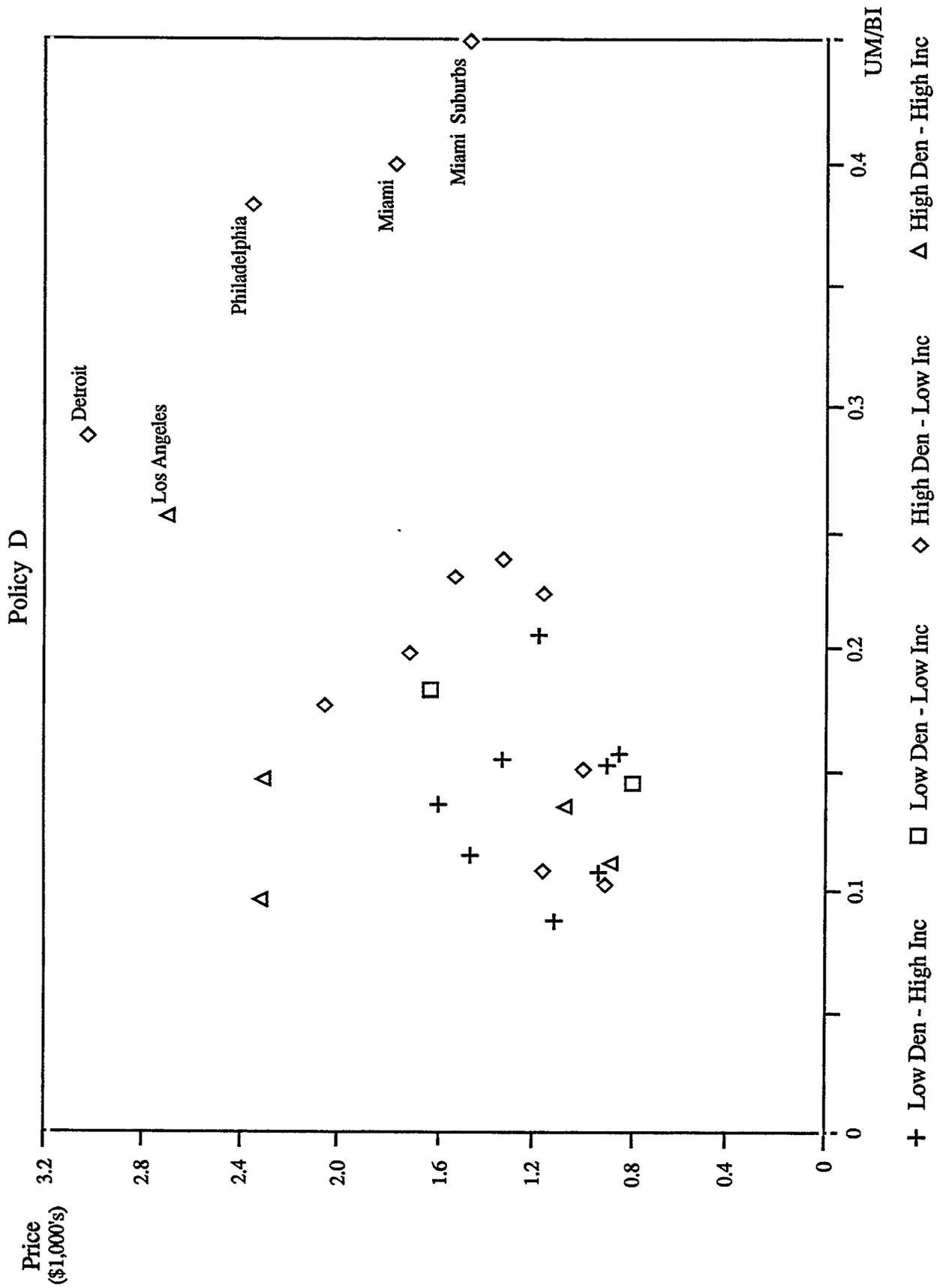
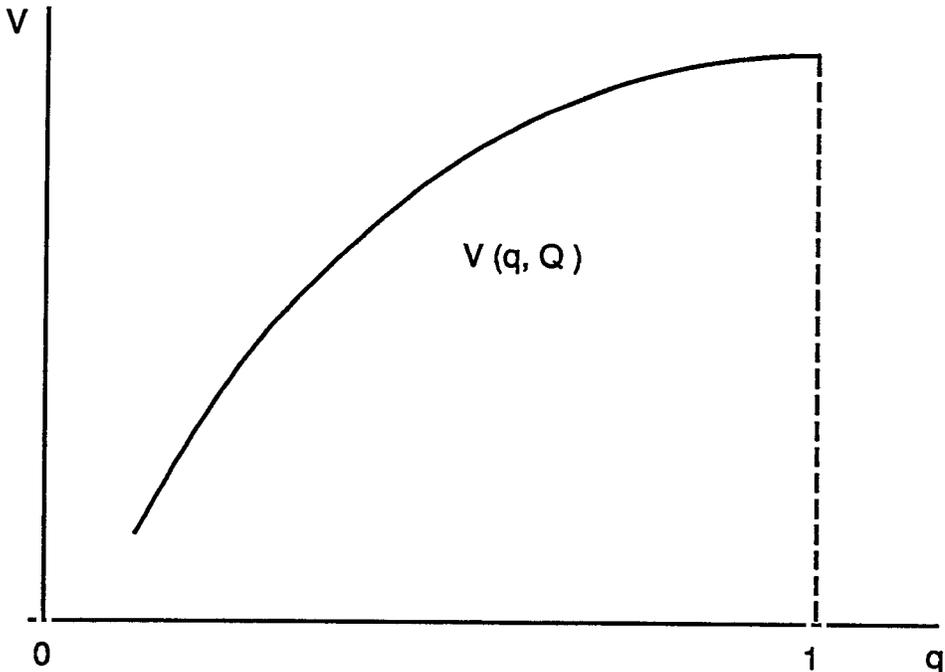


Figure 1d: PREMIUMS VS UNINSURED



(a) high wealth driver



(b) low wealth driver

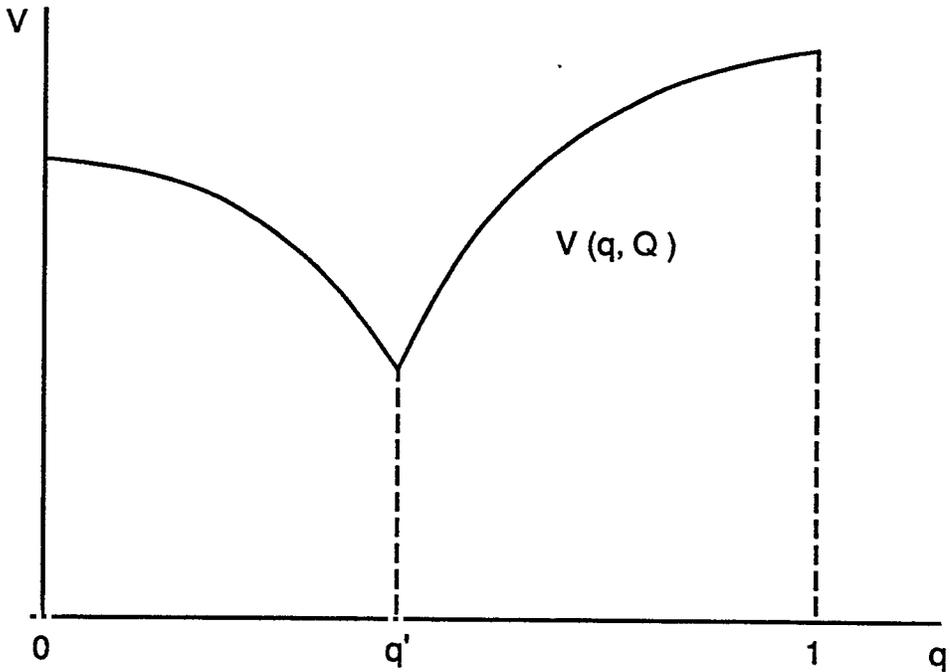


Figure 2: Payoff Functions

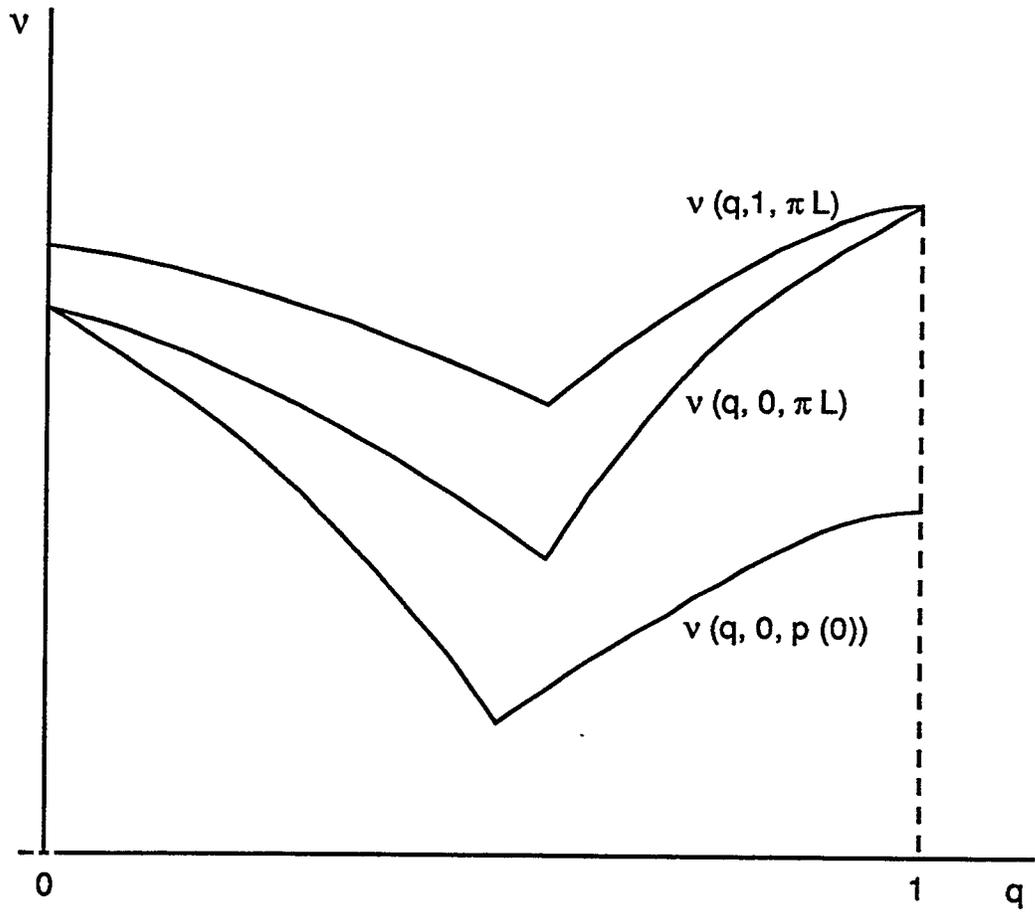


Figure 3: Risk-Price Decomposition

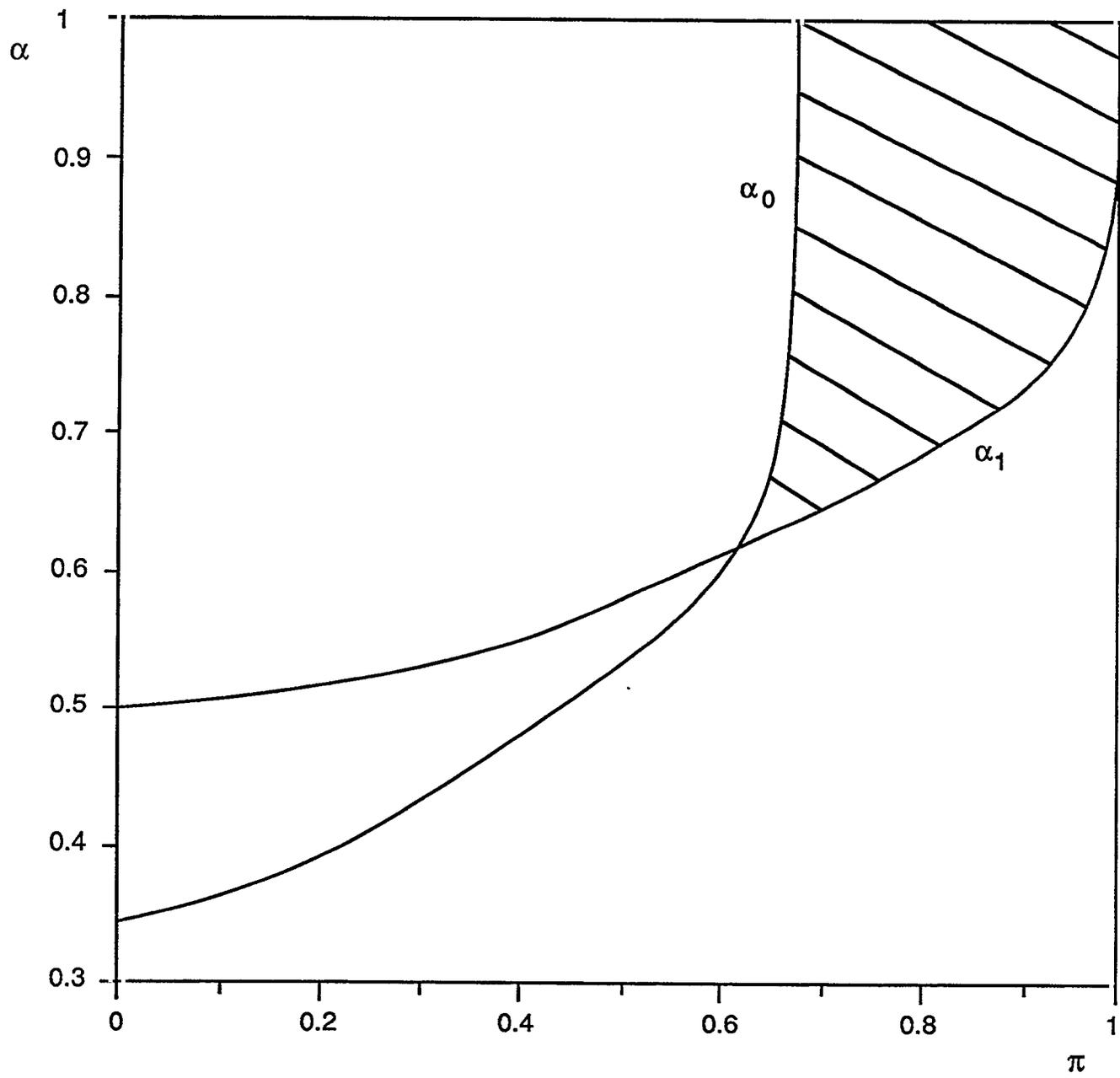


Figure 4: Region of Multiple Equilibria