Strategic Adverse Selection: Raising Competitor Costs in the Insurance Industry*

Kevin Shaver†
Duquesne University
March 11, 2011

Abstract

The potential for adverse selection in insurance markets and related concerns for pricing insurance contracts has been well established. Consequently, the cost of selling insurance policies for a firm is contingent upon not only the number of policies sold but to whom they are sold. This feature differentiates insurance markets from conventional markets and admits novel strategies through which firms may exert market power. We develop a two stage spatial model of Bertrand price competition with an endogenously determined rule for sharing demand to highlight the role that information asymmetries between competing firms may play. These asymmetries, which exist due to variance in the ability of firms to discern the cost of entering into an insurance contract, create an opportunity for the advantaged firm (the firm most adept at perceiving differentiation in consumer costs) to profitably raise its rivals’ costs. Competitor costs increase as a result of adverse selection problems created solely by the advantaged firm’s pricing and categorization decisions. Consequently, the advantaged firm is able to isolate subsets of the market from competition and price them above marginal cost even as free entry and other basic competitive forces effectively promote marginal cost pricing throughout the rest of the market. Additional implications of the model are that the exercise of this type of market power explains, at least in part, anomalous features of insurance markets such as the apparent failure in the law of one price, and that it may exacerbate market trends such as premium inflation. Evidence of the use of these strategies is presented by testing implications of the model against data from the Washington private passenger automobile insurance market.

---

*I am deeply indebted to many for their help and support, including Marcus Berliant, Bruce Petersen, and Chuck Moul. A special thanks to the National Association of Insurance Commissioners and to the Washington Office of the Insurance Commissioner for retaining and making public the data necessary to carry out this work.

†E-mail: shaverk@duq.edu
1 Introduction

A key feature of insurance markets, as modeled in Rothschild and Stiglitz’s (1977) seminal paper, is that the cost of selling insurance policies is contingent upon not only the number of policies sold but to whom they are sold. This differentiates insurance and other similarly structured markets from conventional markets and admits novel strategies, such as "cream skimming," through which firms may project market power. Yet "cream skimming" efforts, hereafter referred to as segmentation strategies, have never been satisfactorily modeled and competition in insurance markets where innovation in categorization is relatively unfettered has never been tested for their effective use. When considered at all, segmentation strategies have been modeled in a relatively ad hoc fashion (Buzzacchi and Valletti (2005), Schwarze and Wein (2005), and Strauss and Hollis (2007)). This paper clarifies how segmentation strategies differ from simple increases in pricing precision, identifies the implications of their use, and provides evidence of their effective utilization. To these ends, I specify a two stage spatial model of Bertrand price competition, with an endogenously determined rule for sharing demand, to identify the consequences of the strategic use of information asymmetries between competing insurance firms. Two implications that follow from the model’s equilibrium are tested against an original dataset, which provides comprehensive pricing and categorization data for the Washington state non-standard automobile insurance market. This data set provides the first opportunity to test for the use of these types of strategies in a categorically mature insurance market.

A segmentation strategy consists of categorizing and pricing of insurance consumers specifically to exploit information asymmetries between firms. These asymmetries, i.e., variation in the capacity of firms to discern the expected cost of entering into insurance contracts, create the opportunity for advantaged firms (those relatively adept at perceiving cost differentiation of insurance consumers) to categorize consumers with more precision than disadvantaged firms. However segmentation strategies cannot be characterized solely as increases in pricing precision, as they entail pricing in combination with the categorization structure. In particular by elevating the price of insurance consumers in new high cost categories while retaining the market price level in categories consisting of low risk consumers, the advantaged firm is able to shift the mix of business in the market. This shift results in more high cost consumers choosing to insure with disadvantaged competitors, which compels them to increase their prices to maintain profitability. Consequently, the advantaged firm is able to isolate the customers in the newly defined low cost categories of the market from competition and price them above marginal cost even as free entry and other basic competitive forces effectively promote marginal cost pricing throughout the rest of the market. Thus, this type of anticompetitive behavior is difficult to identify by standard measures of competition. Furthermore, segmentation strategies unambiguously reduce consumer welfare, and in the case of non-compulsory insurance, may lead some consumers to self insure to avoid paying an inflated price for coverage. Additional results of interest are that
the use of segmentation strategies explains, at least in part, anomalous features of insurance markets such as the significant level of price dispersion, insurance shortages, and premium inflation.

The remainder of the paper is organized as follows. Section 2 provides motivation. The model is developed in section 3, first laying out a general specification of the model and then proving existence of equilibrium for both the compulsory and noncompulsory insurance cases. Section 4 gives a characterization of equilibrium, then briefly analyzes some comparative statics of interest, and concludes with a discussion of the welfare effects. Section 5 provides empirical evidence of segmentation strategies in the Washington state non-standard private passenger automobile (PPA) market. Section 6 concludes and suggests future research.

2 Motivation

Clearly uncertainty is a significant and pervasive element of economic phenomena. Consequently, mechanisms for risk management are of great value. Among these mechanisms insurance markets play a vital role by allowing economic agents to trade unlikely but severe losses for certain but relatively small losses. It is difficult to overstate the importance of functionally sound insurance markets to the U.S. economy. In 2008 direct premiums written were $1.072 trillion - a substantial fraction of GDP devoted to risk spreading.\(^1\) Because of the insurance industry’s role in distributing risk through the economy, adverse trends in the industry are likely to have a magnified affect on the economy as a whole, and so are of particular importance. Thus, it is critical for economists to have a deep understanding of insurance markets, including how such mechanisms for risk management may be distorted through market power.

Most models of insurance markets make strong competitive assumptions that obscure the potential of market power to focus on other important features of interest. The standard model of competition in insurance markets (Rothschild and Stiglitz (1976), Wilson (1977), and Crocker and Snow (1986)) assumes symmetric categorization and has firms compete through the simultaneous selection of the price and quantity of insurance contracts offered (where quantity refers to the limits of insurance per policy). This model is most appropriate in relatively unconcentrated insurance markets where policies are not standardized. However, policy limits tend to be standardized and not shift significantly in many markets like private passenger automobile (PPA) and homeowners insurance. Competition in markets characterized by many consumers and standardized policies may be more accurately modeled in an oligopolistic framework where competition occurs through pricing and categorization. To focus on this aspect of competition, the model presented here assumes away competition in quantity and explicitly allows for competition in categorization. The model can be extended to include quantity competition (Strauss and Hollis (2007)), however

\(^1\)III Fact book 2010, Insurance Information Institute
the model’s results would not change significantly and the analysis is greatly simplified by its omission.

Analysis of the potential for market power through collusion in insurance markets is limited considering the history of abuse prior to the McCarran-Ferguson Act, institutional features conducive to collusion, and the frequency of insurance shortages. However, this is not surprising given the impact of regulation and the influential empirical work of Joskow (1973) and others. In his study of automobile insurance Joskow argues that, despite recurrent claims to the contrary, no significant market power remains in the hands of automobile insurance firms due to strong competitive pressures such as minimal barriers to entry, relatively low industry concentration, and constant returns to scale in production. His case is strengthened by the observation that average industry profits were relatively low (though profits have increased in the intervening years). Subsequent work has provided limited evidence of collusive pricing between firms and shown that reducing regulation leads to more competitive pricing (Barros (1996) and Chidambaram, Pugel, and Saunders (1997)). Thus, anticompetitive tactics present in insurance markets must be robust to these competitive pressures.

If one is to assume that insurance markets are perfectly competitive, several features of firm pricing are puzzling and require more rigorous examination. First, there is a surprising amount of price dispersion evident in insurance markets. It is not uncommon to find the premium quotes for an individual to range from a maximum quote that is 2 to 5 times that of the lowest quote offered (Shaver 2008). This is particularly surprising as insurance expenditures tend to be large relative to disposable income and should exhibit relatively low price dispersion (Pratt, Wise, and Zeckhauser (1979)). A common explanation of this follows the Salop and Stiglitz (1977) model where a mass of uninformed consumers make it profitable for some firms to raise prices above the competitive level. There is some empirical evidence for this position (Brown and Goolsbee (2002)), but it is not clear that this explanation is sufficient to fully explain price dispersion in insurance markets.

The differentiation in pricing and categorization structures across firms in many insurance markets is another puzzling feature. Under strong competitive pressure one expects to see similar pricing and categorizing strategies, marginal cost pricing within those categories, and a relatively homogeneous mix of business across competitors. However, it is not clear that competition in insurance markets is consistent with those expectations. Most U.S. PPA insurance markets show significant variation in rating strategies, e.g., the use of insurance scoring and the variation in discounts offered.

Buzzacchi and Valletti (2005) use a variation of the Hotelling model to ar-

\footnote{As measured in Shaver (2008), there is significant variation in market segmentation by firms in the Washington PPA liability market. In 2004 the maximum number of categories set by a firm was approximately 227,446,971,155,517,000, while the median was 1,474,472,372, and the minimum was 239,752.}

\footnote{Shaver (2008) provides evidence of significant variation in firm discounts for the Washington PPA insurance market. In 2000, of 73 categories of discounts offered only seven were offered by more than half of companies active in the market.
gue that full categorization of risks is a dominant strategy for competing firms. The Nash equilibrium in their model implies that firms will adopt symmetric categorization strategies. This result depends on three key assumptions that are relaxed in this paper. First, they assume symmetry in the implementation cost and the benefit of new rating variables. Yet it is not clear that the cost and benefit of incorporating innovative techniques into pricing strategies is uniform across firms. Second, important dynamics of insurance pricing are obscured by assuming that pricing decisions are made simultaneously. In a simultaneous move game, given symmetric implementation costs, it is a dominant strategy for firms to categorize in the face of categorical competition. However, this approach overlooks the impact of timing in the implementation of new categorization strategies. It is clear that firms do not categorize using all feasible rating variables even when they are clearly available. The profits from adopting a rating variable after one’s competitor are not necessarily sufficient to warrant the cost of its adoption. Following a categorical leader by duplicating its rating structure provides no additional profits since it leads to direct price competition across larger segments of the market. Instead, lagging firms may seek profits by shifting segmentation efforts towards other less utilized rating variables.

Finally, Buzzacchi and Valletti assume that all firms are equally capable in screening and categorizing consumers on the basis of their expected cost. The convergence of several factors is suggestive of why firms may diverge in the ability to evaluate the expected cost of an insurance contract. First, firms often use past business experience to estimate the effectiveness of new rating strategies. However, business experience is not randomly generated, so a firm’s in-house data may be systematically biased, obscuring or over estimating the value of potential rating variables. Potential sources of bias in data collection include the firm’s mix of business, managerial determination of the data to be collected, and the ability/clout to collect the desired information. Additionally, many firms do not have the market share to generate sample sizes sufficient to match up with larger competitors. Second, the lag before insurance contract costs are realized makes pricing experimentation without supporting experience data very risky. Most firms extensively study the costs of pricing and categorization changes before implementing a new strategy. Third, differences in the organizational design of firms likely contribute to heterogeneity in innovative capabilities across firms. Fourth, observing the introduction of a new rating variable by a competitor may not provide a firm with the knowledge needed to incorporate that variable into its own pricing scheme. Not only does the adoption of a new rating variable require an understanding of how it is correlated with other variables in one’s own rating scheme, often aspects of rating techniques are not visible to competitors because they are either hidden or considered to be proprietary. Thus, it can be costly for other firms to develop techniques to match their competitors. Even when the methods a competitor uses are visible, simply

\[\text{Shaver (2008) provides evidence of the diffusion of several rating variables over the years 1999-2005. For example, credit information, which was first used in the early 90's, has been shown to be a powerful rating variable. In 1999 31\% of insurance companies used credit information in rating, seven years later only 63\% had adopted its use.}\]
copying a competitor’s strategy may not be viable due to differences between the firms underwriting practices, technological capability, modes of distribution, and other firm heterogeneities.

3 The Model

The model highlights competitive pressures that influence firm decisions regarding the categorization and pricing of insurance consumers. These decisions are modeled with a two stage game in which three profit/market share maximizing firms engage in Bertrand price competition for the business of a continuum of consumers differentiated solely by their probability of having a loss. The advantaged firm (firm 1) is the only firm endowed with a technology capable of screening consumers, and thus is the only firm capable of pricing according to a consumer’s categorical designation. This capability is modeled as the ability of firm 1 to partition the market into low and high cost market segments (or categories) and price each segment separately, while firms 2 and 3 are limited to setting one price for the entire market. No firm knows the cost type of any particular consumer. The expected cost of insuring a consumer chosen at random from the market and any of its segments is common knowledge.

3.1 Timing of Moves

The game consists of two stages as depicted in figure 1. At the beginning of the first stage firm 1 partitions the market and sets a price for each segment of the insurance market. At the beginning of the second stage the remaining two firms move simultaneously, each choosing one price for the entire market. Payoffs are realized at the end of the second stage.\(^5\)

---

\(^5\)The categorization advantage drives the model’s results, not a first mover advantage, similar results obtain if the order of moves is reversed.
3.2 Consumers

The demand side of the insurance market consists of a continuum of insurance consumers distributed over the interval \([0, \overline{q}]\). Let \(f(q)\) be a non-atomistic probability distribution function that describes the distribution of consumers over the interval \([0, \overline{q}]\). Consumers face the possibility of two states of the world, one of which they want to insure against; no loss \((t = 0)\) or loss \((t = 1)\). For any consumer \(q \in [0, \overline{q}]\), let the consumer’s wealth be \(W_0 = W\) in the no loss state and \(W_1 = W - L\) in the loss state, where \(W\) denotes initial wealth and \(L\) denotes the loss amount. It is assumed that \(W > L > 0\) and that \(W\) and \(L\) are constant and identical for all consumers. Each firm only offers policies of full insurance. Let \(\rho_q\) be consumer \(q\)’s probability of the loss state, where \(\rho_q \in [\underline{\rho}, \overline{\rho}]\) and \(\overline{\rho} > \rho > 0\). Consumers are organized in order of increasing probability of the loss state \(\rho_q\). Given these foundations, for any configuration of the \(\rho\)'s expected cost of insuring any consumer \(q\) can be represented by some weakly increasing function \(C : [0, \overline{q}] \to \mathbb{R}_+\).

Consumers have identical preferences over wealth in the possible states characterized by a Von Neumann-Morgenstern expected utility function \(V(q, W; L) = (1 - q)U(W) + qU(W - L)\), where \(U''(W) < 0\). Insurance contracts are made available to consumers at a premium level \(P_i\), where \(i\) indexes the firm, and are purchased when insurance is not compulsory by consumer \(q\) if and only if \(\exists P_i\) such that \(P_i \leq W - U^{-1}((1 - \rho_q)U(W) + \rho_qU(W - L))\). Consumers are limited to purchasing one contract each. Finally, in the non-compulsory case it is assumed that \(V(\cdot)\) and the \(\rho\)'s are such that all consumers will choose to insure at a price equal to the expected marginal cost of insuring a consumer selected at random from the insurance market:

\[
\int_0^{\overline{q}} C(q)f(q) dq \leq W - U^{-1}((1 - \rho_q)U(W) + \rho_qU(W - L)) \quad \forall q \in [0, \overline{q}]
\]

3.3 Firms

The supply side of the insurance market consists of 3 risk neutral firms denoted by \(i\), each offering homogeneous policies. Firm 1 is the advantaged firm, i.e., the firm with the superior consumer selection technology. A strategy for firm 1 consists of choosing a categorical division \(\sigma\) and setting prices \(P_{1l}\) and \(P_{1h}\) for each category to maximize its payoff given the expected competitors’ responses. Firm 1’s selection of \(\sigma \in [0, \overline{q}]\) partitions the continuum of consumers into two subsets or market segments \(m \in \{l, h, a\}\), where \(l\) denotes the low cost market segment \([0, \sigma]\), \(h\) denotes the high cost consumer market segment \([\sigma, \overline{q}]\), and \(a\) denotes the entire market. A consumer categorized in market \(l\) (categorized as low cost) is denoted by \(q_l\). Similarly, \(q_h\) denotes a consumer located in market \(h\) (categorized as high cost). Formally, Firm 1’s strategy is a vector \(P_1\), where \(P_1 = (\sigma, P_{1l}, P_{1h}) \in [0, \overline{q}] \times \mathbb{R}_+ \times \mathbb{R}_+\). The advantaged firm looks to the consequence of each strategy in its strategy space, \(P_1\), and predicts the outcome
given its competitors’ payoff maximizing behavior were that action taken. Firm 1 then selects the strategy that maximizes its own payoff.

A strategy for each disadvantaged firm \( i \), for \( i = 2, 3 \), consists of selecting \( P_i \in \mathbb{R}_+ \) conditional upon the advantaged firm’s strategy and the simultaneous movement of the other disadvantaged firm to maximize its payoff. Define \( \mathbf{P} = (P_1, P_2, P_3) \) to be a strategy profile where \( \mathbf{P} \in [0, \pi] \times \mathbb{R}_+^2 \times \mathbb{R}_+ \). Each firm seeks to maximize its payoff given by its results function \( R_i : \mathbb{R} \times [0, 1] \rightarrow \mathbb{R} \). The results function for firm \( i \) is simply a lexicographic preference over its expected profits, \( \Pi_i \), and market share, \( MS_i \). The payoff function is specified in this way for two reasons. First, market share provides a tiebreaker for outcomes that would otherwise lead to many equilibria that are effectively the same. This assumption is rather weak as it is analogous to assuming in a Bertrand pricing game, all other things equal, that each firm prefers to price at marginal cost and sell to a portion of the market rather than price itself out of the market. The second reason follows from analysis of market strategies in the short-run. In such scenarios market share, in and of itself, may be a factor in firm decisions as the greater its share of the market, the more data it gathers for improving its rating in the future.

### 3.4 The Sharing Rule

The sharing rule is endogenized to address existence of equilibrium issues common to spatial games with continuous strategy spaces. The endogenization of the sharing rule has two principle effects in this game. First, it guarantees existence of equilibrium in all subgames. Second, while the path of play remains unchanged across admissible sharing rules, the distribution of payoffs does vary.\(^6\)

A sharing rule in subgame \( \Gamma(P_1) \) can be defined as, \( s_i(P_1) = (s_1, s_2, s_3) \in \mathbf{S} \), where \( \mathbf{S} = \{ s_i \in \mathbb{R}_+^3 | \sum_{i=1}^3 s_i = 1 \ and \ s_i \geq 0 \ \forall i \} \). From here on \( s \) will be used for \( s_i(P_1) \), where the subgame is clear from the context. In the case of a three way tie, the share each firm receives of the market over which they are tied is given by \( s_i \). If two firms, \( i \) and \( j \), tie firm \( i \) receives the share \( s_i^2 = \frac{s_i}{s_i + s_j} \). If a tie occurs between firms \( i \) and \( j \), where \( s_i = s_j = 0 \), it is assumed that the firms split the market evenly. A sharing rule that does not yield existence of equilibrium for a subgame is deemed inadmissible and is excluded from the set of potential sharing rules for that subgame.

### 3.5 Subgames

The full game can be defined as \( \Gamma = \{ \{ 1, 2, 3 \}, \{ P_i \}_{i=1,2,3}, \{ R_i(\Pi_i, MS_i) \}_{i=1,2,3} \} \), where the timing of the game is as outlined above. A proper subgame of the game \( \Gamma \) consists of the second stage simultaneous play of the disadvantaged firms, conditional upon firm 1’s action in the first stage of the game and the sharing rule \( s \). An example of a subgame can be seen in figure 2, where price

---

\(^6\) The basic results of this paper are robust to this variation with the caveat for some extreme sharing rules and cost functions, the ordering of market share may vary.
is measured on the vertical axis and consumers are measured on the horizontal axis. Firms 2 and 3 simultaneously make their pricing decisions taking the categorization, $\sigma$, and Firm 1’s prices, $P_1^l$ and $P_1^h$, as given. Define $\Gamma(P_1) = \{\{2, 3\}, \{P_i\}_{i=2,3}, \{R_i(\Pi_i(\mathbf{P}, \mathbf{s}), MS_i(\mathbf{P}, \mathbf{s}))\}_{i=2,3}\}$ to be a proper subgame game. There is a unique proper subgame associated with each element of firm 1’s strategy space. In the following, the strategy $P_1$ is used as shorthand for $\Gamma(P_1)$, the subgame that follows the play of $P_1$ in the first stage.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Subgame $\Gamma(P_1)$.}
\end{figure}

### 3.6 Demand and Cost functions

Define the set of consumers from market $m$ that will purchase insurance given $\mathbf{P}$ to be:

$$d_m(\mathbf{P}) \equiv \{q \mid q \in m \text{ and } W - U^{-1}[(1 - \rho_q)U(W) + \rho_q U(W - L)] \geq \min(P_1, P_2, P_3)\}$$

In the compulsory insurance case this distinction is unnecessary as $d_m(\mathbf{P}) = m$ for all $m$. However, in the more general case where insurance is voluntary, consumers may be priced out of the market such that for some market $m$, $d_m(\mathbf{P}) \subset m$. Let the lowest probability consumer to demand insurance given prices $\mathbf{P}$ be denoted by: $q_m = \inf d_m(\mathbf{P})$. All consumers in market segment $m$ with $\rho_q$ s.t. $\rho_q > \rho_{q_m}$ will also purchase insurance, consequently the total demand for insurance by consumers in segment $m$ at prices $\mathbf{P}$ can be represented as $q_m = \overline{q}_m - q_{m}^{-}$, where $\overline{q}_m = \sigma$ and $\overline{q}_h = \overline{q}$. Figure 3 provides an illustration of the demand for insurance by market for category break $\sigma$ and market prices $P_1^l$ and $P_1^h$.

Given the sharing rule and the designated market segments, demand for firm $i$ in market $m$ given the strategies of the other firms $j$, and $k$ is given by the
following:

\[ D_{im}(P, s) = \begin{cases} 
q_m & \text{if } \min(P_{jm}, P_{km}) > P_{im} \\
q_m \cdot s_j & \text{if } P_{km} > P_{jm} = P_{im} \\
q_m \cdot s_k & \text{if } P_{jm} > P_{km} = P_{im} \\
q_m \cdot s_i & \text{if } P_{jm} = P_{km} = P_{im} \\
0 & \text{if } \min(P_{jm}, P_{km}) < P_{im}
\end{cases} \]

Figure 3 - Demand when insurance is non-compulsory.

Total demand for firm \(i\) is given by the summation of the demand for firm \(i\)'s product over both market segments, \(M = \{l, h\}:\)

\[ d_i(P, s) = \sum_{m \in M} D_{im}(P, s) \]

For any \(P\), it is useful to summarize the expected cost function \(C(q)\) with the five key values given below:

1. The expected marginal cost of insuring the lowest risk consumer: \(C(0) = C(0)\)
2. The expected marginal cost of insuring a consumer selected from the entire market:
   \[ C_a(P) = \int_0^\sigma C(q)f(q)dq \]
3. The expected marginal cost of insuring a consumer selected from the low cost market \(l\):
   \[ C_l(P) = \int_0^\sigma C(q)f(q)dq \]
4. The expected marginal cost of insuring a consumer selected from the high cost market $h$:

$$C_h(P) = \int_{\mathcal{Q}_h} C(q)f(q) dq$$

5. The expected marginal cost of insuring the highest risk consumer: $\overline{C} = C(\overline{q})$

Figure 4 gives a graphical representation of the compulsory market with the summary values of $C(q)$.

![Figure 4 – Key cost values in the compulsory market.](image)

For the non-compulsory case, it is important to distinguish between the expected cost of insuring an individual in a market segment $m$ when only a fraction of consumers choose to insure, and the expected cost when all consumers in category $m$ choose to insure. Let $C_m$ be shorthand for $C_m(P)$, when $d_m(P) = m$, while $C_m(P)$ will be used when prices may influence demand such that $d_m(P) \subseteq m$ for $l$, $h$, and $a$.

Given the demand and cost functions, the payoff function $\Pi_i$, for firm $i$ can be fully specified, where each element can be defined as follows:

$$\Pi_i(P, s) = \sum_{m \in M} (P_{im} - C_m)D_{im}$$

$$MS_i(P, s) = \sum_{m \in M} \frac{D_{im}}{\sum_{m \in M} q_m}$$
3.7 Existence of Equilibrium

The solution concept used to solve the game is Subgame Perfect Nash equilibrium. A solution consists of a strategy profile \( \mathbf{P^*} = (P^*_1, P^*_2, P^*_3) \) and a sharing rule \( s_{(P_1)} \) for each subgame \( \Gamma_{(P_1)} \). The following is the SPNE of interest and is the limit of the equivalent finite strategy space games as the strategy space approaches the continuous strategy space with proportional demand sharing between firms. For theorems 1 and 2 assume insurance is compulsory.

**Theorem 1** Given an exogenously set category break \( \sigma \in (0, \bar{q}] \), a pure strategy Subgame Perfect Nash equilibrium exists where the path of play consists of the strategy portfolio \( \mathbf{P^*} = [(\sigma, C_a, C_h), (C_h, C_h), (C_h, C_h)] \) and the endogenous sharing rule \( s_{(P^*)} = (\left( \frac{1}{3} \right), \left( \frac{1}{3} \right), \left( \frac{1}{3} \right)) \).

**Proof:** See appendix.

**Remark 1** This theorem holds for any \( \sigma \in (0, \bar{q}] \). Categorizing at either of the boundaries is equivalent to not categorizing at all and results in the standard Bertrand outcome where \( P^*_m = C_a \) for all firms \( i = 1, 2, 3 \) and both market segments \( m = l, h \). Thus, when determining the location of the optimal category break one needs only focus on the payoff of one subgame, \( P^*_l = (\sigma, C_a, C_h) \), for each possible \( \sigma \).

**Remark 2** The equilibrium of theorem 1 is not unique. However, the path of play is effectively the same across all pure strategy SPNE.

**Remark 3** The price \( P_{1l} = C_a \) serves as a ceiling for the segmenting firm’s price in the low cost market \( l \). Any price set above \( C_a \) by firm 1 provides the opportunity to undercut \( P_{1l} \) in the low cost market.

Relaxing the assumption that \( \sigma \) is exogenously set, it is of interest to understand how the advantaged firm will categorize the market. Given the sharing rule assignment in theorem 1, theorem 2 builds on the result of theorem 1.

**Theorem 2** There exists a results maximizing category break for any cost function \( C : [0, \bar{q}] \rightarrow \mathbb{R}_+ \). If \( C(q) \) is such that the set \( \Sigma \equiv \{q \mid q \in [0, \bar{q}] \text{ and } C(q) = C_a \} \) is nonempty, defining \( \Sigma \) to be the closure of \( \Sigma \), then the results maximizing category break is \( \sigma^* \), where \( \sigma^* = \sup(\Sigma) \). If \( C : [0, \bar{q}] \rightarrow \mathbb{R}_+ \) is discontinuous such that there exists no consumer \( q \) where \( C(q) = C_a \), then that point of discontinuity is the result maximizing category break.

**Proof:** See appendix.

**Remark 4** It follows directly from theorems 1 and 2 that the strategy portfolio \( \mathbf{P^*} = [(\sigma^*, C_a, C_h), (C_h, C_h), (C_h, C_h)] \), where \( \sigma^* = \sup(\Sigma) \), and the endogenous sharing rule \( s = (\left( \frac{1}{3} \right), \left( \frac{1}{3} \right), \left( \frac{1}{3} \right)) \) give the path of play for the SPNE of the full game where firm 1 is free to act on the entire set of choice variables: \( \sigma \), \( P_{1l} \), and \( P_{1h} \).
Relaxing the assumption that insurance is compulsory has little effect on the model’s equilibrium. Theorem 3 is the non-compulsory analog of theorem 1 that ensures existence of a pure strategy equilibrium. A characterization of the game when $\sigma$ is a choice variable follows from a simple analogue of theorem 2.

**Theorem 3** For any exogenously set $\sigma \in (0, 7]$. A pure strategy Subgame Perfect Nash equilibrium exists where the path of play consists of the strategy portfolio $P^{**} = [(\sigma, C_a, C_h(P)), (C_h(P), C_h(P)), (C_h(P), C_h(P))]$ and the endogenous sharing rule $s(\mathbf{p}^{*}) = ((\frac{1}{4}), (\frac{1}{4}), (\frac{1}{4}))$, where $C_h(P)$ is the expected cost of insuring an individual drawn at random from the insureds that remain in the high cost market at the price $P_h = C_h(P)$.

**Proof:** See appendix.

**Remark 5** When insurance is non-compulsory, the selection of the category break directly influences how many consumers will purchase insurance. The category break affects the actuarially fair price in market $h$, and so is of importance for welfare considerations.

### 4 Characteristics of Equilibrium and Welfare

Since the segmenting equilibrium is robust to features that are usually suggestive of competitive markets, such as low concentration, tests for standard forms of market power will not discern the presence of segmentation. However, the model provides results that can be used to identify the use of segmentation strategies.

#### 4.1 Characterization of Equilibrium

It has been shown for the compulsory case that for a large class of expected cost functions that there exists an equilibrium with the path of play $P^* = [(\sigma^*, C_a, C_h), (C_h, C_h), (C_h, C_h)]$ and the sharing rule $s = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3}))$. The equilibrium suggests relationships between variables that are observable in insurance markets, and so provides the opportunity to test whether segmentation is an effective strategy for acquiring market power. The following outlines features of the equilibrium that are of particular interest.

Along the equilibrium path of play, the advantaged firm’s profits and market share exceed those of the disadvantaged firms as given below:

$$\Pi_1^* = (C_a - C_l)D_d = (C_a - C_l)q_l > \Pi_2^* = \Pi_3^* = 0$$

$$MS_1^* = \frac{q_l + \frac{1}{3}q_h}{\sum_{m \in M} q_m} > MS_2^* = MS_3^* = \frac{\frac{1}{3}q_h}{\sum_{m \in M} q_m} > 0$$

The advantaged firm earns its profits entirely in market $l$ where it undercuts its disadvantaged competitors’ prices. Market $h$ is divided between all three firms at cost, $C_h$. So all firms sell insurance contracts in equilibrium, all firms
sell insurance at the marginal cost in market \( h \) while only the advantaged firm is competitively priced in segment \( l \). Thus, one must look beyond entry to determine how competitive an insurance market is. Disadvantaged firms are free to enter the market segment that consists of the riskiest consumers, but face certain losses if they seek to price competitively in the market segment of low cost consumers.

The fact that the advantaged firm is able to price and sell insurance above cost in market segment \( l \) is reflected in its loss ratio. Define the equilibrium expected loss ratio for firm \( i \) to be:

\[
LR_i = \frac{\sum_{m \in M} (C_m \cdot D_{im})}{\sum_{m \in M} (P_{im} \cdot D_{im})}
\]

It follows from the equilibrium profits that \( LR_1 \) is lower for the advantaged firm such that, \( 1 = LR_2 = LR_3 > LR_1 \geq 0 \), where

\[
LR_1 = \frac{\frac{1}{3}q_l C_l + \frac{2}{3}q_h C_h}{\frac{1}{3}q_l C_l + \frac{2}{3}q_h C_h} < 1
\]

\[
LR_i = 1 \quad \text{for} \quad i = 2, 3
\]

Price dispersion for market segment \( m \), measured as 

\[
PD_m = \max(P_{1m}, P_{2m}, P_{3m}) - \min(P_{1m}, P_{2m}, P_{3m})
\]

is greater than \( 1 \) in equilibrium for market segment \( l \) since disadvantaged firms are unable to price market segments separately. There is no price dispersion in market \( h \):

\[
PD_l = \frac{P_{il}}{P_{il}} = \frac{C_l}{C_a} \quad \forall i \quad \text{and} \quad PD_h = \frac{P_{ih}}{P_{jh}} = \frac{C_h}{C_h} \quad \forall i, j
\]

So the advantaged firm prices at the low end of the distribution of prices in categories that are low cost and prices competitively in the high cost category along its dimension of advantage.

Finally, the average premium level across the entire market, \( P_a^* \) is inflated by the categorization and pricing efforts of the advantaged firm to a level above the actuarially fair price \( (P_a = C_a) \):

\[
P_a = C_a < \frac{\int_{\frac{q_l}{2}}^{\sigma} C_a f(q) dq + \int_{\frac{q_h}{2}}^{\frac{q}{2}} C_h f(q) dq}{\sigma} = P_a^*
\]

### 4.2 Comparative Statics

Three additional questions can be addressed with the model. First, how does variation in the concavity of the expected cost function, \( C(q) \), influence the optimal categorization choice and the advantaged firm’s profits? Second,
effect does the inclusion of additional high risk consumers have on the effectiveness of these strategies? And third, what happens to the optimal category break as the distribution of consumers becomes skewed?

The location of $\sigma^*$ on the interval $(0, \overline{q})$ and the equilibrium price in each market segment depend on both the function $C(q)$ and the p.d.f. $f(q)$ as they are the two critical factors in determining the set of optimal categorical breaks, $\Sigma$. The following analysis assumes a cost function of the form $C(q; n) = Aq^n + b$, that is twice continuously differentiable, where $A, n > 0$, and a uniform probability distribution $f(q) = \frac{1}{\overline{q}}$. The parameter $n$ serves to adjust the concavity of the expected cost function. As $n$ increases $C(q; n)$ goes from being concave to convex. Proposition 1 addresses how the concavity of the $C(q; n)$ influences $\sigma^*$, holding constant the intercept and the expected cost of an individual drawn from the entire market.

**Proposition 1** Holding $C_a$, $b$, and $\overline{q}$ the uniform distribution $f(q)$ constant, $\frac{\partial \sigma^*}{\partial n}$ takes the sign of the expression $(n + 1) \ln(n + 1) - \ln(\overline{q}) - n$. Given that $C(q; n)$ is convex (concave), the greater that convexity (concavity) the greater (lower) the value of $\sigma^*$ when $(n + 1) \ln(n + 1) - \ln(\overline{q}) - n > 0$. The reverse holds when $(n + 1) \ln(n + 1) - \ln(\overline{q}) - n < 0$. Thus, shifts in expected costs and differences in costs across states can have multiple effects depending on $\sigma^*$.

**Proof.** Take any expected cost function $C(q; n) = Ax^n + b$, where $A = \frac{(C_a - b)(n + 1)}{\overline{q}} > 0$ and $b$ is some positive valued constant. Let $f(q)$ be the uniform distribution over the interval $[0, \overline{q}]$. Theorem 1 implies that we only need to consider the set of subgames $P(\sigma) = [(\sigma, C_a, C_h), (C_h, C_h), (C_h, C_h)]$ for all $\sigma \in [0, \overline{q}]$. Consider an arbitrary sharing rule $s$, such that $s = (s_1, s_2, s_3)$ where $s_i \geq 0 \forall i$. The advantaged firm will face the following profit function (where $P_{1l} = C_a$) and expression for the profit maximizing $\sigma$:

$$\Pi_1(P_{1l}, \sigma; C_a, b, n, \overline{q}) = (P_{1l} - b)\sigma - \frac{(C_a - b)}{\overline{q}^n} \sigma^{n+1}$$

The optimal category break can then be solved for as:

$$\sigma^*(n) = \left(\frac{\overline{q}^n}{n + 1}\right)^{\frac{1}{n+1}}$$

It follows then that the change in the optimal category break can be characterized as:

$$\frac{\partial \sigma^*}{\partial n} = \frac{1}{n^2(n + 1)} \cdot \left(\frac{\overline{q}^n}{n + 1}\right)^{\frac{1}{n+1}} [(n + 1) \ln(n + 1) - \ln(\overline{q}) - n]$$

The first two terms are clearly positive, however the last term’s sign depends on the values of $n$ and $\overline{q}$. ■

It is easiest to see what is going on here graphically. Figure 5 graphs two expected cost functions. As $n$ is increased the expected cost function becomes
more convex, so the high cost individuals’ costs increase relative to the low cost consumers. Given that the expected cost of insuring an individual selected at random from the entire market is $C_a$, if $(n + 1) \ln(n + 1) - \ln(\bar{q}) - n > 0$ then the optimal category break increases with $n$. But, if it is $C'_a$, then $(n + 1) \ln(n + 1) - \ln(\bar{q}) - n < 0$ and the category break decreases.

The second proposition concerns the impact of expanding the market to include additional high risk consumers which has the unambiguous effect of increasing the categorical break and the profitability of segmentation strategies.

Proposition 2 All other things equal, for any function $C(q)$, an increase in $\sigma$ leads to an increase in the optimal category break and an increase in the advantaged firm’s profits.

Proof. Consider any expected cost function of the form $C(q) = Aq^n + b$. Assuming that $P_t = C_a$, the profits for any $\sigma$ can be given by the following profit function:

$$\Pi_1(\sigma; b, n, \bar{q}) = \frac{A}{\bar{q}(n + 1)} (\sigma^n - \sigma^{n+1})$$

It follows that:

$$\frac{\partial \sigma^*}{\partial n} = \frac{1}{\bar{q}} \left( \frac{\bar{q}}{n + 1} \right)^{\frac{1}{n}} > 0 \forall \bar{q} : \bar{q} > 0$$

$$\frac{\partial \Pi_1^*}{\partial n} = \frac{An^2}{\bar{q}^n (n + 1)^2} \left( \frac{\bar{q}^{n+2}}{n + 1} \right)^{\frac{1}{n}} > 0 \forall \bar{q} : \bar{q} > 0$$
Finally, the greater the expected cost of insuring in the high cost market relative to the low cost market, the greater reward of segmenting strategies to the advantaged firm.

**Proposition 3** All other things equal, for any strictly increasing function \( C(q) \), a shift of the distribution of consumers \( f(q) \) towards \( \bar{q} \) (towards 0), the greater (lower) the value of \( \sigma^* \).

**Proof.** Consider a continuous strictly increasing expected cost function \( C(q) \) and a distribution of consumers \( f(q) \), defined on the interval \([0, \bar{q}]\). Along the equilibrium path of play, consumers in the low market will pay \( P_{1l} = C_a \). Market \( l \) will have the upper bound \( \sigma^* \), where \( \sigma^* \) is such that \( C(\sigma^*) = C_a \). Shifting any positive weight of the distribution \( f(q) \) towards \( \bar{q} \) generates a new distribution function \( f^*(q) \). The distribution \( f^*(q) \) must have a higher expected cost for the entire market than before so \( C_{a^*} > C_a \), but this implies that \( \sigma^{**} > \sigma^* \) since \( C(q) \) is strictly increasing, where \( \sigma^{**} \) is the results maximizing category break given \( f^*(q) \). ■

The change in the advantaged firm’s profits depends on whether the increase in the price charged to the low market out weighs the loss in profits from consumers that are moved from the low cost market as a result of the shift from \( F(q) \) to \( F^*(q) \). Clearly if the shift of weight occurs purely in the high cost market the advantaged firm’s segmenting strategy will increase in profitability, thus shifts in frequency or severity of accidents for some groups should lead to greater profits for the firms best at segmenting the market.

### 4.3 Welfare Implications

The following analysis focuses on welfare in the short-run. In considering the welfare effects of segmentation strategies, it is helpful to use the non-segmentation scenario, \( P_{im} = C_a \) \( \forall i \in I \) and \( \forall m \in M \), as the benchmark for comparison. In the compulsory case, segmentation has no impact on the members of market segment \( l \) since \( P_{1l} = C_a \), which is the actuarially fair price for the entire market in the absence of segmentation. However, those in segment \( h \) will pay an increased rate, \( P_h = C_h > C_a \), for the same amount of coverage that they would have received at a price of \( P_{1h} = C_a \) without segmentation. For any consumer \( q \) purchasing insurance, individual welfare is given by \( V(q, W, L) = U(W - P_h) \). It follows that utility at segmentation prices is reduced in market \( h \), and thus are unequivocally worse off since:

\[
U(W - P_a) = U(W - C_a) > U(W - C_h) = U(W - P_h)
\]

Furthermore, if the purchase of insurance is non-compulsory, prices and consumption in market \( l \) will remain unchanged. However, in the high cost market segment, consumers \( q \in h \), with a loss probability \( \rho_q : \rho_q > \rho_{q_h} \), will purchase insurance at the elevated rate and suffer a welfare loss as in the compulsory case. Also, any consumer \( q \in h \), with a loss probability, \( \rho_q : \rho_{q_h} > \rho_q > \sigma^* \),
will choose not to buy insurance at the elevated market price, $P_h^* = C_h(P)$, and suffer a welfare loss since they are no longer insured.

An alternative benchmark to consider is a market where segmentation abilities across firms are symmetric, such as a pure increase in pricing precision. Under this scenario the equilibrium price for each market segment is the actuarially fair price for that segment since symmetric categorization leads to marginal cost pricing in all segments. Although consumers in market $h$ face the same price under segmentation and this benchmark case, those categorized in market $l$ are unambiguously better off in this benchmark case. So regardless of the benchmark employed, some consumers are worse off under the asymmetric segmentation of the market.

Long-run welfare depends on the rate at which new methods of categorizing consumers diffuse throughout the market. The second benchmark case shows that innovation in rating variables can have a positive effect since the price that individuals are charged as categorization improves more accurately reflects the true cost of insuring them. This kind of result can have several implications. As detailed in Hoy (1984) categorization may resolve the existence of equilibrium concerns raised in Rothschild and Stiglitz (1977) and under certain conditions enhances welfare. Also as shown in Crocker and Snow (1986) and Bond and Crocker (1991), though not explicitly modeled here, categorization can increase efficiency by providing incentives for consumers of insurance. For mutable rating variables, efficiency depends on the incentives of insureds being altered such that they wish to decrease the riskiness of their behavior to balance its cost and benefit. When insurance is not compulsory, categorization over immutable variables is also efficiency enhancing in that those who chose not to insure due to the elevated cost will directly face the costs associated with their actions and so act accordingly. This could be suboptimal if it leads to them taking too many precautions.

5 Empirical Evidence

The model yields several testable results that are indicative of the effective use of segmentation in insurance markets. Two results, those concerning the loss ratio and market share, are tested against data that measures the relative segmentation ability of firms writing business in the nonstandard Washington PPA liability insurance market. The model’s implications concerning prices, relative price levels and patterns of price dispersion, are beyond the scope of this paper.\(^7\)

The panel data set spans the years 1999–2005 and was constructed from two separate sources. Data concerning premiums earned, losses incurred, and other variables measuring the financial position of insurance companies come from NAIC annual statements. Data concerning firm level pricing, categorization, and rating variables come from rate and rule filings submitted by companies to

\(^7\)Shaver (2010) provides evidence of price levels and price dispersion that is consistent with the model’s predictions.
the Washington Office of the Insurance Commissioner. In total the rate and rule filings consist of over 150,000 pages of micro level data covering each firm's pricing and categorization strategy and detail how those strategies evolve over time. Complete records of filings for 131 insurance companies were used to generate the measures of segmentation that are unique to this data set.\(^8\)

The measure of segmentation is calculated for the number of effective categories, i.e., categories that correspond to price differentials, serve as a proxy for the categorization described in the model. These measures of segmentation were generated with two goals in mind. First, to create a reasonable and consistent measure of categorization that is appropriate to use across all firms.\(^9\) Second, to capture the variation in categorization both within and between bundled coverages.\(^10\)

PPA liability insurance consists of two constituent coverages: Bodily Injury (BI) and Property Damage (PD). The standard approach to calculating insurance rates is to set a base rate for each coverage and then adjust that rate using a series of rating variables that correspond to insureds observable characteristics. Rating variables, e.g., driving record, marital status, garaging address, are the dimensions of categorization used to categorize insurance consumers.\(^11\) The final policy premium is the summation of the premium calculated for each constituent coverage.

The measure of segmentation counts the number of categories associated with each rating variable and sums them for both coverages. If a rating variable has a policy wide effect, meaning it impacts both coverages in the same way, for example a multicar discount that is a flat 25\% for all coverages, it was counted as two effective categories: multicar and single car. But, if a firm sets discount levels by coverage, say 20\% for BI and 13\% for PD, then the discount is counted as four effective categories. The measure of total effective segmentation is the product of the number of categories calculated for all rating variables used in a firm’s rating algorithm. Given that rates are often changed several times a year, a day weighted average of total segmentation is calculated for each year the firm

\(^8\)Of those 131 companies, any observation where a company failed to write and to earn $100,000,000 in premiums was dropped from the sample. Besides not being active players in the market (this is a very low policy count level), with premium levels below the cutoff one large loss or a reserve decrease can significantly distort a firm’s loss ratio, and present a significant outlier problem. Multiple lower bounds were considered and the main results are robust to most of the levels tested.

\(^9\)Filings often provide categorizations that go well beyond the level that is likely to be utilized in the market and could significantly distort any comparison categorization across firms. For example, some firms provide categories for accident/violation point levels well beyond that which any firm would accept. Segmentation was calculated for the following risk characteristic ranges: Driver ages 16-90, gender, marital status, 2 cars, 3 drivers, model year/vehicle age up to 11 years. Also driver violation levels ranged from a clean record to one with 1 At-fault accident, 1 DWI, and 2 speeding tickets.

\(^10\)Some rating variables used in rating have one specific factor that impacts on a policy wide level, others have coverage specific factors. This measure counts the individual coverage categorization as well as policy level categorization.

\(^11\)For example, marital status is often used as a rating variable. A rating factor of 1.15 could be assigned if a consumer is single and 1.00 otherwise. If the factor influences rates multiplicatively, then being single increases one’s premium by 15\% relative to being married.
writes business. Finally, a measure of relative segmentation advantage for each year is calculated by simply ranking all firms (where 1 denotes the greatest level of segmentation) that were active during that year. This measure does overstate the number of categories, but only so the variation across coverages that would otherwise be lost can be included.\footnote{Shaver (2010) uses several other measures of segmentation. These results are robust to a variety of measurements of segmentation, including a strict measure of potential effective categories.}

The control variables used in the analysis originate from both data sources. Each control can be classified in one of three general categories: liability market, physical damage market, and company characteristics. Liability market controls include the average base rate level for liability coverage, the number of liability insurance limits available to consumers, defense and containment costs, the commission rate paid to insurance agents and brokers, and the percent of every dollar earned by the company that is returned to insureds as dividends. Also included are dummy variables indicating which submarkets in which a company writes business. Automobile insurance markets are traditionally divided by underwriting criteria into three submarkets: preferred, standard, and nonstandard. While the focus here is on the nonstandard market, companies write in multiple submarkets might differ systematically from those that target only one submarket.\footnote{The average base liability rate level is calculated by averaging the liability base rates from 4 territories that range from urban, suburban, town, and rural.}

Physical damage market controls are meant to address the impact of complementary coverages that are often sold with liability coverages, namely comprehensive and collision coverages. The controls included are the average physical damage base rate and the number of physical damage coverage limits offered. The remaining control variables capture company level characteristics including total group advertising expenditure, the firm level expense ratio, Kenny capacity (a measure of financial health for insurance firms), and the amount of homeowners premiums earned by the company during the year.

A partial reduced form approach is used to test the impact of a relative segmentation advantage on a firm’s loss ratio and market share. The following pooled OLS regression is estimated:

\[
Y_{it} = \beta_0 + \beta_1 SEGRNK_{it} + \beta_2 SEGRNK^2_{it} + X_{it}'\theta + \epsilon_{it}
\]

\(SEGRNK_{it}\) is the measure of the segmentation ranking of firm \(i\) relative to all other firms in year \(t\). \(X_{it}\) is a vector of control variables. The square of \(SEGRNK_{it}\) is introduced to allow for nonlinearities in the impact of a firm’s segmentation ranking. \(Y_{it}\) denotes each of the two dependent variables used. First, \(LR_{it}\), the pure loss ratio, is used to test the degree to which firms are able to price above cost. In the regressions where \(LR_{it}\) is the dependent variable the joint effect of the segmentation variables should be positive.\footnote{As a firm’s ability to segment the market relative to its competitors, the value indicating its ranking will increase in value. For example, the model implies that a firm that drops from 1st to 4th most effective segmenting firm in the market should see its loss ratio increase and market share fall.} Second, \(MS_{it}\),
the percent of total liability insurance premiums earned by firm $i$ in the market, is used to test whether relative segmentation advantage is negatively correlated with market share. The joint effect of the segmentation variables should be negative.

Given the reduced form approach and the potential for endogeneity problems. Tables A1 in the appendix provide the results in a stepwise approach to show that the coefficients of interest are robust to many potential biasing factors due to variation in the specification of the regression.¹⁵ With both approaches, regressions (1) and (5) are simple tests for the correlations predicted by the model. In Table A1, regressions (1) and (5) have the expected signs, though neither coefficient is significant at the 10% level.

Regressions (2) and (6) add controls for the liability market factors and introducing time dummy variables, all of the relative segmentation coefficients have the expected sign. The loss ratio regression is significant at the 10% level while the market share regression segmentation coefficients remain statistically insignificant. Equations (3), (4), (7) and (8) include all controls and vary the use of time dummy variables. Time dummy variables are included to control for the impact of exogenous shocks and the cyclical nature of insurance markets an make no significant change to the results. The coefficients have the correct signs but are not significant at the 10% level.

The OLS regression results suffer from the omission of several firm level variables that are unobservable to the econometrician: claims policy, underwriting standards, method of distribution, and firm reputation. All of these variables are likely correlated with segmentation decisions and the dependent variables. It is likely that a firm’s claims policy and underwriting standards will negatively bias OLS estimates of the relationship between a firm’s segmentation strategy on its loss ratio. In general, insurance firm’s claims policies are relatively constant, but they are likely to vary across firms. All other things equal, the more strict a firm’s claims policy (meaning the less it tends to pay to insured’s that file claims), the less aggressive it needs to be in segmenting the market to maintain a low loss ratio. Similarly, underwriting standards, which are standards used to screen consumers before the are categorized and priced, vary across firms and are likely to be correlated with a firm’s segmentation strategy. The more restrictive a firm is in who it will consider insuring, the less the firm needs to be able to price and categorize relative to its competitors for any given loss ratio. The remaining omitted variables are likely to have the same impact on OLS estimates. A final issue that is not addressed in my specification but will serve to bias the impact of segmentation ranking on market share towards zero comes from a limitation of the data. While the market share result derived in the model measures market share in terms of the number of policies sold, the data available only gives total premiums earned by a firm. Given the model’s implication that prices set by advantaged firms are lower than those of disadvantaged firms, the inclusion of price in market share measures will tend to

¹⁵ Bruesh-Pagan tests were run to test for heteroskedasticity. The results were positive so robust standard errors are used.
understate the market share of advantaged firms and overstate the market share of disadvantaged firms.

To address these problems the following fixed effects estimation approach is estimated:

\[ Y_{it} = \alpha_i + \beta_1 SEGRNK_{it} + \beta_2 SEGRNK^2_{it} + X_{it}^\prime \beta + \epsilon_{it} \]

Both insurance group level and company level fixed effects specifications were estimated. The company level results are presented in Table A2. Group level fixed effects are not presented since company effects should capture all of the group level effects plus additional company specific factors. Variables denoting the submarkets served, dividends paid, and the amount of homeowners insurance that a firm writes are dropped due to limited variability.

For the loss ratio regressions (1), (2), (3), and (4) the segmentation ranking variables have the expected sign and are jointly significant regardless of the specification. The signs of the control variables are consistent with expectations. The results are also consistent with the expectation of the omitted variables having a negative bias on OLS estimates. Robust standard errors are reported, however given that the data is unlikely to be independent across observations, in particular for insurance companies that are members of the same insurance group, cluster errors were used with nearly identical results.

Consider the full regression model (4) From Table A2. The coefficients on the segmentation ranking variables indicate that segmenting the market better than one’s competitors creates a significant advantage. The coefficient of .99 indicates that for a firm with a relatively high ability to segment, moving up one level in the rank will decrease its losses. From equation (4), if a firm improves its segmentation rank by 5 places, it can expected to see its loss ratio decrease by more than .05, i.e., for every dollar of premium earned over five cents less is paid out in claims. Given that the average firm’s loss ratio in the sample is 67.6, a five cent decrease in results in a 7.5% decrease in claims costs (the nonlinear term amplifies this effect over most of the range included in the sample).

The market share regressions also show consistency across signs and magnitude and the full model, regression (8), is significant at the 5% level. This indicates, as expected from the theoretical model, that a firm’s market share tends to be higher as its relative segmentation ability improves. From equation (8), the decrease in market share as a firm’s segmentation ranking drops is reasonably large considering that nearly half of firms in the market have market shares below 1%. This should be considered a lower bound due to the bias introduced by premium weighted market shares. If the price variance could be accounted for in the model, the impact of segmentation on market share would strengthen.

6 Conclusion

This paper draws on the Industrial Organization and Insurance literatures, combining research on insurance markets and cost-raising market strategies to argue,
contrary to the cases made in Joskow (1973) and Buzzacchi and Valletti (2005), that significant market power may be present in insurance markets. Rather than focusing on competition in prices and quantities, our model focuses on insurance pricing and the competition between firms to categorize insurance consumers. It is shown that a pure strategy SPNE exists in the model and that a categorization advantage generates the ability for the advantaged firm to price above cost. The exploitation of these strategies is shown to lead to an unambiguous decrease in the welfare of insurance consumers while the categorization advantage exists.

The model predicts that if market power is being generated through segmentation strategies, the categorization of consumers, price level, and the mix of business should vary systematically across firms. Several testable implications follow. First, an advantaged firm’s ability to segment the market beyond that of its competitors should result in a decline in its loss ratio, an increase in its market share, and a lower average rate level. Second, within pricing categories defined more broadly by disadvantaged competitors, price dispersion should decline as the expected cost of consumers increases along the dimension of segmentation advantage. Third, within pricing categories defined more broadly by disadvantaged competitors, a firm with a segmenting advantage should systematically be in the low end of the distribution of prices for categories of consumers considered to be low risk along the dimension of segmentation, while pricing comparably to competitors in higher risk categories.

Regression results are provided showing that data from the nonstandard Washington PPA liability market are consistent with the model regarding the relationship between segmentation and loss ratios and market share. It is an empirical question as to whether segmentation strategies are effectively utilized by firms in insurance markets beyond the Washington PPA liability market. However, many insurance markets exhibit the dispersion in prices and variation in categorization indicative of the use of segmentation strategies.

If segmentation strategies are frequently used, it is important that the approach to regulating insurance markets be reconsidered. It is shown here that a maintained segmentation advantage leads to an unambiguous welfare loss for consumers. However, the gains from segmentation strategies may be considered to be a return to innovation. If the returns from segmentation are high enough to spur innovation and the diffusion of these innovations through the market is relatively rapid, then there is a clear upside to the use of segmentation advances involving mutable variables (Buzzacchi and Valletti (2005)). Incentives could be improved for insureds by reducing the premium paid by those who engage in loss reducing behavior that is identifiable through rating variables. Additionally, the subsidization of high risk insureds by low risk insureds would decrease, penalizing risky behaviors with higher, but actuarially fair premiums. If segmentation strategies fail to generate a reasonable return to innovation due to rapid competitor adoption, regulators may want to stimulate innovation in the pricing of insurance risks by offering limited exclusive rights to innovators, to promote more effective categorization.

The results of this paper suggest several lines of future research that should
be pursued. First, work needs to be done to model and confirm the effect of segmentation strategies in more complex cost environments with the potential for rating on multiple dimensions. Also, it is important that we better understand the nature of innovation in pricing techniques and rate of their diffusion through the insurance industry. Finally, work must be done to identify if segmentation strategies are effectively used in other similarly structured markets like credit markets, where information concerning expected default rates is critical to setting the interest rate on loans and has the potential to exploited with segmentation strategies by advantaged firms.
References


[22] Shaver, K., 20010, Strategic Use of Adverse Selection in Automobile Insurance, Unpublished Manuscript,


Appendix

7.1 Proofs

**Theorem 1** Given an exogenously set category break \( \sigma \in (0, 7) \), a pure strategy Subgame Perfect Nash equilibrium exists where the path of play consists of the strategy portfolio \( P^* = [(\sigma, C_a, C_h), (C_h, C_h), (C_h, C_h)] \) and the endogenous sharing rule \( s(P^*) = (\left( \frac{1}{3}, \left( \frac{1}{3}, \left( \frac{1}{3}, \right) \right) \right) \).

**Proof.** The strategy of this proof is simply to establish through backward induction that an equilibrium exists in each proper subgame and then to compare the payoffs to firm 1 over all the proper subgames to determine its optimal strategy and the path of play, \( P^* \). It is easiest to proceed by partitioning the set of subgames,

![Subgame Partitions](image)

Figure 6 - Subgame Partitions.

so define \( r_n(\sigma) \subset \mathbb{R}^2_+ \) and \( r(\sigma) = \bigcup r_n(\sigma) \) to be a partition of firm 1’s strategy space, illustrated in Figure 6.

The vertical axis indicates the price set by the advantaged firm for the low cost market in stage 1. The horizontal axis indicates the price set by the ad-
vantaged firm for the high cost market in the stage 1. The following presents a strategy and sharing rule for every subgame by partition.

Consider the following partitions of the set of subgames:

1. For any subgame in partition \( r_a = \{ P_1 \mid P_1 \in [0, \bar{p}] \times (C_a, \infty) \times (C_a, \infty) \} \), an equilibrium strategy for firm \( i, i = 2, 3 \), is given by the sharing rule \( s = (\left( \frac{1}{3}, \frac{1}{3}, \frac{1}{3} \right), (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) ) \) and \( P_i^* = (C_a, C_a) \). This follows directly from the standard Bertrand price competition result, with constant marginal cost \( C_a \) for both disadvantaged firms (2 and 3).

2. For any subgame in partition \( r_b = \{ P_1 \mid P_1 \in [0, \bar{p}] \times [C_l, \infty) \times (0, C_l) \} \), an equilibrium is given by the strategy \( P_i^* = (C_l, C_l) \) for firm \( i, i = 2, 3 \) and the sharing rule \( s = ((\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) , (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) ) \). For firm \( i \), offering insurance at the price \( P_i^* \) implies that \( \Pi_i = (C_l - C_l) \cdot D_{il} = 0 \) and \( MS_i = \frac{1}{2} \sigma \). Consider alternative strategies, clearly if firm \( i \) lowered its price by some \( \epsilon > 0 \) such that \( P_i > P_{ih} \), it would capture all of market \( l \) at a loss, \( \Pi_i < 0 \). Further reductions in \( P_i \) would lead only to greater losses from decreasing revenue in market \( l \) and the potential to capture business from market \( h \) where firm \( i \) would be inadequately priced. Alternatively, any increase in \( P_i \) from \( P_i^* = (C_l, C_l) \) implies \( \Pi_i = 0 \) and \( MS_i = 0 \). Thus \( C_L \) is the optimal strategy for firm \( i \).

3. For partition \( r_c = \{ P_1 \mid P_1 \in [0, \bar{p}] \times [0, C_l) \times [0, \infty) \} \), the sharing rule \( s = ((\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) , (\frac{1}{3}, \frac{1}{3}, \frac{1}{3}) ) \) and the strategy \( P_i^* = (C_h, C_h) \) for \( i = 2, 3 \), constitute an equilibrium where the results are \( \Pi_i = 0 \) and \( MS_i \geq 0 \). Consider the alternatives, clearly market share can never be profitably held by a disadvantaged firm in market \( l \) when firm 1 prices it below \( C_l \). Thus, we only need to focus on potential profits from market \( h \). Two cases must be considered:

   (a) \( P_{ih} \geq C_h \): Firm \( i \) will price at cost \( C_h \) by the standard Bertrand price competition argument. Thus \( P_i^* \) is an equilibrium price and the corresponding results are \( \Pi_i = 0 \) and \( MS_i > 0 \).

   (b) \( P_{ih} < C_h \): The disadvantaged firms cannot profitably charge a price that ties or undercuts firm 1 in either of the markets since \( P_{il} < C_l \) and \( P_{ih} < C_h \). Thus any price greater than \( P_{ih} \) (including \( P_{ih}^* \)) yields the results \( \Pi_i = 0 \) and \( MS_i = 0 \) and is an equilibrium price.

4. For partition \( r_d = \{ P_1 \mid P_1 \in [0, \bar{p}] \times [P_{ih}, \infty) \times [C_l, C_a] \} \), the sharing rule \( s = (1, 0, 0) \) and the strategy \( P_i^* = (P_{ih}, P_{ih}) \) for firm \( i = 2, 3 \) is an equilibrium. For firm \( i \), the strategy of \( P_i^* \) implies that \( \Pi_i = (P_i - C_l) \cdot D_{il} \geq 0 \) and \( MS_i \geq 0 \). For any strategy \( P_i \), where \( P_i > P_i^* \), firm \( i \) is priced out of the market and so earns results of \( \Pi_i = 0 \) and \( MS_i = 0 \). Suppose that firm \( i \)'s strategy is price \( P_i \), where \( P_i^* > P_i \), then \( \min( P_{il}, P_{ih}, P_j ) > P_i \). Consequently firm \( i \) will capture the entire market at a price below \( C_a \), which implies \( \Pi_i < 0 \).

28
5. For partition \( r_\alpha = \{P_1 \mid P_1 \in [0, \overline{q}] \times [C_l, C_a) \times (P_{1l}, \infty)\} \), the sharing rule \( s = (\left(\frac{1}{3}, \frac{1}{2}, \frac{1}{3}\right) \) and strategy \( P^*_i = (C_h, C_h) \) for firm \( i, i = 2, 3 \), is an equilibrium. The strategy of \( P^*_i \) yields the results \( \Pi_i = 0 \) and \( MS_i \geq 0 \). For any \( P_i > P^*_i \) firm \( i \) is priced out of the market so profits and market share are trivially zero. Suppose firm \( i \) were to charge a price lower than \( P^*_i \). For any \( P_i : C_h > P_i > P_{1h} \), again firm \( i \) is priced out of the market so \( \Pi_i = 0 \) and \( MS_i = 0 \). For any \( P_i : P_{1h} \geq P_i > P_{1l} \), \( i \)'s profits are \( \Pi_i = (P_i - C_h) \cdot D_{ih} < 0 \) and for any \( P_i : P_{1l} \geq P_i > 0 \), \( i \)'s profits are \( \Pi_i = (P_i - C_l) \cdot D_{il} + (P_i - C_h) \cdot D_{ih} < 0 \). So every strategy from both intervals yields negative profits.

6. For any subgame in partition \( r_\zeta = \{P_1 \mid P_1 \in [0, \overline{q}] \times [C_a, C_a) \times (C_a, \infty)\} \), the sharing rule \( s = (\left(\frac{1}{3}, \frac{1}{2}, \frac{1}{3}\right) \) and the strategy \( P^*_i = (C_h, C_h) \) for firm \( i, i = 2, 3 \), is an equilibrium. Two cases need to be considered for this partition:

(a) \( P_{1h} \geq C_h \): For firm \( i \), charging \( P^*_i \) implies that \( \Pi_i = 0 \) and \( MS_i > 0 \). Suppose firm \( i \), were to charge any price \( P_i > P^*_i \), it would be undercut by firm \( j \), yielding the results \( \Pi_i = 0 \) and \( MS_i = 0 \). To charge a lower price implies negative profits. For any \( P_i : C_h \geq P_i > P_{1l} \), \( i \) captures market \( h \) but is inadequately priced and so profits are \( \Pi_i = (P_i - C_h) \cdot D_{ih} < 0 \). And for any \( P_i : P_{1l} \geq P_i \geq 0 \), \( i \)'s profits are \( \Pi_i = (P_i - C_l) \cdot D_{il} + (P_i - C_h) \cdot D_{ih} < 0 \).

(b) \( C_h > P_{1h} > C_a \): Clearly for firm \( i \), charging any \( P_i > P_{1h} \) implies that \( \Pi_i = 0 \) and \( MS_i = 0 \). This applies to \( P^*_i \) since \( P^*_i = C_h > P_{1h} \). Furthermore, for any \( P_i : P_{1h} \geq P_i > P_{1l} \), \( i \) captures market share in \( h \) but is inadequately priced and so profits are \( \Pi_i = (P_i - C_h) \cdot D_{ih} < 0 \). And for any \( P_i : P_{1l} \geq P_i \geq 0 \), \( i \)'s profits are \( \Pi_i = (P_i - C_l) \cdot D_{il} + (P_i - C_h) \cdot D_{ih} < 0 \).

Finally, to show that \( \mathbf{P}^* \) is the path of play for the SPNE it must be clear that firm 1 maximizes profits by setting the price (selecting the subgame) \( P^*_1 = (\sigma, C_a, C_h) \) given the sharing rule \( s = (\left(\frac{1}{3}, \frac{1}{2}, \frac{1}{3}\right) \). Since \( \sigma \) is exogenously set, firm 1’s results from playing \( P^*_1 \) are:

\[
\Pi^*_1 = (C_a - C_l) \cdot D_{il} = (C_a - C_l) \cdot \sigma > 0
\]

\[
MS^*_1 = \frac{\sigma + \frac{1}{2} (\overline{q} - \sigma)}{\overline{q}} > 0
\]

Now consider the maximum payoff firm 1 could expect from each of the partitioned sets of subgames:

1. \( \Pi_1 = 0 \) for all subgames in partition \( r_\alpha \) since both disadvantaged firms undercut its price in both markets.
2. For partition $r_\beta$, given that $P_2^* = P_3^* = (C_i, C_l)$, firm 1’s results yield a negative profit in all subgames since $P_{li} > C_l$ and $P_{lh} < C_l$. Thus firm 1 sells nothing in market $l$ and captures market $h$ at some price $P_{lh} : C_h > C_l > P_{lh}$, but the break even price in market $h$ is $P_{lh} = C_h$, so $\Pi_1 < 0$.

3. For partition $r_{\gamma}$, consider market $l$, $P_2 = P_3 = C_h$ but for this set of subgames firm 1’s maximum price $P_{li} : C_h > C_l > P_{li}$. So firm 1 will capture all of this market at a loss in each subgame. For market $h$, firm 1’s competitors price at the breakeven price. Clearly for any $P_{li}$ to the breakeven price, there is no true profit maximizing subgame in this partition due to the problem of maximizing on an open set. For market $h$, $P_{ih} = P_{ih} = C_h$, which implies that $\Pi_1 = 0$ and $MS_1 = 1$. All other subgames lead to negative profits or zero profits with less market share.

4. Firm 1 will always serve market $h$ in its entirety at a price below or even to the breakeven price, $C_h$, for all subgames in partition $r_\delta$ given $P_i^* = (P_{ih}, P_{ih})$ and the sharing rule $s = (1, 0, 0)$. For market $l$, any price $P_{li}$ sets above $C_a$ will be undercut by the disadvantaged firms. Thus the greatest results possible in this partition of prices is $P_{li} = P_{lh} = C_a$, which implies that $\Pi_1 = 0$ and $MS_1 = 1$. All other subgames lead to negative profits or zero profits with less market share.

5. For partition $r_{\zeta}$, there is no true profit maximizing subgame in this partition due to the problem of maximizing on an open set. For market $h$, $P_{lh} = C_h$ gives the optimal result of tying with the competing firms at the breakeven price. In market $l$, profits strictly increases as $P_{li}$ approaches $C_a$ and market share remains constant. So for any arbitrarily small $\epsilon > 0$, let $P_{li} = C_a - \epsilon$, then $\Pi_1 = (P_{li} - C_l) \cdot D_{li} + (P_{lh} - C_h) \cdot D_{lh} = (C_a - \epsilon - C_l) \cdot D_{li} + 0 \cdot D_{lh} = (C_a - C_l) \cdot D_{li} \cdot \sigma < \Pi_1^*$.

6. For partition $r_{\xi}$, given that firm $i$ plays $P_i^* = (C_h, C_h)$ for any prices set by firm 1 and $P_{li}$ is fixed at $C_a$, the goal is to find the optimal $P_{lh}$. Consider the profit function over the subgames $\Pi_1 = (C_a - C_l) \cdot \sigma + (P_{lh} - C_h) \cdot D_{lh}$. Clearly for any $P_{lh} \leq C_h$, profits increase as $P_{lh}$ increases. At $P_{lh} = C_h$, $\Pi_1 = (C_a - C_l) \cdot \sigma = \Pi_1^*$. It is easy to see that any further price increases lead to no changes in profits; however this is not the case for market share. $MS_1 = \frac{\sigma + \frac{k}{2}(l - \sigma)}{q} > 0$ for any $P_{lh} \leq C_h$, however for any $P_{lh}$ such that $P_{lh} > C_h$, $MS_1 = \frac{\sigma}{q}$, which is strictly less. Thus given the payoff function $R_1$, the optimal set of prices/subgame for firm 1 in this partition is, $P_i^* = (\sigma, C_a, C_h)$, the path of play for the subgame equilibrium.
Theorem 2 There exists a results maximizing category break for any cost function $C : [0, \bar{q}] \to \mathbb{R}_+$. If $C(q)$ is such that the set $\Sigma = \{ q \mid q \in [0, \bar{q}] \}$ and $C(q) = C_a$ is nonempty, defining $\Sigma$ to be the closure of $\Sigma$, then the results maximizing category break is $\sigma^*$, where $\sigma^* = \sup(\Sigma)$. If $C : [0, \bar{q}] \to \mathbb{R}_+$ is discontinuous such that there exists no consumer $q$ where $C(q) = C_a$, then that point of discontinuity is the results maximizing category break.

Proof. Consider a cost function $C(q)$ that is continuous and weakly increasing over its domain $[0, \bar{q}]$. It follows that $\Sigma$ must be nonempty. Theorem 1 ensures that an equilibrium exists for each $\sigma \in (0, \bar{q})$, so it must be shown that there exists a results maximizing category break $\sigma^*$ and that it is the greatest element of $\Sigma$. First consider the payoff that follows from any $\sigma \in \Sigma$ relative to that of any $\sigma \notin \Sigma$. Define $\sigma_l \in \{ \sigma \mid \sigma \notin \Sigma \text{ and } \sigma < \inf(\Sigma) \}$ and $\sigma_h \in \{ \sigma \mid \sigma \notin \Sigma \text{ and } \sigma > \sup(\Sigma) \}$. Consider the equilibrium payoffs to firm 1 if it selects a categorical break $\sigma \in \Sigma$. By theorem 1 the SPNE path of play for any $\sigma$ is $P^* = [(\sigma, C_a, C_h), (C_h, C_h), (C_h, C_h)]$ with the endogenous sharing rule $s = (\left( \frac{1}{2} \right), \left( \frac{1}{2} \right), \left( \frac{1}{2} \right))$. Consequently the profits earned by firm 1 are $\Pi^*_l = (C_a - C_l) \cdot D_{il} = (C_a - C_l) \cdot \sigma > 0$. Now consider the equilibrium payoffs to firm 1 if it selects some categorical break $\sigma_l$. The expected marginal cost of insuring additional consumers $q \in (\sigma_l, \inf(\Sigma))$ must be strictly less than $P_{il} = C_a$ and so can be profitably priced in market $l$ by increasing the category break to include them. Thus, no $\sigma_l$ can be a profit maximizing categorical break choice. Consider the equilibrium payoffs to firm 1 if it selects any categorical break $\sigma_h$. The expected marginal cost of insuring additional consumers $q \in (\sup(\Sigma), \sigma_h)$ must be strictly greater than $P_{il} = C_a$ and cannot be profitably priced in market $l$. So, no $\sigma_h$ is a profit maximizing category choice. Thus, if a payoff maximizing category break $\sigma^*$ exists, $\sigma^* \in \Sigma$.

If the function $C(q)$ is strictly increasing over the range where $C(q) = C_a$ then $\Sigma$ has one element, $\sigma^* = \sup(\Sigma)$ which maximizes the firm’s results. If $C(q)$ is continuous but weakly increasing, $\Sigma$ is nonempty, single valued, and $C(q^*) = C_a$, if $C(q)$ is strictly increasing in a neighborhood of $q^*$.

If $C(q)$ is constant over a range such that $\Sigma$ consists of an interval, many points could potentially serve as categorical breaks when considering profits alone. However, to maximize the advantaged firm’s results function the optimal categorical break must be $\sigma^* = \sup(\Sigma)$. For consider any other element of $\Sigma$ as a categorical break. Clearly, the inclusion of consumers with the expected cost $C_a$ will not reduce expected profits in market $l$ since in the optimal case firm 1 will set the price at $P_{il} = C_a$. So decreasing the break from $\sigma^* = \sup(\Sigma)$ by some $\epsilon > 0$ will not alter firm 1’s profits. But, market share shifts due to the fact that the advantaged firm captures all of market segment $l$ and splits segment $h$ with at least one competitor. Hence, the results maximizing advantaged firm will select $\sigma^* = \sup(\Sigma)$.

Finally, consider the case where there is a discontinuity in $C(q)$ such that $\Sigma = \emptyset$. Since the distribution is non-atomistic the point at which the discontinuity occurs is $\sigma^*$, this follows from an argument similar to that made in the continuous case. ■
Theorem 3 For any exogenously set \( \sigma \in (0, \overline{\sigma}] \). A pure strategy Subgame Perfect Nash equilibrium exists where the path of play consists of the strategy portfolio \( P^{**} = [(\sigma, C_a, C_h(P_1)), (C_h(P), C_h(P))], (C_h(P), C_h(P))] \) and the endogenous sharing rule \( s(P^{**}) = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3})) \), where \( C_h(P) \) is the expected cost of insuring an individual drawn at random from the insureds that remain in the high cost market at the price \( P_h = C_h(P) \).

Proof. This proof follows the same strategy as the proof of theorem 1. The key difference is shorthand convention used to denote any expected cost for a market segment where all consumers categorized in a market segment purchase insurance given the price level. Consider the following partitions of subgames:

1. For any subgame in partition \( r_\alpha = \{P_1 \mid P_1 \in [0, \overline{\sigma}] \times (C_a, \infty) \times (C_a, \infty)\} \), an equilibrium strategy for firm \( i, i = 2, 3 \), is given by the sharing rule \( s = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3})) \) and \( P_i^* = (C_a, C_a) \). This follows directly from the standard Bertrand price competition result, with constant marginal cost \( C_a \) for both disadvantaged firms.

2. For any subgame in partition \( r_\beta = \{P_1 \mid P_1 \in [0, \overline{\sigma}] \times (C_l, \infty) \times [0, C_l]\} \), an equilibrium is given by the strategy \( P_i^* = (C_l, C_l) \) for firm \( i, i = 2, 3 \) and the sharing rule \( s = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3})) \). For firm \( i \), offering insurance at the price \( P_i^* \) implies that \( \Pi_i = (C_l - C_i) \cdot D_{il} = 0 \) and \( MS_i = \frac{1}{2} \sigma \). Consider alternative strategies, clearly if firm \( i \) lowered its price by some \( \epsilon > 0 \) such that \( P_i > P_{ih} \), it would capture all of market \( l \) at a loss, \( \Pi_i < 0 \). Further reductions in \( P_i \) would lead only to greater losses from decreasing revenue in market \( l \) and the potential to capture business from market \( h \) where firm \( i \) would be inadequately priced. Alternatively, any increase in \( P_i \) from \( P_i^* = (C_l, C_l) \) implies \( \Pi_i = 0 \) and \( MS_i = 0 \). Thus \( C_l \) is the optimal strategy for firm \( i \).

3. For partition \( r_\gamma = \{P_1 \mid P_1 \in [0, \overline{\sigma}] \times [0, C_l] \times [0, \infty]\} \), the sharing rule \( s = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3})) \) and the strategy \( P_i^* = (C_h(P), C_h(P)) \) for \( i = 2, 3 \), constitute an equilibrium where the results are \( \Pi_i = 0 \) and \( MS_i \geq 0 \). Consider the alternatives, clearly market share can never be profitably held by a disadvantaged firm in market \( l \) when firm \( 1 \) prices it below \( C_l \), thus we only need to focus on potential profits from market \( h \). Two cases must be considered:

(a) \( P_{ih} \geq C_h(P) \): Firm \( i \) will price at cost \( C_h(P) \) by the standard Bertrand price competition argument. If all consumers in segment \( h \) purchase insurance at a price of \( P_h = C_h = C_h(P) \) where \( d_{ih}(P) = h \). If some \( q \in h \) and have choke prices below \( C_h \), then as they drop out of the market the expected cost of insuring an individual from market \( h \) increases as those who exit must be lower cost than those that remain. There always exists a stable price/quantity insured for market \( h \), as the highest risk individual in the market, \( C \), will always purchase insurance at the price \( P_h = C(C) \). Thus the actuarially fair price will
exist at some $P_h = C_h(P) > C_h$, where $C_h(P) : \overline{C} \geq C_h(P) \geq C_h$.
Thus $P_i^*$ is an equilibrium price and the corresponding results are
$\Pi_i = 0$ and $MS_i > 0$.

(b) $P_{1h} < C_h(P)$: The disadvantaged firms cannot profitably charge a
price that ties or undercut firm 1 in either of the markets since $P_{1h} < C_i$ and $P_{1h} < C_h(P)$. Thus any price greater than $P_{1h}$ (including $P_{1h}^*$)
yields the results $\Pi_i = 0$ and $MS_i = 0$ and is an equilibrium price.

4. For partition $r_8 = \{P_1 \mid P_1 \in [0, \overline{P}] \times [P_{1h}, \infty) \times [C_l, C_a]\}$, the sharing
rule $s = (1, 0, 0)$ and the strategy $P_i^* = (P_{1h}, P_{1i})$ for firm $i = 2, 3$ is an
equilibrium. For firm $i$, the strategy of $P_i^*$ implies that $\Pi_i = (P_i - C_i) \cdot
D_{il} \geq 0$ and $MS_i \geq 0$. For any strategy $P_i$, where $P_i > P_i^*$, firm $i$ is priced
out of the market and so earns results of $\Pi_i = 0$ and $MS_i = 0$. Suppose
that firm $i$’s strategy is price $P_i$, where $P_i > P_i^*$, then min($P_{1i}, P_{1h}, P_j) > P_i$. Firm $i$ captures the entire market at a price below $C_a$, which implies
$\Pi_i < 0$.

5. For partition $r_6 = \{P_1 \mid P_1 \in [0, \overline{P}] \times [C_l, C_a] \times (P_{1i}, \infty)\}$, the sharing
rule $s = ((1/3), (1/3), (1/3))$ and the strategy $P_i^* = (C_h(P), C_h(P))$ for firm $i$,
$i = 2, 3$, is an equilibrium. The strategy of $P_i^*$ yields the results $\Pi_i = 0$
and $MS_i \geq 0$, where market share depends on the level of $P_{1h}$. For any
$P_i > P_i^*$ firm $i$ is priced out of the market so profits and market share
are trivially zero. Suppose firm $i$ were to charge a price lower than $P_i^*$. For any
$P_i : C_l(P) > P_i > P_{1h}$, again firm $i$ is priced out of the market
so $\Pi_i = 0$ and $MS_i = 0$. For any $P_i : P_{1h} \geq P_i > P_{1i}$, $i$’s profits are
$\Pi_i = (P_i - C_l(P)) \cdot D_{ih} < 0$ and for any $P_i : P_{1i} \geq P_i \geq 0$, $i$’s profits are
$\Pi_i = (P_i - C_l(P)) \cdot D_{ih} + (P_i - C_h(P)) \cdot D_{ih} < 0$. So every strategy from both
intervals yields negative profits.

6. For any subgame in partition $r_5 = \{P_1 \mid P_1 \in [0, \overline{P}] \times [C_a, C_a] \times (C_a, \infty)\}$,
the sharing rule $s = ((1/3), (1/3), (1/3))$ and the strategy $P_i^* = (C_h(P), C_h(P))$
for firm $i$, $i = 2, 3$, is an equilibrium. Two cases need to be considered for
this partition:

(a) $P_{1h} \geq C_h(P)$: For firm $i$, charging $P_i^*$ implies that $\Pi_i = 0$ and
$MS_i > 0$. Suppose firm $i$, were to charge any price $P_i > P_i^*$, it would
be undercut by firm $j$, yielding the results $\Pi_i = 0$ and $MS_i = 0$. To
charge a lower price implies negative profits. For any $P_i : C_l(P) \geq
P_i > P_{1i}, i$ captures market $h$ but is inadequately priced and so profits
are $\Pi_i = (P_i - C_l(P)) \cdot D_{ih} < 0$. And for any $P_i : P_{1i} \geq P_i \geq 0$, $i$’s profits are
$\Pi_i = (P_i - C_l(P)) \cdot D_{il} + (P_i - C_h(P)) \cdot D_{ih} < 0$.

(b) $C_h(P) > P_{1h} > C_a$: Clearly for firm $i$, charging any $P_i > P_{1h}$ implies
that $\Pi_i = 0$ and $MS_i = 0$. This applies to $P_i^*$ since $P_i^* = C_h(P) > P_{1h}$.
Furthermore, for any $P_i : P_{1h} \geq P_i > P_{1i}, i$ captures market
share in $h$ but is inadequately priced and so profits are $\Pi_i = (P_i - C_l(P)) \cdot D_{ih} < 0$. And for any $P_i : P_{1i} \geq P_i \geq 0$, $i$’s profits are
$\Pi_i = (P_i - C_l(P)) \cdot D_{il} + (P_i - C_h(P)) \cdot D_{ih} < 0$.

33
Finally, to show that $\mathbf{P}^*$ is the path of play for the SPNE it must be clear that firm 1 maximizes profits by setting $P^*_1 = (\sigma, C_a, C_h(\mathbf{P}))$ given the sharing rule $\mathbf{s} = ((\frac{1}{3}), (\frac{1}{3}), (\frac{1}{3}))$. Since $\sigma$ is exogenously set, firm 1’s results from playing $P^*_1$ are:

$$\Pi_1^* = (C_a - C_l) \cdot D_{1l} = (C_a - C_l) \cdot \sigma > 0$$

$$MS_1^* = \frac{\sigma + \frac{1}{3}q_h}{\sum_{m \in M} q_m} > 0$$

Now consider the maximum payoff firm 1 could expect from each of the partitioned sets of subgames:

1. $\Pi_1 = 0$ for all subgames in partition $r_\alpha$ since both disadvantaged firms undercut its price in both markets.

2. For partition $r_\beta$, given that $P^*_2 = P^*_3 = (C_l, C_l)$, firm 1’s results yield a negative profit in all subgames since $P_{1l} > C_l$ and $P_{1h} < C_l$. Firm 1 sells nothing in market $l$ and captures market segment $h$ at some price $P_{1h} : C_h(\mathbf{P}) > C_l > P_{1h}$, so $\Pi_1 < 0$.

3. For partition $r_\gamma$, consider market $l$, $P_2 = P_3 = C_h(\mathbf{P})$ but for this set of subgames firm 1’s maximum price $P_{1l} : C_h(\mathbf{P}) > C_l > P_{1l}$. So firm 1 will capture all of this market at a loss in each subgame. For market $h$, firm 1’s competitors price at the breakeven price, $P_{1h} = C_h(\mathbf{P})$. Clearly the best case for market $h$ is to price at the break even price and gain some of the market at cost. Thus, $\Pi_1 = (P_{1l} - C_l) \cdot D_{1l} + (P_{1h} - C_h(\mathbf{P})) \cdot D_{1h} < 0$.

4. Firm 1 will always serve market $h$ in its entirety at a price below or even to the breakeven price, $C_h(\mathbf{P})$, for all subgames in partition $r_\delta$ with $P^*_1 = (P_{1h}, P_{1l})$ and the sharing rule $\mathbf{s} = (1, 0, 0)$. For market $l$, any price firm 1 sets above $C_a$ will be undercut by the disadvantaged firms. Thus the greatest results possible in this partition of prices is $P_{1l} = P_{1h} = C_a$, which implies that $\Pi_1 = 0$ and $MS_1 = 1$. It is easy to see that all other subgames lead to negative profits or zero profits with less market share.

5. For partition $r_\epsilon$, there is no true profit maximizing subgame in this partition due to the problem of maximizing on an open set. For market $h$, $P_{1h} = C_h(\mathbf{P})$ gives the optimal result of tying with the competing firms at the breakeven price. In market $l$, profits strictly increases as $P_{1l}$ approaches $C_a$ and market share remains constant. So for any arbitrarily small $\epsilon > 0$, let $P_{1l} = C_a - \epsilon$, then $\Pi_1 = (P_{1l} - C_l) \cdot D_{1l} + (P_{1h} - C_h(\mathbf{P})) \cdot D_{1h} = (C_a - \epsilon - C_l) \cdot D_{1l} + 0 \cdot D_{1h} = (C_a - \epsilon - C_l) \sigma < \Pi_1^*$.

6. For partition $r_\zeta$, given that firm $i$ plays $P^*_i = (C_h(\mathbf{P}), C_h(\mathbf{P}))$ for any prices set by firm 1 and $P_{1l}$ is fixed at $C_a$, the goal is to find the optimal $P_{1h}$. Consider the profit function over the subgames $\Pi_1 = (C_a - C_l) \cdot \sigma + (P_{1h} - C_h(\mathbf{P})) \cdot D_{1h}$. Clearly for any $P_{1h} \leq C_h(\mathbf{P})$, profits increase as $P_{1h}$
increases. At \( P_1 = C_h(P) \), \( \Pi_1 = (C_a - C_l)\sigma = \Pi_1^* \). It is easy to see that any further price increases lead to no change in profits; however this is not the case for market share. \( MS_1 = \frac{\sigma + \frac{1}{2}q_h}{\sum_{m \in M} q_m} > 0 \) for any \( P_1 \leq C_h(P) \), however for any \( P_1 \) such that \( P_1 > C_h(P) \), \( MS_1 = \frac{\sigma}{\sum_{m \in M} q_m} \), which is strictly less. Thus given the payoff function \( R_1 \), the optimal set of prices/subgame for firm 1 in this partition is, \( P_1^* = (\sigma, C_a, C_h(P)) \), the path of play for the subgame equilibrium.
## 7.2 Regression Results

### Table A1. OLS Results - Washington Nonstandard Private Passenger Automobile Market

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Ratio</td>
<td>N=327</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segment Ranking</td>
<td>0.528</td>
<td>0.771</td>
<td>0.791</td>
<td>0.811</td>
<td>-0.055</td>
<td>-0.044</td>
<td>-0.076</td>
<td>-0.074</td>
</tr>
<tr>
<td>(Segmentation Ranking)*</td>
<td>-0.008</td>
<td>-0.010</td>
<td>-0.011</td>
<td>-0.011</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Liability Base</td>
<td>-0.034</td>
<td>-0.033</td>
<td>-0.034</td>
<td>-0.034</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Preferred Mkt</td>
<td>-1.657</td>
<td>-2.097</td>
<td>-1.979</td>
<td>0.069</td>
<td>-0.001</td>
<td>-0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Mkt</td>
<td>-1.913</td>
<td>-2.542</td>
<td>-3.121</td>
<td>0.925</td>
<td>1.135</td>
<td>1.074</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liablity Limits</td>
<td>0.132</td>
<td>0.133</td>
<td>0.132</td>
<td>0.132</td>
<td>-0.007</td>
<td>-0.010</td>
<td>-0.012</td>
<td>-0.012</td>
</tr>
<tr>
<td>Commission Rate</td>
<td>-0.416</td>
<td>-0.439</td>
<td>-0.425</td>
<td>-0.425</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dividend Ratio</td>
<td>1.915</td>
<td>1.706</td>
<td>1.473</td>
<td>-0.689</td>
<td>-0.468</td>
<td>-0.509</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeowners</td>
<td>-0.006</td>
<td>-0.005</td>
<td>-0.005</td>
<td>-0.005</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expense Ratio</td>
<td>0.018</td>
<td>0.015</td>
<td>-0.003</td>
<td>-0.003</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defense Containment Costs</td>
<td>0.910</td>
<td>0.975</td>
<td>0.927</td>
<td>-0.041</td>
<td>-0.048</td>
<td>-0.049</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenny Capacity</td>
<td>-0.440</td>
<td>-0.407</td>
<td>0.449</td>
<td>0.458</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advertising</td>
<td>-0.007</td>
<td>-0.012</td>
<td>0.002</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Damage Base</td>
<td>0.0137</td>
<td>0.0131</td>
<td>0.0128</td>
<td>0.0065</td>
<td>0.0000</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Dmg. Limits</td>
<td>-0.061</td>
<td>-0.092</td>
<td>-0.088</td>
<td>0.010</td>
<td>0.011</td>
<td>0.011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Dummies</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>R²/P-val for F test</td>
<td>0.007</td>
<td>0.402</td>
<td>0.1340</td>
<td>0.000</td>
<td>0.1180</td>
<td>0.041</td>
<td>0.1350</td>
<td>0.019</td>
</tr>
</tbody>
</table>

Notes: Standard errors in parentheses. Due to Heteroskedasticity White/Huber S.E.’s are used

*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level
<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Loss Ratio</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Segmentation Ranking</td>
<td>1.463</td>
<td>0.934</td>
</tr>
<tr>
<td></td>
<td>(0.681)**</td>
<td>(0.646)*</td>
</tr>
<tr>
<td>(Segmentation Ranking)^2</td>
<td>-0.030</td>
<td>-0.026</td>
</tr>
<tr>
<td></td>
<td>(0.012)**</td>
<td>(0.013)*</td>
</tr>
<tr>
<td>Liability Base</td>
<td>-0.084</td>
<td>-0.079</td>
</tr>
<tr>
<td></td>
<td>(0.045)*</td>
<td>(0.037)**</td>
</tr>
<tr>
<td>Liability Limits</td>
<td>2.206</td>
<td>2.713</td>
</tr>
<tr>
<td></td>
<td>(2.7)</td>
<td>(2.579)</td>
</tr>
<tr>
<td>Commission Rate</td>
<td>-1.130</td>
<td>-1.176</td>
</tr>
<tr>
<td></td>
<td>(0.331)***</td>
<td>(0.304)***</td>
</tr>
<tr>
<td>Expense Ratio</td>
<td>0.047</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>(0.071)</td>
<td>(0.066)</td>
</tr>
<tr>
<td>Defense Containment Costs</td>
<td>1.195</td>
<td>1.244</td>
</tr>
<tr>
<td></td>
<td>(0.68)*</td>
<td>(0.684)*</td>
</tr>
<tr>
<td>Kenny Capacity</td>
<td>2.919</td>
<td>2.967</td>
</tr>
<tr>
<td></td>
<td>(2.316)</td>
<td>(2.144)</td>
</tr>
<tr>
<td>Advertising</td>
<td>0.013</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Physical Damage Base</td>
<td>0.0489</td>
<td>0.0559</td>
</tr>
<tr>
<td></td>
<td>(0.028)*</td>
<td>(0.028)*</td>
</tr>
<tr>
<td>Physical Dmg. Limits</td>
<td>0.230</td>
<td>-0.192</td>
</tr>
<tr>
<td></td>
<td>(0.642)</td>
<td>(0.603)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time Dummies</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

R^2/F-val for F test: 0.001/0.046 0.025/0.000 0.026/0.001 0.026/0.000 0.003/0.576 0.034/0.023 0.043/0.044 0.038/0.002

Notes: Standard errors in parentheses. Due to Heteroskedasticity White/Huber S.E.’s are used
*** Significant at the 1% level
** Significant at the 5% level
* Significant at the 10% level