

**Incentives in Firm's Unobservable, Endogenous Decisions:  
Diversity and Service Effort**

by

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A dissertation submitted in partial satisfaction of the  
requirements for the degree of  
Doctor of Philosophy

in

Business

in the

Graduate Division  
of the  
University of California, Berkeley

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Spring 2013

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## Abstract

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Firms make optimal decisions on the level of various marketing-mix variables to maximize profits. Some of these marketing-mix variables are unobserved by researchers, yet they are important to understand when they are endogenous in that a firm has incentives to increase or decrease them depending on how they change its profit. This thesis is focused on understanding a firm's incentive in two unobservable, endogenous decisions: workforce diversity and service effort. This thesis further builds theoretical frameworks around these two concepts, validates/estimates the model using public and proprietary data, and draws implications in market competition and policy experiment.

The literature in business, psychology, and sociology shows that there is a trade-off in hiring diverse workforce: diversity brings creative ideas that help solving problems, but it also creates friction among members. Under competition, the decision on the level of diversity of workforce is an important strategic decision that gives firms a competitive edge. We build a theoretical model with symmetric firms and find that the better a firm can deal with a diverse workforce or the more competition there is in the market, the more diverse workforce the firm will hire. We also find that a firm's profit decreases with the intensity of market competition as expected, but increases with the firm's inability to deal with diverse workforce as the inability deters competition between firms. Finally, we extend the model to firms with asymmetric private marginal costs and empirically validate the positive relationship between the diversity of workforce and the intensity of competition (industry concentration ratio, in particular) using two datasets from 1997: National Organizations Survey and Economics Census.

Service effort, often referred to as customer service, is also another important unobservable, endogenous decision that firms must make. Empirically quantifying or measuring the service effort is difficult because it is often unobservable. This paper proposes an empirical framework of the role of service effort in demand, along with other traditional marketing mix instruments. This model allows us to measure the unobserved effort level without data on effort, which is hardly available in most empirical settings. The paper also presents an application to a unique data set obtained from a franchise operating in

the car radiator market. This framework can be useful in examining various aspects of service-intensive industries. In particular, this study investigates a much-debated public policy question regarding resale price ceiling in franchising. A policy evaluation shows that resale price ceiling lowers franchisees' profits and weakens their incentive to exert effort, which reduces consumer welfare. However, I find that, overall, resale price ceiling enhance consumer welfar in the car radiator market due to the lower price generated by the price ceiling.

To my beloved family, who always encourages and supports me to do what I love.

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## Preface

Firms make optimal decisions on the level of various marketing-mix variables to maximize profit. Some of the marketing-mix variables are often observed by researchers and are taken into account in studying consumer demand and market supply. For instance, Berry et al. (1995) used price, the number of cylinders, number of doors, weight, horsepower, length, and EPA miles per gallon rating (MPG) of automobiles in the U.S. to study consumer demand and firms' profit function. When rich data in observable variables is available, researchers can make meaningful inference on customer response to firms' observable marketing-mix variables.

In other settings, unobservable marketing-mix variables may be of interest. When the unobservable variable of interest is a result of a firm's endogenous decision, a theoretical framework can be developed to understand the incentives of firms in the market. Among the many unobservable, endogenous decisions that firms make, this thesis is focused on workforce diversity and service effort. Workforce diversity contributes to higher chance of a superior solution being adopted to solve business problems while it increases higher communication cost among diverse members within the organization. Service effort, often referred to as customer service, provides value to customers and is often cited as one of the top factors that customers take into account when they decide to purchase a product. Both workforce diversity and service effort are endogenous in that a firm has incentives to increase or decrease them depending on how they change its profit. Studying a firm's incentives in these variables offers insights into not only demand and supply in the market, but also policy implications. This thesis builds theoretical frameworks around these two concepts, validates/estimates the model using public and proprietary data, and draws implications in market competition and policy experiment.

This thesis consists of two chapters. In Chapter 1, we discuss workforce diversity in the context of market competition. Literature in business, psychology, and sociology shows that there is a trade-off in hiring a diverse workforce: diversity brings creative ideas that help to solve problems, but it also creates friction among members. Under competition, the decision on the level of diversity of workforce becomes an important strategic decision that gives competitive edge to firms. We build a theoretical model with symmetric firms and find that the better a firm can deal with diverse workforce or the more competition there is in the market, the more diverse workforce the firm will hire. We also find that a firm's profit decreases with the intensity of market competition as expected, but increases with the firm's inability to deal with diverse workforce as the inability deters competition between firms. Finally, we extend the model to firms with asymmetric private marginal costs and empirically validate the positive relationship between the diversity of workforce and the intensity of competition (industry concentration ratio, in particular) using two data sets from 1997: National Organizations Survey and Economics Census.

In Chapter 2, service effort in franchise industry is discussed. Consumers respond not only to the price and the product attributes, but also to the service effort provided by the seller. Empirically quantifying or measuring the service effort is difficult because

it is often unobservable. This paper proposes an empirical framework for the role of service effort in demand, along with other traditional marketing mix instruments. The model allows us to measure the unobserved effort level without data on effort, which is hardly available in most empirical settings. The paper also presents an application to a unique data set obtained from a franchise in the car radiator market. This framework can be useful in examining various aspects of service-intensive industries. In particular, this study investigates a much-debated public policy question regarding resale price ceiling in franchising. A policy evaluation shows that resale price ceiling lowers franchisees' profits and weakens their incentive to exert effort, which reduces consumer welfare. However, I find that, overall, resale price ceiling is consumer welfare enhancing in the car radiator market due to the lower price generated by the price ceiling.

## Acknowledgments

This dissertation would not have been possible without the encouragement and guidance from several people. First and foremost, I am deeply indebted to my dissertation committee chair, J. Miguel Villas-Boas, whose relentless enthusiasm and rigor in research inspired me to work hard day and night. I often knocked on his office door multiple times in a day, many days in a row, interrupting him with my random thoughts and questions, yet he always greeted me with a smile and offered me luminous ideas and answers.

I am also grateful to the rest of my dissertation committee: Teck-hua Ho has been a staunch supporter of me from Day 1. He encouraged me to take on diverse exciting projects and to broaden my horizons, which I plan to continue. Ganesh Iyer supported my research through the years and was even willing to meet with me on a Sunday. Denis Dekipelov offered me ample time during busy semesters to share valuable insights that helped shape my research questions. Minjung Park asked me hard questions and caught me off guard more than once, but the experience helped me to think more critically and analytically.

I would also like to express my gratitude to Clayton Critcher, Lucas Davis, Ming Hsu, Przemyslaw Jeziorski, and Zsolt Katona for their insightful comments and feedback during the job market process and beyond.

I was also blessed to have great colleagues - doctoral students in the UC Berkeley marketing department for their congeniality and intellectual stimulation. Coming to the office was always fun.

Last but not least, I thank my family - my parents Joonyun Kim and Gyungnam Kim and my sister Chantel Sowon Kim - for believing in me. I could not have done this without you.

# Chapter 1

## Diversity and Competition

\* This is a joint work with Teck-Hua Ho and Ganesh Iyer

## 1.1 Introduction

Diversity of workforce has been a popular topic in the areas of psychology, sociology, public policy, political economy, management, and organizational behavior. In business literature, many researchers have posited that diversity improves team performance, whereas others have been skeptical. Hoffman (1959) and Hoffman and Maier (1961) showed that groups composed of diverse characteristics brought a broader range of perspectives and thus produced better solutions to complex problems. Watson, Kumar, Micaelson (1993) showed in their experiment with MBA students that culturally diverse groups outperformed in task measures associated with creativity and the range of perspectives and alternatives generated. Hong and Page (2001) used a computer simulation to argue that diverse groups, and therefore diverse algorithms, are more effective in solving a complex problem. Although this school of thought upholds a diverse workforce as a way to bring creative solutions to a problem, others find that diverse workforce hurts team performance. Byrne's similarity-attraction theory (1971) claims that attitude similarity is closely related to attraction; therefore, people are attracted to others with similar beliefs and expectations. Jackson et al (1991) found evidence in the banking industry: heterogeneity (no race information, mainly experience in other industries) in management teams in banking is associated with a higher turnover rate. Tsui, Egan, and O'Reilly (1992) conducted random sample surveys to workers of three large companies and found that high diversity in gender/race is associated with less emotional attachment to the firm and intent to stay, and higher number of absences. These studies all agree that the cost of diverse workforce should not be understated. These positive and negative views of diverse workforce are resonated and can easily be found in the field. Hewlett-Packard's webpage on diversity writes, "diversity and inclusion are key drivers of creativity, innovation, and invention," highlighting literature's positive view that a diverse workforce brings creative solutions to complex problems. On the contrary, General Motor's page on diversity shows that GM is more interested in the other side of the diversity coin. Its mission on diversity is "to create a culture and a business environment based upon inclusion, mutual respect, responsibility, and understanding." General Motors goes even further by instituting a company-wide campaign, "I am GM," to coagulate its diverse workforce, acknowledging the existence of friction among its diverse members in a sense. This campaign is described as the following on GM's website: "*I am GM* represents men and women of many cultures, ethnic backgrounds, ages, sexual orientation, and physical abilities." Although both HP and GM thrive in technology-intensive industries, their views on diversity are strikingly different. These examples show that firms acknowledge cost and benefit of diverse workforce, which opens a door to an interesting question in marketing strategy: can diversity of workforce be a strategic decision in a competitive environment? ExxonMobil's webpage on diversity confirms our suspicion: "ExxonMobil's greatest strength is the exceptional

quality of our employees and the combined talents of our diverse workforce help us to lead the competition.” ExxonMobil views a diverse workforce as something more than just “the right thing to do.” Rather, it considers diverse workforce as a competitive advantage over other firms. In this paper, we model firms’ choice of diversity of workforce in regards to intensity of market competition and try to illustrate how market parameters influence firms’ decisions and profits. First we construct a basic model of two symmetric firms competing under complete information and zero marginal costs. We then extend the model to a case where firms face asymmetric marginal costs that are private information. Lastly, the main prediction of this extension is empirically tested using two data sets from 1997.

## 1.2 Basic Model

### 1.2.1 Model Setup

We begin with a basic model that is based on a two-period model with Hotelling setup. Consumers of density 1 are uniformly distributed on  $[0, 1]$ . Two firms,  $i$  and  $j$ , each offer a single product at the two ends of the unit line: firm  $i$  offering a product at  $x = 0$ , and firm  $j$  at  $x = 1$ . The product by firm  $i$  ( $j$ ) is offered at  $p_i$  ( $p_j$ ). Consumers incur a travel cost of  $t > 0$  per unit length. Therefore, a consumer located at  $x \in [0, 1]$  incurs a travel cost of  $tx$  for buying from firm  $i$  and  $t(1 - x)$  for buying from firm  $j$ . Each consumer has a unit demand and receives base utility of  $\eta > 0$  by purchasing a product from either firm. The base utility  $\eta$  is assumed to be large enough such that all consumers buy from one of the firms in equilibrium. Consumers also receive an incremental utility of  $s_i$  and  $s_j$  by purchasing from firm  $i$  and firm  $j$ , respectively. These incremental utilities can be interpreted as product qualities offered by the firms, based on the best product idea generated by employees; this process will be detailed in the following section. Figure 1.1 illustrates the setup of our model:

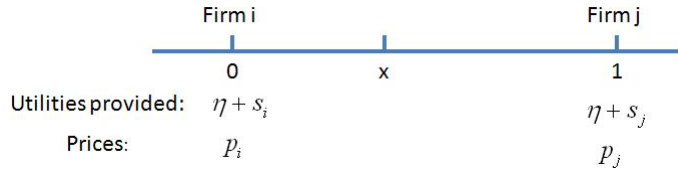


Figure 1.1: Market Setup

In launching a new product, product quality is often determined during the R&D stage: employees generate ideas for the new product’s design and quality, and the firm commercializes the best idea among them. In our model, the incremental utility  $s_f$  represents the best idea from firm  $f$ ’s employees,  $f \in \{i, j\}$ . We suppose that ideas of potential employees of firm  $f$  are distributed uniformly along a line segment  $[\frac{1}{2} - \frac{d_f}{2}, \frac{1}{2} + \frac{d_f}{2}]$ , where

$0 \leq d_f \leq 1$  is the degree of diverse ideas from which firm  $f$  hires. Better or higher idea means that a firm can offer a new product of higher quality to consumers. Workforce with more diverse dimensions - such as age, gender, ethnicity, education background, and organizational tenure - brings a more diverse pool of ideas for the new product. For instance, if a firm chooses the most heterogeneous, diverse idea pool for the new product ( $d_f = 1$ ), then ideas can be generated anywhere between 0 and 1 (i.e. more diverse ideas). If the firm chooses the most homogeneous idea pool instead ( $d_f = 0$ ), then all the ideas for the new product will be at  $\frac{1}{2}$ . The setup of the idea pool is illustrated in Figure 1.2:

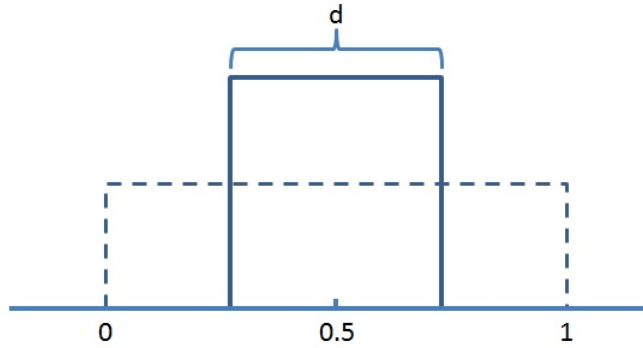


Figure 1.2: Idea Pool

Once each firm chooses  $d_f$ , it hires  $N \geq 2$  i.i.d. draws of employees from the idea pool  $[\frac{1}{2} - \frac{d_f}{2}, \frac{1}{2} + \frac{d_f}{2}]$ , where  $N$  is considered as the size of hires. The best idea out of the  $N$  ideas drawn, denoted as  $s_f$ , becomes the product quality or the incremental utility to consumers. Mathematically,  $s_f$  is the first-order statistics of  $N$  i.i.d draws from a uniform distribution. The probability density function of the the first-order statistics  $s_f$  among  $N$  draws from  $U[\frac{1}{2} - \frac{d_f}{2}, \frac{1}{2} + \frac{d_f}{2}]$  can then be calculated as  $f(s_f) = \frac{N}{d_f} \left[ s_f - \left( \frac{1-d_f}{2} \right) \right]^{N-1}$ .

Literature with a negative view on diversity posits that there are costs associated with diverse workforce. Such costs may arise in various forms, such as employee dissatisfaction (Tsui et al. 1992), communication/interaction friction (Byrne 1971), and a high turnover rate (Jackson et al. 1991). The cost of having diverse workforce or ideas can be thought of as an interaction cost in searching for the best one out of  $N$  ideas. We assume that the searching cost is increasing and strictly convex in  $d_f$ . Such form of quadratic cost is common in previous literatures (e.g., Mussa and Rosen 1978, Moorthy 1998). The interaction cost also increases quadratically in  $N$  based on the fact that the bubble sorting algorithm requires an order of  $N^2$  iterations to sort  $N$  elements. Thus, we define the cost of diversity or interaction cost of choosing  $d_f$  as  $CD_f = \frac{1}{2}kd_f^2N^2$ , where  $k > 0$  is a firm's inherent inability to deal with diverse ideas. Such inability may be measured through outward qualities, such as a firm's policy on affirmative action and diversity training for managers, as well as more subtle qualities, such as a firm's culture in encouraging creative, alternative ideas and managing disagreement among diverse members.



Firms make the following decisions in two periods. In period 1, firms simultaneously choose the diversity of the idea pool,  $d_i$  and  $d_j$ . In period 2, firms observe the competitor's best idea or product quality drawn from  $[\frac{1}{2} - \frac{d_f}{2}, \frac{1}{2} + \frac{d_f}{2}]$ , denoted by  $s_f$ ,  $f \in \{i, j\}$ , and price their products simultaneously. Consumers then observe the product qualities and prices from both firms, and demand is realized. In the basic model, the firm's marginal cost is assumed to be constant and normalized to zero, and it will be extended to a non-zero, asymmetric marginal cost case in subsequent sections.

### 1.2.2 Consumer

A consumer at  $x$  enjoys utility of  $\eta + s_i - p_i - tx$  for buying from firm  $i$  and  $\eta + s_j - p_j - t(1 - x)$  from firm  $j$ . Hence the consumer at  $x$  will buy from firm  $i$  if and only if  $\eta + s_i - p_i - tx \geq \eta + s_j - p_j - t(1 - x)$ . Otherwise, the consumer buys from firm  $j$ . The firms' respective demands are

$$D_i(p_i, p_j) = x = \frac{(s_i - p_i) - (s_j - p_j) + t}{2t} \quad (1.1)$$

$$D_j(p_i, p_j) = 1 - x = \frac{(s_j - p_j) - (s_i - p_i) + t}{2t} \quad (1.2)$$

### 1.2.3 Period 2

Given the product qualities  $s_i$  and  $s_j$ , firms simultaneously choose the prices of their products to maximize profit:

$$\max_{p_i} \pi_i | s_i, s_j = \max_{p_i} p_i D_i(p_i, p_j) | s_i, s_j \quad (1.3)$$

$$\max_{p_j} \pi_j | s_i, s_j = \max_{p_j} p_j D_j(p_i, p_j) | s_i, s_j \quad (1.4)$$

The first-order conditions for firm  $i$  and  $j$  yield  $p_i = \frac{s_i - (s_j - p_j) + t}{2}$  and  $p_j = \frac{s_j - (s_i - p_i) + t}{2}$ , and the second-order conditions are satisfied. Solving the two first-order conditions simultaneously, we obtain the following conditional Nash Equilibrium given  $s_i$  and  $s_j$ :

$$p_i | s_i, s_j = \frac{s_i - s_j + 3t}{3} \quad (1.5)$$

$$D_i | s_i, s_j = \frac{s_i - s_j + 3t}{6t} \quad (1.6)$$

$$\pi_i | s_i, s_j = \frac{(s_i - s_j + 3t)^2}{18t} \quad (1.7)$$

$$p_j | s_i, s_j = \frac{s_j - s_i + 3t}{3} \quad (1.8)$$

$$D_j | s_i, s_j = \frac{s_j - s_i + 3t}{6t} \quad (1.9)$$

$$\pi_j | s_i, s_j = \frac{(s_j - s_i + 3t)^2}{18t} \quad (1.10)$$

**Lemma 1:** To ensure strictly positive market demand and price given any realized values of  $s_i, s_j \in [0, 1]$ , we require  $t > \frac{1}{3}$ .

*proof:* For strictly positive prices and demands,  $s_j - s_i + 3t > 0$  and  $s_i - s_j + 3t > 0$  are required for all values for  $s_i$  and  $s_j$ . Since  $s \in [0, 1]$ , the lower bound of  $s_i - s_j + 3t$ ,  $s_j - s_i + 3t$  is  $-1 + 3t$ . For this lower bound to be strictly positive, we require  $t > \frac{1}{3}$ . Q.E.D. The equilibrium results show how product qualities  $s_i, s_j$  and the travel cost  $t$  influence the price, the demand and the profit. As firm  $i$ 's product quality  $s_i$  becomes more superior to that of firm  $j, s_j$ , the optimal price, demand, and profit of firm  $i$  increase because higher product quality provides more value to consumers. Also note that increase in travel cost  $t$  unilaterally increases prices and profits of both firms because higher  $t$  means a higher degree of product differentiation, therefore less competition between firms.

## 1.2.4 Period 1

Consider now the firm's strategic decision on the diversity of the idea pool,  $d_f$ , in the first period. Firms do not know what product quality  $s_f$  will be realized, so they form an expectation about  $s_f$ . During period 1, a firm sorts out the best out of  $N$  ideas by incurring the interaction cost  $CD_f$ . Denoting  $\alpha_f \equiv \frac{1}{2} - \frac{d_f}{2}$ ,  $\beta_f \equiv \frac{1}{2} + \frac{d_f}{2}$ , firm  $i$ 's expected profit in period 1 is written as the following:

$$\begin{aligned}
E\pi_i &= \int_{\alpha_j}^{\beta_j} \int_{\alpha_i}^{\beta_i} f(s_i, s_j) [\pi_i | s_i, s_j - CD_i] ds_i ds_j & (1.11) \\
&= \int_{\alpha_i}^{\beta_i} f(s_i) \int_{\alpha_j}^{\beta_j} f(s_j) \left[ \frac{(s_i - s_j + 3t)^2}{18t} \right] ds_j ds_i - \frac{1}{2} k d_i^2 N^2 \\
&= \frac{1}{18t} \int_{\alpha_i}^{\beta_i} f(s_i) \left\{ s_i^2 + E(s_j^2) + 9t^2 - 2s_i E(s_j) + 6s_i t - 6E(s_j)t \right\} ds_i - \frac{1}{2} k d_i^2 N^2 \\
&= \frac{1}{18t} \left\{ E(s_i^2) + E(s_j^2) - 2E(s_i)E(s_j) + 6t [E(s_i) - E(s_j)] \right\} + \frac{t}{2} - \frac{1}{2} k d_i^2 N^2
\end{aligned}$$

The second equality is established using the fact that all the draws taken are i.i.d. Firm  $j$ 's expected profit can be written similarly. After some algebra and integration by part, the moments of the first-order statistics are found:  $E(s_f) = \frac{1}{2} + d_f R$ ,  $E(s_f^2) = \left(\frac{1+d_f}{2}\right)^2 - \frac{2d_f}{N+1} \left[\frac{1+d_f}{2} - \frac{d_f}{N+2}\right]$ , where  $R \equiv R(N) = \frac{N-1}{2(N+1)}$ . The expectation of product quality  $s_f$  shows that the larger  $d$  is chosen, the higher  $s$  is likely to be in expectation. Firm  $i$  and  $j$  then maximize the following expected profit functions over all possible  $d_i$  and  $d_j$ :

$$\max_{d_i} \frac{1}{18t} \left\{ E(s_i^2) + E(s_j^2) - 2E(s_i)E(s_j) + 6t [E(s_i) - E(s_j)] \right\} + \frac{t}{2} - \frac{1}{2} k d_i^2 N^2 \quad (1.12)$$

$$\max_{d_j} \frac{1}{18t} \left\{ E(s_i^2) + E(s_j^2) - 2E(s_i)E(s_j) + 6t [E(s_j) - E(s_i)] \right\} + \frac{t}{2} - \frac{1}{2} k d_j^2 N^2 \quad (1.13)$$

The first-order conditions yield the following:

$$d_i^* = \frac{2R [3t - Rd_j^*]}{18tkN^2 - Q} \quad (1.14)$$

$$d_j^* = \frac{2R [3t - Rd_i^*]}{18tkN^2 - Q} \quad (1.15)$$

From these equations, we can see that the diversity of the idea pool is a strategic substitute: as firm  $i$  ( $j$ ) increases its diversity of idea pool, firm  $j$ 's ( $i$ 's) best response is to decrease the diversity of its idea pool. To ensure the existence of global maximum of the profit functions, we need the following second-order condition:

$$\frac{d^2 E\pi_f}{dd_f^2} < 0 \iff DN \equiv DN(t, k, N) = 18tkN^2 - Q > 0, f \in \{i, j\} \quad (1.16)$$

Solving for  $d_i^*$  and  $d_j^*$  in the two first-order conditions, we find the optimal diversity level for firms:

**Proposition 1** Under Lemma 1, the optimal level of diversity of the idea pool for each symmetric firm is

$$d_s^* \equiv d_i^* = d_j^* = \frac{6Rt}{DN + 2R^2} \quad (1.17)$$

Both firms' choice of the diversity of the idea pool  $d_s^*$  decreases in the intensity of competition, in the firm's inability to deal with diverse ideas  $k$ , and in the number of hires  $N$ .

*proof:* See Appendix

The results of Proposition 1 show that as the travel cost  $t$  increases (or the competition eases), firms gain more market power because higher  $t$  means larger product differentiation. Therefore, firms are less incentivized to further provide incremental utility to attract more consumers because firms can only expect higher incremental utility by expanding the diversity of the idea pool that accompanies higher interaction cost. Proposition 1 also states that as firms become less able to deal with diverse ideas (i.e. higher  $k$ ), firms choose less diverse idea pool to lower the interaction cost. Lastly, the degree of diversity and the number of hires are substitutable because increase in  $d_s$  and  $N$  both increase the expected product quality and the interaction cost. Therefore, firms choose less diverse idea pool as the number of hires increases.

### 1.2.5 Equilibrium analysis

Before investigating the profit functions of firms, the following conditions need to be established:

**Lemma 2:**  $tk \geq \frac{Q+6Rt-2R^2}{18N^2}$  ensures  $d_s^* \in [0, 1]$

*proof:*  $d_s^* = \frac{6Rt}{DN+2R^2} \leq 1 \implies 6Rt \leq DN + 2R^2$

**Claim 1:** Under Lemma 1, Lemma 2 is a stronger condition than the second-order condition..

*proof:* The second order condition can be rewritten as  $tk > \frac{Q}{18N^2}$ . To show that Lemma 2 is a stronger condition, we need to show  $\frac{Q+6Rt-2R^2}{18N^2} > \frac{Q}{18N^2}$  or  $6RT - 2R^2 = 2R(3t - R) > 0$ . This can be easily proven by the fact that  $t > \frac{1}{3}$  (Lemma 1) and the fact that  $0 < R < \frac{1}{2}$ . Q.E.D.

**Proposition 2:** The expected profits of symmetric firms decrease in the intensity of competition (i.e. as  $t$  decreases), but increase in the firm's inability to deal with diverse ideas (i.e. as  $k$  increases).

*proof:* See Appendix

The effect of competition on the expected profits is as expected: both direct effect and strategic effect of higher competition (i.e. lower travel cost  $t$ ) decrease the expected profit because firms gain less market power due to less product differentiation. The effect of a firm's inability to deal with diverse ideas on the expected profit is less intuitive: as the firms' inability to deal with diversity increases (i.e.  $k$  increases), the direct effect decreases the firm's profit, but the strategic effect increases the firm's profit even more and dominates. In other words, firms' inability to deal with diverse ideas acts as a deterrent against firms engaging in higher competition through higher  $d_f$ .

### 1.3 Extension: Asymmetric Firms with Private Info

We now consider an extension to the basic model. We construct a model with nonzero asymmetric marginal costs that are private information. There are two reasons why this extension is useful: first, this model is a more realistic representation of actual markets, taking non-zero asymmetric marginal cost into account. Second, this model lets us test the relationship between the diversity and market concentration ratio, a measure of competition which can be observed and measured. In our basic model,  $t$  measures the intensity of competition in the Hotelling model. Regardless of how we interpret  $t$ , whether as the true travel cost to consumers or the degree of product differentiation, finding the right observable measure for  $t$  can be difficult. On the contrary, market concentration ratios of different industries/sectors are published by the U.S. Census Bureau every five years. This extension is similarly set up as the basic model, except the actual draws of non-zero marginal costs are not known to the competitor, but the distribution of the marginal cost is known to both firms. Assume the marginal costs are uniformly distributed along  $[c_l, c_h]$ , with the mean denoted as  $\mu_c$ ,  $0 < c_l < 1$ , and  $c_h > 1$ . Firms' decision timings are similar to the basic model, except now that their private marginal cost information is drawn in period 0:

- In period 0, marginal costs of firm  $i$  and  $j$ , denoted as  $c_i$  and  $c_j$ , are drawn from the marginal cost distribution and unknown to its competitor (private information).

- In period 1, firms simultaneously choose the degree of diversity of idea pool,  $d_f$ ,  $f \in \{i, j\}$ .
- In period 2, firms simultaneously price the products

### 1.3.1 Period 2

In period 2, firm  $i$  faces the same reduced-form demand function as in the basic model.

$$D_i = x_i = \frac{(s_i - p_i) - (s_j - p_j) + t}{2t} \quad (1.18)$$

Similarly, firm  $j$ 's demand can be found. Unlike the basic model, firm  $i$  does not know what exactly  $p_j$  is without knowing the true marginal cost of firm  $j$ . Therefore, firm  $i$  maximizes its profit based on the expected  $p_j$ , thus expected demand  $E(D_i) = \frac{(s_i - p_i) - (s_j - E(p_j)) + t}{2t}$ :  $\max_{p_i} E\pi_{i3} = (p_i - c_i)E(D_i)$ . Given  $s_i$  and  $s_j$ , the first-order condition for each firm  $f$ ,  $E(D_f) - \frac{p_f - c_f}{2t} = 0$ , yields the following:

$$p_i = \frac{s_i - (s_j - E(p_j)) + t + c_i}{2} \quad (1.19)$$

$$p_j = \frac{s_j - (s_i - E(p_i)) + t + c_j}{2} \quad (1.20)$$

Using these expressions, competitors' expected prices can be calculated:

$$E(p_i) = \frac{s_i - s_j + 3t + 3\mu_c}{3} \quad (1.21)$$

$$E(p_j) = \frac{s_j - s_i + 3t + 3\mu_c}{3} \quad (1.22)$$

Substituting these expected costs into the first-order conditions yields optimal prices in terms of the drawn product qualities of both firms, the intensity of competition, the mean marginal cost, and the firm's own private marginal cost:

$$p_i^* | s_i, s_j = \frac{s_i - s_j + 3t}{3} + \frac{\mu_c + c_i}{2} \quad (1.23)$$

$$p_j^* | s_i, s_j = \frac{s_j - s_i + 3t}{3} + \frac{\mu_c + c_j}{2} \quad (1.24)$$

The first term is the optimal price of the symmetric model where marginal costs are zero. The nonzero marginal costs enter in the second term as an average of its own marginal cost  $c_f$ , which is private information, and the expected marginal cost of its competitor. The optimal price increases as its own marginal cost or the expectation of the competitor's marginal cost rises. The expected demand at these optimal prices is derived from the first order condition:

$$E(D_{ji}(p_i^*)) | s_i, s_j = \frac{1}{2t} \left[ \frac{s_i - s_j + 3t}{3} + \frac{3\mu_c - 3c_i}{6} \right] \quad (1.25)$$

$$E(D_j(p_j^*)) | s_i, s_j = \frac{1}{2t} \left[ \frac{s_j - s_i + 3t}{3} + \frac{3\mu_c - 3c_j}{6} \right] \quad (1.26)$$

The expected profits of firms in period 2 at the equilibrium can therefore be written as the following:

$$E\pi_i(p_i^*) | s_i, s_j = (p_i^* - c_i)E(D_i(p_i^*)) = \frac{1}{2t} \left[ \frac{s_i - s_j + 3t}{3} + \frac{3\mu_c - 3c_i}{6} \right]^2 \quad (1.27)$$

$$E\pi_j(p_j^*) | s_i, s_j = (p_j^* - c_j)E(D_j(p_j^*)) = \frac{1}{2t} \left[ \frac{s_i - s_j + 3t}{3} + \frac{3\mu_c - 3c_i}{6} \right]^2 \quad (1.28)$$

These results correctly predict that firm's profit increases in its competitor's expected marginal cost and decreases in its own marginal cost.

### 1.3.2 Period 1

In period 1, firms determine the optimal levels of diversity of ideas  $d_i$  and  $d_j$ , from which the product quality  $s_f$  is drawn. A larger  $d_f$  gives the firm a better chance at drawing a higher  $s_f$  but comes at a cost with higher interaction cost to search the best out of  $N$  drawn ideas. Firm  $i$  in period 1 then maximizes the following profit function over all possible  $d_i$ :

$$\begin{aligned} E\pi_i &= E[E\pi_i | s_i, s_j - \frac{1}{2}kd_i^2 N^2] \\ &= \frac{1}{2t} E \left[ \frac{s_i - s_j + 3t}{3} + \frac{3\mu_c - 3c_i}{6} \right]^2 - \frac{1}{2}kd_i^2 N^2 \end{aligned} \quad (1.29)$$

Similar, the expression for firm  $j$  can be found. The first order conditions for firm  $i$  and firm  $j$  result in the the optimal  $d$  in terms of the number of hires  $N$ , the intensity of competition  $t$ , and the expected competitor's diversity of its idea pool:

$$d_i^* = \frac{6Rt - 2R^2 E(d_j^*)}{DN} \quad (1.30)$$

$$d_j^* = \frac{6Rt - 2R^2 E(d_i^*)}{DN} \quad (1.31)$$

The marginal costs do not enter this equation because both firms have the same marginal cost distribution, specifically the same mean marginal costs. Note that since a firm does not observe its competitor's actual marginal cost, it can only form an expectation of the competitor's optimal  $d$ . Similar to calculations in period 2, these expressions can be used to calculate the competitor's expected diversity level by taking expectations and solving them simultaneously:

$$E(d_i^*) = E(d_j^*) = \frac{6Rt}{DN + 2R^2} \quad (1.32)$$

By substituting these expressions into the first-order conditions, we find each firm's optimal level of diversity of idea pool in terms of the number of hires, intensity of competition, inability of firm's dealing with diversity, mean marginal cost, and each firm's private information on marginal cost:

$$d_i^* = \frac{6Rt}{DN + 2R^2} + \frac{3R}{DN}(\mu_c - c_i) \quad (1.33)$$

$$d_j^* = \frac{6Rt}{DN + 2R^2} + \frac{3R}{DN}(\mu_c - c_j) \quad (1.34)$$

The first term is the same as the optimal diversity level of symmetric firms. The second term is due to non-zero marginal costs. It shows that the optimal diversity level increases in the competitor's expected marginal cost and decreases in its own marginal cost. Note that the second order condition is the same as in the basic model ( $DN > 0$ ). Without loss of generality, we assume  $c_i = 1$  and  $c_j = \alpha$ ,  $1 < \alpha < c_h$  (i.e. firm  $i$  has cost advantage):

$$d_i^* = \frac{6Rt}{DN + 2R^2} + \frac{3R}{DN}(\mu_c - 1), \quad d_j^* = \frac{6Rt}{DN + 2R^2} + \frac{3R}{DN}(\mu_c - \alpha) \quad (1.35)$$

### 1.3.3 Diversity vs. Concentration Ratio

This asymmetric model allows us to conceptually test the relationship between diversity and market concentration ratio. First define the average diversity of idea pool as the mean of two firms' optimal diversity decisions:

$$d_{Avg}^* = \frac{d_i^* + d_j^*}{2} = \frac{6Rt}{DN + 2R^2} + \frac{3R\mu_c}{DN} - \frac{3R}{2DN}(\alpha + 1) \quad (1.36)$$

In addition, we define the realized revenue of firm  $f$  as  $Rev_f = p_f^* D_f^*$ , where

$$p_i^* = \frac{s_i - s_j + 3t}{3} + \frac{\mu_c + 1}{2} \quad (1.37)$$

$$p_j^* = \frac{s_j - s_i + 3t}{3} + \frac{\mu_c + \alpha}{2} \quad (1.38)$$

$$D_i^* = \frac{s_i - s_j + 3t}{6t} + \frac{\alpha - 1}{4t} \quad (1.39)$$

$$D_j^* = \frac{s_j - s_i + 3t}{6t} + \frac{1 - \alpha}{4t} \quad (1.40)$$

**Lemma 3:**  $t > \frac{3\alpha-1}{6}$  guarantees  $p_f^*$ ,  $D_f^*$  to be strictly positive for all values of  $s_f \in [0, 1]$ .

*proof:* For strictly positive prices and demands, we need  $D_j^* > 0$ , or  $\frac{-1+3t}{6t} + \frac{1-\alpha}{4t} > 0$  because  $s \in [0, 1]$ . Rearranging term, we find  $t > \frac{3\alpha-1}{6}$ . Q.E.D.

**Proposition 3:** As the asymmetry in marginal costs increases (i.e.  $\alpha$  increases), the average diversity of idea pool decreases (i.e.  $d_{Avg}^*$  decreases), whereas the market concentration ratio, defined as  $\frac{Rev_i}{Rev_i+Rev_j}$ , increases.

*proof:*

First,  $\frac{d}{d\alpha}d_{Avg}^* = -\frac{3R}{2DN} < 0$ . Now, we need to show  $sgn\left[\frac{d}{d\alpha}\frac{Rev_i}{Rev_i+Rev_j}\right] > 0$ . Note that

$$\frac{d}{d\alpha}Rev_i = \frac{d}{d\alpha}Rev_i \frac{d}{d\alpha}p_i^*D_i^* = \frac{p_i^*}{4t}, \quad \frac{d}{d\alpha}Rev_j = \frac{d}{d\alpha}p_j^*D_j^* = \frac{1}{2}\left[D_j^* - \frac{p_j^*}{2t}\right].$$

$$\begin{aligned} sgn\left[\frac{d}{d\alpha}\frac{Rev_i}{Rev_i+Rev_j}\right] &= sgn\left[\frac{dRev_i}{d\alpha}Rev_j - Rev_i\frac{dRev_j}{d\alpha}\right] & (1.41) \\ &= sgn\left[\frac{p_i^*}{2}\left(\frac{p_j^*}{2t} - D_i^*D_j^*\right)\right] \\ &= sgn\left(\frac{p_j^*}{2t} - D_i^*D_j^*\right) \\ &= sgn\left[M + \left(\frac{s_i - s_j}{6t}\right)^2 + \left(\frac{\alpha - 1}{4t}\right)^2\right] \end{aligned}$$

where  $M \equiv \frac{(s_i - s_j)(\alpha - 1 - 2t) + 3t(\alpha + \mu_c) + 3t^2}{12t^2}$ . It can be easily shown that the first term is positive:

$$\begin{aligned} \frac{(s_i - s_j)(\alpha - 1 - 2t) + 3t(\alpha + \mu_c) + 3t^2}{12t^2} &\geq \frac{-(\alpha - 1 - 2t) + 3t(\alpha + \mu_c) + 3t^2}{12t^2} \\ &> \frac{\frac{2}{3} + 3t(\alpha + \mu_c) + 3t^2}{12t^2} > 0 \end{aligned}$$

where the first inequality is established by the fact that  $0 \leq s_i, s_j \leq 1$ , and the second equality by Lemma 3. Since the last two squared terms are non-negative,  $sgn\left[\frac{d}{d\alpha}\frac{Rev_i}{Rev_i+Rev_j}\right] > 0$ . Q.E.D

## 1.4 Empirical Test

In this section we empirically test the predicted negative relationship between the diversity of idea pool (or diversity of workforce in data) and the concentration ratio in Proposition 3. We collected two separate data sets for the two measures: the 1996-1997 National Organizations Survey (NOS), which contains information on diversity of workforce of 1002 U.S. organizations, and the 1997 Economics Census by the U.S. Census Bureau, which has concentration ratios across industries and sectors.

### 1.4.1 Data

The NOS data was collected through stratified sampling out of roughly 15 million workplaces from Dun and Bradstreet's Information Services data file. This survey has



information on types of organization (e.g. for-profit/nonprofit), the industry identified by Standard Industrial Classification (SIC), the size of the organization (e.g. number of total employees, sales revenue), the diversity of workforce in terms of the percentages of white workers and female workers, the existence of a separate department (or a person) responsible for equal employment opportunity or affirmative action matters, ownership structure of the firm, and market positioning (e.g. geographical footprint, consumer base, etc).

1997 Economic Census was conducted by the U.S. Census Bureau and contains information on the total revenues, the number of companies, and the concentration ratio in terms of the revenue percentage of the top 4, 8, 20, and 50 firms at industry/sector level. We use top 50 firms concentration ratio as a measure of competition in this test. Unlike NOS, Economic Census uses North America Industry Classification System (NAICS) instead of SIC. NAICS is a new industry code standard initiated in 1997 to include (exclude) new (obsolete) industries across North America. The U.S. Census Bureau published a matching table between the two standards, but it is not a global one-to-one matching. We tried to map the two standards as accurately as possible using the Census Bureau’s matching table as a guide.

NOS has 1002 observations. Removing non-profit organizations, observations with missing data (e.g. no percentage of white/female workers, no industry concentration ratio, etc), and companies with less than 100 employees left us with 122 observations for analysis. There are 25 Industries/sectors represented in this data: Accommodation; Chemicals and allied products; Electrical and electronic equipment; Fabricated metal products; Finance & insurance; Food services & drinking places; Furniture and fixtures; Industrial machinery and equipment; Leather and leather products; Lumber and wood products; Museums, historical sites, & similar institutions; Office administrative services; Petroleum and coal products; Primary metal industries; Professional, scientific, & technical services; Real estate; Repair & maintenance; Retail trade; Rubber and miscellaneous plastics products; Social assistance; Stone, clay, glass, and concrete products; Tobacco manufacturers; Transportation & warehousing; Transportation equipment; and Wholesale trade. For industries that are both taxable/non-taxable (e.g museums, historical sites, social assistance, etc), we only used the data for taxable industries.

## 1.4.2 Statistical Models

To test the relationship between the diversity and the concentration ratio, we specify statistical models. The first one is an OLS regression of diversity of firm  $i$ ’s workforce on its industry’s concentration ratio:

$$diversity_i = \beta_0 + \beta_1 top50_j + \epsilon_i \quad (1.42)$$

The dependent variable  $diversity_i$  measures diversity of workforce of company  $i$ , combining the percentage of white workers (racial diversity) and the percentage of female workers (e.g. the gender diversity) using the following formula:  $diversity_i = \%white(100 -$

$\%white) + \%female(100 - \%female)$ . A firm with 50% white workers and 50% female workers will have the highest diversity measure.  $top50_j$  is the top 50 firms concentration ratio of industry  $j$  that firm  $i$  belongs to. The top 50 concentration ratio measures the percentage of the top 50 firms' combined revenue to the entire industry's revenue. Under this specification, we do not assume that the error term  $\epsilon_i$  has a constant variance and is uncorrelated across observations. Since we have 122 observed firms in 25 industries, some of the firms in the data belong to the same industry sharing the same concentration ratio, which may cause errors to be correlated. To address this concern, we correct the standard error through clustering by industry, allowing correlation of error within industry but assuming independence across industries.

The second specification takes firm-specific characteristics into account:

$$\begin{aligned} diversity_i = & \beta_0 + \beta_1 top50_j + \beta_2 totalFT_i + \beta_3 k\_dept_i \\ & + \beta_4 k\_person_i + \beta_5 geoarea_i + \epsilon_i \end{aligned} \quad (1.43)$$

Firm-specific characteristics include the total number of full-time employees at firm  $i$ ,  $totalFT_i$ ; existence of a separate department responsible for equal employment opportunity or affirmative action matters at firm  $i$ ,  $k\_dept_i$ ; existence of a person whose job duties include responsibility for equal employment opportunity or affirmative action matters at firm  $i$ ,  $k\_person_i$ ; and the main geographic market/service area of the firm,  $geoarea_i$ .  $k\_dept$  and  $k\_person$  are binary variable: they take 1 if such department or person exists at the firm, and 0 otherwise.  $geoarea_i$  can take values between 0 and 5, where larger value means larger geographical presence of firm  $i$ . For instance, 0 means that the firm operates in a city, 4 means covering the entire U.S., and 5 means serving beyond the U.S. We exploit the same clustering by industry to address the possibility of correlation among firms within an industry.

The last specification controls for industry characteristics:

$$\begin{aligned} diversity_i = & \beta_0 + \beta_1 top50_j + \beta_2 totalFT_i + \beta_3 k\_dept_i \\ & + \beta_4 k\_person_i + \beta_5 geoarea_i + \beta_6 indrev_j + \beta_7 numloc_j + \epsilon_i \end{aligned} \quad (1.44)$$

Industry-specific characteristics are the total revenue of industry  $j$  (in billion \$),  $indrev_j$ , and the total number of establishments (physical locations) of industry  $j$ ,  $numloc_j$ . The standard errors were again corrected through clustering by industry.

### 1.4.3 Results

Table 1.2 summarizes the regression results with p-values in  $< >$ :

The result of the first specification without any controls shows a negative relationship between the diversity and the top 50 firms concentration ratio at 95% confidence level. In other words, less competition (i.e. high top 50 concentration ratio) is associated with less workforce diversity. This result holds after adding firm-specific characteristics and

	No Controls	Firm-specific Controls	Firm- and Industry-specific Controls
<i>const</i>	3806.0 <0.0>	3735.9 <0.0>	3614.5 <0.0>
<i>top50</i>	-10.6* <0.022>	-11.2* <0.014>	-11.6* <0.033>
<i>totalFT</i>	-	0.037 <0.424>	0.030 <0.489>
<i>k_dept</i>	-	-463.8 <0.073>	-424.8 <0.102>
<i>k_person</i>	-	-369.9 <0.266>	-401.6 <0.237>
<i>geoarea</i>	-	115.1* <0.030>	127.1* <0.015>
<i>indrev</i>	-	-	0.239* <0.001>
<i>numloc</i>	-	-	-3E-4 <0.247>
$R^2$	0.036	0.085	0.113

Table 1.2: Regression results

industry characteristics. We also observe a significant positive relationship between the diversity and the geographic areas that the firm serves. This seems plausible since a more diverse workforce pool is expected as a firm hires from the world rather than from a city.

#### 1.4.4 Limitations

There are several limitations in this empirical test. First, we suspect that *k\_dept*, *k\_persons* may be endogenous variables. A firm may have a department or person that is responsible for equal employment opportunities or affirmative action matters because its workforce is already diverse. To address this issue, we need instrument variables. One possibility is to find differences in labor laws concerning affirmative action in different states where the companies are headquartered and use them as instrument variables.

The asymmetric model predicts that, as the degree of marginal cost asymmetry varies across industries, there is a negative relationship between the diversity of workforce and the concentration ratios. In order to test such industry-level predictions, we need industry-level data on both diversity and concentration ratio or a rich firm-level data that can be collapsed to industry-level. Our data, however, leaves us only 122 firm-level observations in 25 industries. Since firms are not representative of the industries, collapsing the data to industry-level with this small number of firms per industry seems unreasonable. Instead of testing our theoretical predictions directly at the industry level, we allowed correlation of errors within the industry and assumed independence across industries. Finding a different data set with industry-level diversity will enable us to test our theory more directly.

The Herfindahl index may characterize the intensity of competition more accurately than the top 50 firms concentration ratio used throughout this paper. Although the Herfindahl index can easily be adopted in our model, we stayed away from it because

the index is not available for the majority of firms in our data. The Herfindahl index is published only for manufacturing companies by the U.S. Census Bureau; out of our 122 observations, only 46 observations are manufacturing companies. However, the correlation between the top 50 firms concentration ratio and the Herfindahl index among the manufacturing companies was 0.85, which implies that we may expect similar results using Herfindahl index had more data been available.

Lastly, our measure of diverse workforce only has racial and gender diversity information. We can conjecture other dimensions that generate diverse, creative ideas such as functional diversity (e.g. sales, marketing, R&D, etc.) and different education background (e.g. business, economics, arts, science, engineering, etc). One possibility is to collect data on the functional diversity and education background of board members of large corporations in addition to racial and gender diversity and construct a diversity measure that accommodates more dimensions of diversity.

## 1.5 Conclusion and Possible Extensions

Previous research efforts show that hiring a diverse workforce has both positive and negative effects on team performance: diverse workforce brings more diverse, creative ideas to the problem but creates friction among team members. Because the degree of workforce diversity has an effect on firm's performance, firms strategically choose its workforce diversity. Firms have more incentives to be strategic about workforce diversity decision as competition stiffens. To understand firm's decision on workforce diversity in regards to the level of market competition, we construct a simple two-period model. In our model, symmetric firms decide on the level of workforce diversity, followed by pricing decisions in a horizontally differentiated market. Our model predicts that firms choose higher diversity as the competition becomes more intense, as the firms' inability to deal with diverse workforce decreases, and as the number of hires decreases. We also show how a firm's profit changes as market parameters change: firm's profit increases as competition decreases as expected. On the contrary, firm's profit increases as the firm's inability to deal with diversity increases because the inability acts as a deterrent against competition, softens competition between firms, and improves profitability.

We extend the symmetric model by incorporating asymmetric marginal costs that are private information. A comparative static shows that as the asymmetry of the marginal costs increases, the average diversity of two firms decreases, whereas the market concentration ratio of the top firm increases. We empirically test this predicted negative relationship between the diversity and the concentration ratio using two data sets from 1997. We specified statistical models of OLS regression with clustered errors, controlled for firms' characteristics and industry-specific characteristics, and confirmed the negative relationship between the level of workforce diversity, in terms of race and gender, and top 50 firms concentration ratios at 95% confident level.

Our current model can be extended in several ways: firms may have asymmetric in-

abilities to deal with diverse workforce ( $k_i \neq k_j$ ) or asymmetric base utilities ( $\eta_i \neq \eta_j$ ). Asymmetric  $k$  captures that firms have different inherent cost functions when it comes to managing diverse workforce. Asymmetric base utilities reflect firm-specific utilities consumers get, such as brand loyalty. Both extensions can provide insights into how different asymmetries affect a firm's decision on diversity and profit. It would also be interesting to incorporate the diversity decision into Salop's entry model to see how diversity affects firms' entry decisions, and vice versa.

## Chapter 2

### When Franchisee Effort Affects Demand:

### An Application to the Car Radiator Market

## 2.1 Introduction

Companies have long acknowledged that consumers respond not only to the price and characteristics of a product, but also to the service effort that the seller provides.<sup>1</sup> The chief financial officer of Home Depot, whose first of 8 company core values states excellent customer service, remarked that “with knowledgeable (sales) associates, customers buy more,”<sup>2</sup> underscoring effort as a determinant of the market outcome. In the media industry, DirecTV’s high customer retention rate was attributed to superior customer service provided by its more than 15,000 call center agents and installation technicians across the country.<sup>3</sup> Companies that recognize the importance of service allocate significant resources to improve the quality of service. For instance, General Motors recently offered up to \$1.5 million to selected dealerships in California to enhance customer service by moving dealer locations, refurbishing dealer facilities, and developing a workshop with Disneyland to train its employees.<sup>4</sup>

Not surprisingly, there is an abundant academic literature regarding a firm’s service effort. See Rust and Chung (2006) for an extensive review of papers in marketing literature that investigates strategies in managing and customizing a firm’s service and the role of customer satisfaction in customer relationship and in a firm’s profitability. While these studies present a useful conceptual framework of a firm’s service effort and consumers’ perception of it, there have not been many rigorous empirical studies of effort that detail customer benefit from the effort and a firm’s incentive for and cost of exerting it. This is mainly because it is difficult to precisely measure effort as it is intangible and unobservable to researchers. Nonetheless, it is important to quantify the level of effort because service is not only observed by consumers, but also taken into account when consumers make purchasing decisions. An empirical model that recovers the unobservable effort level of a firm’s sales channel (e.g., employees, sales agents, retail partners, franchisees, etc.) can open doors to studies regarding the effectiveness of marketing initiatives, of incentive schemes, and the role of public policy.

This paper presents an empirical framework that defines and micro-models the role of service effort in consumer demand and in a firm’s profit. The proposed framework allows us to recover the unobserved effort level without any data on it, which is hardly available in most empirical settings. The model developed in this study does not exclude or contradict demand models used in the literature. Rather, it accommodates the demand model of

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<sup>1</sup>Studies that focus on consumers’ perception and expectation of service tend to use the term “service” or “service quality.” The term “effort” is generally used by the studies that emphasize incentives of the sales channels or the firm’s profitability. In this paper, service, effort, and service effort are considered to be the same construct and are used interchangeably.

<sup>2</sup>Merrick, Amy. “Good Service Gone Bad: What makes one consumer happy may annoy another; It’s easy for companies to cross that fine line.” *Wall Street Journal*. (Eastern edition). Oct 30, 2006. pg. R.4

<sup>3</sup>Neel, K.C. “Putting the Customer First; Service Focus Key Element in DirecTV’s Success.” *Multi-channel News*. (Special Report). Aug. 24, 2009. pg. 24.

<sup>4</sup>Hirsch, Jerry. “Chevrolet staffs to learn Disneyland-style customer service,” *Los Angeles Times*. Oct. 17, 2011.

differentiated goods so that the effect of price, product characteristics, and consumer heterogeneity can be studied in conjunction with the impact of service effort on demand. Once the model is specified, the paper demonstrates how the developed model can be applied to real-world data in franchising. I obtained unique field data from a franchise network in the car radiator market, which includes information on sales, consumers, and vertical arrangement (ownership structure and royalty rates). Using this data, I estimate the econometric model and recover the unobservable effort level given assumptions. The recovered effort is then checked for validity against field evidence.

This framework can be useful in examining various questions faced by service-intensive industries. In particular, this study investigates a much-debated public policy question in franchising industry. Resale price ceiling (or maximum resale price) is a practice in which the upstream firm (e.g. manufacturer, distributor, franchisor) prohibits the downstream firm (e.g., reseller, retailer, franchisees) from selling its product or service above a set price determined by the upstream firm. It had been illegal in the U.S. until the Supreme Court overturned its decision in 1997 after 30 years on the basis of benefit to the consumer. The policy evaluation using a counterfactual based on the estimation results shows that imposing a resale price ceiling (e.g., 5% below the current price on all product lines) lowers the franchisee's incentive to exert effort, thus reducing consumer welfare. However, I find that overall, the resale price ceiling is consumer welfare enhancing due to welfare gain from the lower price generated by the price ceiling.

The role of service effort in a firm's decision and in demand has been discussed extensively in the literature of distribution channel coordination. In the stylized model of the distribution channel with successive firms, the downstream firm is an independent business that determines price and the level of service effort (Tirole 1995, pg. 177-178). In marketing literature, Iyer (1988) investigates channel coordination in a setting where retailers compete with a mix of price and service. Raju and Zhang (2005) also incorporates "demand-stimulating" service in the study of the dominant retailer. In franchising literature, the franchisee's effort gained academic interests. Mathewson and Winter (1985) notes that decisions by the downstream firm, especially service effort, can be contracted, but monitoring and enforcing them costs too much, which partly explains the existence of franchise contracts. Lal (1990) finds that when both the franchisor's and the franchisee's effort affect demand, royalty is needed with monitoring on franchisees. Desai and Srinivasan (1995) investigates the relationship between the (un)observability of franchisees' effort and price contracts.

Studies on sales-force also have explicitly modeled effort. Hauser et al. (1994) studies customer satisfaction incentive schemes and develops an analytical model of effort provided by the firm's risk-averse employees. Misra and Nair (2011) and Chung et al. (2011) investigate sales-force compensation schemes and their impact on the sale agent's level of effort implied by the inter-temporal nature of the compensation schemes and sales data. These two empirical studies address the agency problem in sales-force contracts and examine implications of different contracts. The focus of this paper does not lay on labor contracts. This paper presents a demand model of effort along with other marketing



mix variables by taking advantage of detailed franchise sales data that includes pricing information.

The remainder of this paper is organized as follows. First, the industry being studied is described in Section 2.2. Then, the econometric model with consumer utility, firm's effort, and profit function is specified in Section 2.3. Details on the data used for estimation are discussed in Section 2.4, followed by estimation strategy, identification of effort, and endogeneity issues in Section 2.5. Estimation results and validity checks on the recovered effort are presented in Section 2.6. Finally, Section 2.7 shows the results of a policy evaluation regarding resale price ceiling in franchising before concluding the paper.

## 2.2 Industry Description

In the auto repair industry, service centers - repair shops, body shops, dealerships, etc. - rarely carry much inventory since there are millions of different parts to repair a variety of auto makes/models/years/editions. These service centers rely instead on special distributors for parts delivery when the need arises (e.g., a vehicle owner brings in his/her car for repair). Distribution for car radiators is no exception. A car radiator is a heat exchanger that helps dissipate heat from the engine. It comes in different sizes, materials, fit, or other specifications, making it impractical for service centers to carry a large amount of inventory. For instance, different generations of the same make/model may have different radiators installed. I obtained data on car radiator sales from a car radiator distributor that operates in all major North American markets.<sup>5</sup> A typical order process in this radiator market is as follows: when a service center needs a new radiator (usually one at a time), it calls this company (and potentially competitors), obtains a quote on the price and a delivery time, and makes a purchase decision. This company carries some 2,200 product lines, with the top 71 product lines accounting for 50% of the total quantity sold. Each product line fits a particular set of car make, model, year, and edition. For instance, a radiator for a 1998 Honda CR-V will not fit a Mercedes. In other words, each product line is considered to be a separate market since products across product lines are not compatible.

The studied company has been around for 25 years, and in 2005 it switched from owning all the warehouses to franchising most of them. Now it has more than 200 territories (15 franchisor-owned territories and the rest operated by more than 170 franchisees) with \$120 million in revenue.<sup>6</sup> Each franchisor-owned or franchisee business operates in an exclusive territory defined by a cluster of zip codes that typically includes 750,000 to 1.5

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<sup>5</sup>There are two types of radiator orders: repair and collision. Collision orders are done through an auto insurance claim and require a distributor to go through a bidding process to be a qualified distributor, which is not included in my data here. This paper focuses on repair business in which the distributor deals directly with service centers, where effort or service level matters the most.

<sup>6</sup>The radiator business accounts for 55% of the company's revenue. Other heating and cooling auto parts such as air conditioning parts account for the rest.

million people with an average of 2,000 potential customers (i.e., service centers and auto part shops). Franchisor-owned locations are operated by professional managers and sales agents, whose performances are tightly monitored and rewarded through various compensation schemes. These locations are considered “transitory,” meaning the franchisor wants to re-franchise them to new owners after transforming the business. Franchisee-owned outlets are independent, residual-claimant businesses that are required to transfer a certain amount of money back to the franchisor to stay as a part of the franchise network. A typical franchise contract entails a fixed fee to join the franchise and a periodic royalty payment to the franchisor based on a predetermined percentage of the revenue with a long-term contract duration. This distributor does not require a membership fee, but charges its franchisees a royalty of 6-10% of gross revenue.<sup>7</sup> The company’s standard franchise agreement has an initial term of 20 years with a renewal option. By joining the franchise, franchisees gain access to the company’s Customer Relationship Management (CRM) software, where they can purchase inventory from approved suppliers at the prices that the franchisor negotiated with manufacturers or suppliers through a bidding system. A typical franchise outlet is located in an industrial park with a small office attached to a warehouse. A location with \$1 million annual revenue typically hires 3-4 employees to answer phone calls and deliver radiators to customers. In addition to setting the price of radiators, the franchisee owner(s) puts effort into building customer relationship, promoting business, and providing services to customers. The franchisor views franchisees’ efforts in attracting new customers and providing various customer services as a critical business proposition in this industry. For instance, franchisees are expected to call or visit new/current customers in the territory to determine their needs and to let them know of new promotions or services. The franchisor provides guidelines and training programs to ensure that franchisees maintain a high level of customer service. For example, the franchisor recommends that franchisees keep a certain hours of operation and policies on part returns for misfit/failure, such as lifetime warranty and paying back labor hours for re-installation. Interviews with the franchisor and some franchisees revealed that all the details of effort or service are not enforceable; it is often up to the individual franchisee to decide how much effort to exert or to follow the franchisor’s guideline for customer service. In this study, I include this unobservable, endogenous effort in the model.

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<sup>7</sup>Although there is no fixed fee to join, becoming a franchisee requires an initial investment, such as setting up the office and purchasing initial inventory of more than \$150,000. The royalty rate for a new franchisee increases over time. The current royalty rate is 10% on gross revenue with 20% (i.e., 2% of gross revenue) reinvested in local/national marketing. Interviews with franchisees show that they do not perceive the 2% any differently than the rest of the royalty payment.

## 2.3 Model

### 2.3.1 Illustrative Example

Before describing the full econometric model, I first start this section with a very simple model illustrating how service effort can be incorporated into demand and firm's profit. Suppose a monopoly firm selling a single product to consumers in a single-period market with linear demand that strictly decreases in price ( $p$ ) and increases in service effort ( $e$ ):  $D(p, e) = 1 - p + e$ . The firm then maximizes the following profit function over price and effort:  $\pi(p, e) = [p - c]D(p, e) - \frac{\lambda}{2}e^2$ . The first term is profit from selling the product with a constant marginal cost  $c$ , and the last term is the cost of exerting effort in a convex function with a parameter  $\lambda$ . Note that from the first-order conditions, the optimal level effort is expressed as  $e^* = \frac{p^* - c}{\lambda}$ . The equation implies that the optimal effort increases in the margin and decreases as putting effort becomes more costly. The model developed in this paper will preserve this intuition, which will be revisited in Section 2.3.3. Now I present the full econometric model of this paper by first specifying consumer utility.

### 2.3.2 The Demand Side

Consider a franchise with  $F$  franchise businesses (franchisor-owned or franchisees), each with its own mutually-exclusive territory. Franchise business  $f$  offers  $H$  product lines that are not compatible (i.e., non-competing) and are considered as separate markets. For each product line, consumer  $i$  either buys one from this franchise business or chooses the outside option.<sup>8</sup> Then consumer  $i$  gets the following utility if she buys a product of the product line  $h$  from franchise business  $f$  in time  $t$ . Otherwise she gets normalized mean zero utility:

$$u_{ihft} = \sum_k x_{hkft} \tilde{\beta}_{ik} + e_{ft} + \xi_{hft} + \epsilon_{ihft} \quad (2.1)$$

where  $\tilde{\beta}_{ik} = \bar{\beta}_k + \sum_q a_{iq} \beta_{kq}^o + v_{ik} \beta_k^u$ . First,  $a_{iq}$  denotes consumer  $i$ 's  $q$ -th observed attribute, and  $v_{ik}$  represents unobserved attribute. The term  $x_{hkft}$  is product line  $h$ 's  $k$ -th observed product characteristic. The common demand shock,  $\xi_{hft}$ , is observed by consumers, but not observed by the econometrician. The  $e_{ft}$  term captures the level of effort that franchise business  $f$  provides in time  $t$ . Effort is observed by consumers and incorporated into their decision making, but not by the econometrician. One can consider substituting proxies for this unobservable variable in the analysis, but they can only capture a fraction of the

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<sup>8</sup> The outside option for the consumer is typically either buying from a competing firm or not buying at all. Note that a car cannot be driven without a radiator; hence, not buying means disposing of the car in this industry. It is reasonable to think that the probability of disposing of a car, which is typically worth thousands of dollars, may not significantly change in response to change in radiator prices, whose average is around \$100. In that case, outside option can be thought of as buying from a competitor.

total effort exerted by definition. This paper addresses the lack of observability of effort by directly modeling it in the consumer utility and in the profit function as described below. The literature often refers to this effort as service quality, promotional effort, sales effort, managerial activities, and/or local advertising. Here I broadly define effort as a franchise business's endogenous input that increases consumer utility and effectively shifts demand curve upward. I assume that the franchise business's effort adds to consumer utility uniformly across consumers (i.e.,  $e_{ft}$  is per-consumer effort). The effort is also assumed to be uniform across product lines based on interviews with the franchisor and franchisees that firm's effort, such as customer interaction, local ads, or warranty service, is not product line specific.<sup>9</sup> Finally,  $\epsilon_{ihft}$  is an idiosyncratic random term. The consumer utility can be re-written as the following:

$$u_{ihft} = \psi_{hft} + \mu_{ihft} + \epsilon_{ihft} \quad (2.2)$$

$$\psi_{hft} \equiv \psi_{hft}(X, e, \xi, \bar{\beta}) = \sum_k x_{hkft} \bar{\beta}_k + e_{ft} + \xi_{hft} \quad (2.3)$$

$$\mu_{ihft} \equiv \mu_{ihft}(X, a_i, v_i, \beta^o, \beta^u) = \sum_k \sum_q x_{hkft} a_{iq} \beta_{kq}^o + \sum_k x_{hkft} v_{ik} \beta_k^u \quad (2.4)$$

The term  $\psi_{hft}$  is the mean utility that is common across individuals, and  $\mu_{ihft}$  accounts for consumer heterogeneity in preference towards different product characteristics. Assuming  $\epsilon_{ihft}$  is independently and identically distributed Type 1 extreme value, the probability of consumer  $i$  purchasing product line  $h$  from franchise business  $f$  in time  $t$  is given by the following expression:

$$f_{ihft}(\psi_{hft}, X, a_i, v_i, \beta^o, \beta^u) \equiv \frac{\exp(\psi_{hft} + \mu_{ihft})}{1 + \exp(\psi_{hft} + \mu_{ihft})} \quad (2.5)$$

The predicted market share is then calculated by integrating it over all consumers:

$$s_{hft}(\psi_{hft}, X, a, v, \beta^o, \beta^u) = \int \frac{\exp(\psi_{hft} + \mu_{ihft}(a_i, v_i))}{1 + \exp(\psi_{hft} + \mu_{ihft}(a_i, v_i))} P(da, dv) \quad (2.6)$$

### 2.3.3 The Supply Side

Franchise business  $f$  chooses price and effort level in time  $t$  to maximize the profit:

$$\begin{aligned} \max_{p_{ft}, e_{ft}} \pi_{ft}(p, e; c, s, M, r, \theta) &= \sum_{h=1}^H [p_{hft}(1 - r_f) - c_{hft}] M_{hft} s_{hft}(\psi_{hft}, X, a, v, \beta^o, \beta^u) \\ &\quad - \frac{\lambda}{2} M_{ft} e_{ft}^2 \end{aligned} \quad (2.7)$$

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<sup>9</sup>The model can easily be modified to accommodate effort at the product line level by making changes to consumer utility and profit function.

where  $p_{hft}$ ,  $c_{hft}$ ,  $s_{hft}(\cdot)$ , and  $M_{hft}$  are price, marginal cost, market share, and total market potential of product line  $h$  at franchise business  $f$  in time  $t$ , respectively. The term  $r_f$  denotes the franchise royalty rate at franchise business  $f$ : it is zero for franchisor-owned establishments and 6-10% for franchisees in the data. The  $p$ ,  $c$ ,  $s$ ,  $M$ ,  $r$  denote the vector representation of the aforementioned terms. The vector  $\theta$  is a set of the parameters to be estimated. Note that the first term is the sum of monetary profit from selling  $M_{hft}s_{hft}(\cdot)$  units of product  $h$  at a margin of  $p_{hft}(1 - r_f) - c_{hft}$  at business  $f$  in time  $t$ . The last term represents the cost of effort with a coefficient of  $\lambda > 0$ . Recall that effort exerted by the franchise business,  $e_{ft}$ , is defined at per-consumer level. The total effort is calculated by multiplying the total market potential, i.e., the total number of consumers, at franchise business  $f$  in time  $t$ ,  $M_{ft} \equiv \sum_{h=1}^H M_{hft}$ , by the quadratic function of per-consumer effort.<sup>10</sup> The first-order conditions with respect to price and effort at  $f$  in time  $t$  are given by the following:

$$(1 - r_f)s_{hft} + [p_{hft}(1 - r_f) - c_{hft}] \frac{\partial s_{hft}}{\partial p_{hft}} = 0 \quad \forall h = 1, \dots, H \quad (2.8)$$

$$\sum_{h=1}^H [p_{hft}(1 - r_f) - c_{hft}] M_{hft} \frac{\partial s_{hft}}{\partial e_{ft}} - \lambda M_{ft} e_{ft} = 0 \quad (2.9)$$

From Equation (2.8), the expression for the optimal price is given by  $p_{hft}^* = \frac{c_{hft}}{1 - r_f} - \frac{s_{hft}}{\partial s_{hft} / \partial p_{hft}}$ . The intuition is straightforward: the optimal price is higher when the marginal cost is higher and/or the magnitude of price sensitivity ( $\partial s_{hft} / \partial p_{hft}$ ) is smaller (i.e., demand is less elastic). The royalty rate,  $0 < r < 1$ , effectively creates a double marginalization problem by raising the transfer price to franchisees by  $\frac{1}{1 - r_f}$ . Thus the optimal price is expected to be higher when the royalty rate is higher, which is consistent with other findings.<sup>11</sup> In the following section, this correlational relationship is statistically tested and confirmed.

From Equation (2.9), the optimal effort can be expressed as

$$e_{ft}^*(\cdot) = \frac{1}{\lambda} \sum_{h=1}^H \left\{ [p_{hft}(1 - r_f) - c_{hft}] \frac{\partial s_{hft}}{\partial e_{ft}} \right\} \frac{M_{hft}}{M_{ft}} \quad (2.10)$$

First, more effort is exerted when the cost of effort  $\lambda$  is lower. The rest of the right hand side of the equation can be considered as the weighted sum of  $[p_{hft}(1 - r_f) - c_{hft}] \frac{\partial s_{hft}}{\partial e_{ft}}$  across all product lines with the weight being the relative size of the market potential of

<sup>10</sup>The total cost of effort is assumed to be linear in the market potential size because franchise businesses hire more sales agents as the total market size grows. It also produces the level of effort that is very close to what the executives know and expect of franchisees. Other forms of cost functions, such as  $M_{ft}^2 e_{ft}^2$ , that assume much higher cost of effort for larger franchise businesses (i.e., larger  $M_{ft}$ ) did not align with what the executives knew about their franchisees. For instance, the effort of the better and larger franchisees was measured to be very low mainly due to their large market potentials.

<sup>11</sup> Blair and Lafontaine (1999), Schmidt (1994).

the product line,  $\frac{M_{hft}}{M_{ft}}$ . The intuition is clear: the franchise business exerts more effort when the margin,  $p_{hft}(1 - r_f) - c_{hft}$ , is larger and/or the marginal effect of effort on demand,  $\frac{\partial s_{hft}}{\partial e_{ft}}$ , is larger. Combining Equations (2.8) and (2.9), the optimal effort can be written as

$$e_{ft}^*(p, c, r, M; \psi, \beta^o, \beta^u, \lambda) = -\frac{1 - r_f}{\lambda} \sum_{h=1}^H s_{hft} \frac{\partial s_{hft} / \partial e_{ft}}{\partial s_{hft} / \partial p_{hft}} \frac{M_{hft}}{M_{ft}} \quad (2.11)$$

Unlike the effort expression in Equation (2.10), this expression is written in terms of observed/simulated variables. The royalty rate and market potentials are observed. Market shares and the derivative terms can be obtained through simulation. Hence effort can be recovered once the cost coefficient  $\lambda$  is estimated.

## 2.4 Data

This paper uses a unique set of data from a franchise network that contains information on demand, such as price, quantity sold and observed consumer attributes.<sup>12</sup> In addition, it has information on the vertical arrangement of each establishment (e.g., franchisor-owned or franchisees, royalty rates for franchisees) and proxies for effort, which will be discussed and used in validating recovered effort in Section 2.6.3. First, I use two sets of proprietary data - customer lookup (i.e., product inquiry) history and sales transaction data - to obtain two product characteristics, price and the probability of same-day delivery. These data sets include information on the top 71 product lines<sup>13</sup> (50% of total quantity sold) in repair business at the top 15 establishment in the U.S. (1 franchisor-owned, 14 franchisees)<sup>14</sup> between January 2009 and August 2011, aggregated to monthly levels. The customer lookup history records customers' product inquiries with customer ID, part number, and dates. It also contains inventory availability information for same-day delivery at the time of the lookup. If a radiator is available at the local franchise business warehouse, it can be delivered within a few hours, which consumers highly value. Otherwise it takes more than a day to ship it from the manufacturer, another supplier, or other franchisees. The probability of same-day delivery of a radiator is calculated by averaging this local warehouse availability of each part in each month. If the lookup is

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<sup>12</sup>The company provided data confidentially to the author. Neither the author nor UC Berkeley received financial aid from the company.

<sup>13</sup>Recall that each product line fits a particular set of car make, model, year, and edition.

<sup>14</sup>Top 15 franchise businesses are chosen for the highest total quantities sold in large markets (with at least 1,800 customers). A franchise business may own more than one exclusive territory. For instance, the franchisor runs 15 exclusive territories. Franchisees used in this study are located across the U.S.: Arlington, TX; Phoenix, AZ; Smyrna, GA; Austin, TX; Orange, CA; Kansas city, KS; Dallas, TX; Pomona, CA; Baltimore, MD; Omaha, NB; Houston, TX; Portland, OR; Winston Salem, NC; White Oak, TX; and Brookfield, WI.

converted to a sale, then the sales transaction data keeps track of cost of goods and the final sales price of the sold radiator.<sup>15</sup>

The company also provided a complete list of potential customers (including those who never made any purchase), compiled and updated over the past decade. This list provides the joint distribution of observed consumer characteristics in each franchise  $f$ , such as consumer's type of business (repair shop, dealership, auto part shop, or others) and zip code, which I match to 2000 U.S. Census median household income.<sup>16</sup> Note that the income level is the attribute of the final consumers, i.e., customers of the service centers. It is assumed that the service center's price sensitivity is correlated with the income level of its customers. This list is utilized to account for consumer heterogeneity in preference towards price. In Equation (2.4), the first term captures the observed consumer attributes  $a$  from the list and the last the unobserved attribute  $v$ . The distribution of the unobserved consumer attribute  $v$  is assumed to be standard lognormal in each franchise business. Then random draws  $(a, v)$  are taken in each franchise business for simulating the market share expression in Equation (2.6).<sup>17</sup>

Market potential is defined as the total demand for new car radiators for repair. The total annual car radiator market is estimated to be \$900 M, which is divided by the average price of all the radiators in the data to obtain the total quantity, which is further adjusted for the top 71 product lines in repair business. This quantity is then divided into market potential for each line/business/time based on the proportion of the product inquiries in the customer lookup data.

## 2.5 Estimation and Identification

The estimation strategy is similar to that of Generalized Method of Moments (GMM) used in Berry, et al. (1995), with some modification to incorporate a firm's effort. The first set of moments matches the predicted market shares,  $s_{hft}(\cdot)$ , to the observed market shares in the data,  $s_{hft}^N$ :

$$s_{hft}(\psi(\theta), \theta) - s_{hft}^N = 0, \forall h, f, t \quad (2.12)$$

where  $\theta$  is the set of parameters to be estimated. Berry(1994) shows that there is a unique value of  $\psi$  that matches these two market shares, which can be found using a contraction mapping as in Berry, et al. (1995). Additional moment conditions can be constructed by making assumptions on the demand shock  $\xi$ . For each product line  $h$  at franchise business  $f$  in time  $t$ , the unobserved demand shock  $\xi_{hft}$  is assumed to be uncorrelated with  $Z$ , a set of instrumental variables including exogenous variables:

$$E[\xi_{hft}(\theta) | Z_{hft}] = 0 \forall h, f, t \quad (2.13)$$

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<sup>15</sup>Average conversion rate is about 25%.

<sup>16</sup>Some studies use CPS as the assumed distribution of consumer attributes.

<sup>17</sup>The simulation sample size is 300.

There are two variables - price and effort - in Equation (2.3) that are potentially correlated with the demand shock  $\xi$ , which may bias the estimates (endogeneity issue). First, the demand shock is not observable to the econometrician, but the firm observes it and takes it into account when it sets the price, making the two likely correlated. I use average sales tax rate of each location in the data and the state per-hour minimum wage<sup>18</sup> to instrument for radiator prices. Another potential source of endogeneity is in the expression for effort. Remember  $\psi_{hft}(\theta) \equiv \sum_k x_{hkft} \bar{\beta}_k + e_{ft} + \xi_{hft}$  where  $e_{ft}^*(\cdot) = -\frac{1-r_f}{\lambda} \sum_{h=1}^H s_{hft} \frac{\partial s_{hft}/\partial e_{ft}}{\partial s_{hft}/\partial p_{hft}} \frac{M_{hft}}{M_{ft}}$ . Since  $s_{hft}$  and its derivatives are a function of  $\xi_{hft}$ , I cannot rule out correlation between  $e_{ft}$  and  $\xi_{hft}$  because  $e_{ft}$  is a weighted sum of market share and its derivatives of all product lines. If I can find an instrument that is only a function of product lines other than  $h$ , it should be structurally uncorrelated with  $\xi_h$ . I use the average probability of same-day delivery (exogenous variable) of other product lines at the business,  $\frac{1}{H-1} \sum_{h' \neq h} x_{h'ft}$ , as an instrumental variable. The correlation between this instrument variable and the effort term comes from the fact that the market share and its derivatives of product lines other than  $h$  are a function of the probability of same-day delivery,  $x_{h'}$ . Also, because all franchisee businesses use the same replenishment recommendation system in the CRM, the probabilities of same-day delivery at different locations,  $x_{hft}$  and  $x_{h'ft}$ , are correlated, allowing the probability of same-day delivery of other product lines at other locations,  $\sum_{h' \neq h} \sum_{f' \neq f} x_{h'f't}$  to be used as an additional instrumental variable.

Denote the sample analog of the moment condition in Equation (2.13) as  $\hat{m}(\theta)$ , the optimal estimators are obtained in the following expression:<sup>19</sup>

$$\hat{\theta} = \arg \min_{\theta \in \Theta} \hat{m}(\theta)' \hat{W}(\theta) \hat{m}(\theta) \quad (2.14)$$

where the weighting matrix  $\hat{W}$  is a consistent estimator of  $E[Z'Z]^{-1}$  in the first step and of  $E[Z'\xi(\hat{\theta}_1)\xi(\hat{\theta}_1)'Z]^{-1}$  in the second step using the estimates from the first step,  $\hat{\theta}_1$ . Note that the effort  $e_{ft}$  is a function of  $(\psi, \beta^o, \beta^u, \lambda) \subset \theta$ , so it needs to be updated for newly found  $\theta$  in each iteration of search. For every new set of  $\theta$  in the outer loop, I first find  $\psi(\theta)$  that satisfies market share moment condition in Equation (2.12) through the contraction mapping. Then effort is updated through Equation (2.11), which in turn is used to calculate  $\xi(\theta, \psi, e, X)$ . Standard errors of the estimates are calculated by finding the analytical derivatives of  $\hat{m}(\theta)$ . More details on the GMM estimation can be found in the Appendix.

The identification of most parameters, i.e., macro parameters  $\bar{\beta}$  and micro parameters  $\beta^o, \beta^u$ , is straightforward and similar to identifying conditions in Berry, et al (1995). The cost of effort  $\lambda$  is a new parameter added from micro-modeling effort, whose identification can be better understood in a simpler model. Consider the case of a single product

<sup>18</sup>The historical state minimum wages are obtained from the U.S. Department of Labor website.

<sup>19</sup>I follow 2-step GMM estimation in Hansen (1982).



line with homogeneous consumers (logit model). Then Equation (2.3) and (2.11) can be re-written as the following:

$$\log\left(\frac{s_{ft}}{1-s_{ft}}\right) = \sum_k x_{kft}\bar{\beta} + e_{ft} + \xi_{ft} \quad (2.15)$$

$$e_{ft} = -\frac{1}{\lambda\beta_{price}}[(1-r_f)s_{ft}] \quad (2.16)$$

From data, effort is implied to be high when  $(1-r_f)s_{ft}$  is high. The cost of effort  $\lambda$  is identified in the following way: define  $Y \equiv \log\left(\frac{s}{1-s}\right)$  and  $X \equiv (1-r)s$ . Ignoring other terms,  $-\frac{1}{\lambda\beta_{price}}$  is simply the slope of the regression line passing through data points  $(Y, X)$ . Since the price sensitivity  $\beta_{price}$  is identified from the market share change in response to price variation, the cost of effort  $\lambda$  can be separately identified by taking the inverse of the slope and dividing it by  $-\beta_{price}$ .

## 2.6 Results

### 2.6.1 Descriptive Statistics

Table 2.1 presents descriptive statistics:

Table 2.1: Descriptive Statistics

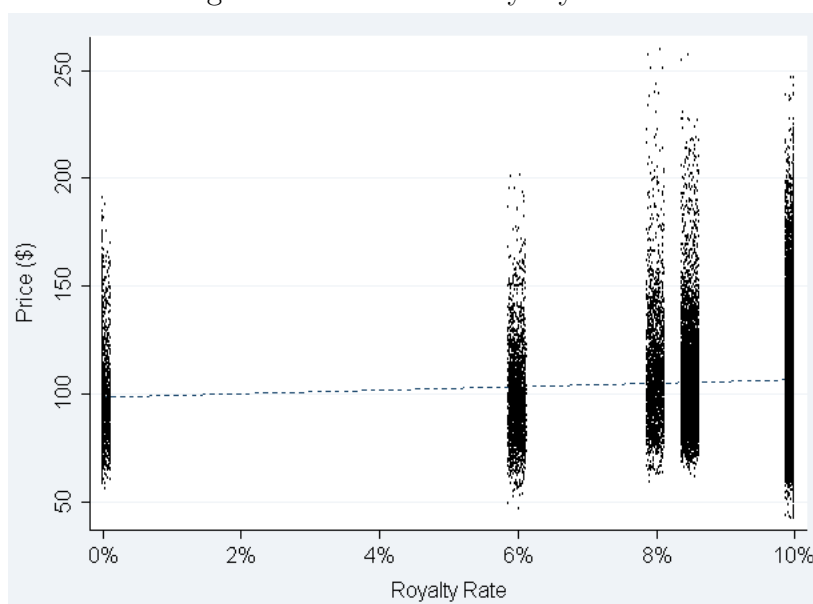
Variable	All Businesses		Franchisor-owned		Franchisees	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Same-day Delivery	0.34	0.13	0.34	0.07	0.34	0.13
Observed Market Share (%)	10.20	5.27	9.37	2.80	10.26	5.40
Cost of Goods (\$)	59.23	16.37	59.59	15.91	59.21	16.40
Price Sold (\$)	105.57	25.70	98.48	21.53	106.08	25.90

Note: This table summarizes monthly data from January 2009 to August 2011 for the top 71 product lines in repair business at the top 15 establishments in the U.S (34,080 data observations). Price Sold is the price the 15 franchise businesses change their consumers (i.e., service centers, auto part shops, etc.).

The average probability of same-day delivery is 34% and does not differ between franchisor-owned businesses and franchisees since they all share the same purchasing software in the CRM system. A part of the CRM system includes an inventory replenishment algorithm developed by an external company. Franchise businesses take inventory recommendations from the software and make their decision on the type/quantity/timing of inventory replenishment. The average market share for the top 71 product lines is 10.2% for the franchise businesses in this data, with that of franchisor-owned location slightly lower at 9.37%. The cost of goods (between \$59 and \$60) is similar between two ownership types. However, franchisees set noticeably higher price than the franchisor-owned establishment.

This is in line with the result of the first-order condition in Equation (2.8), where the optimal price increases in royalty rate. Figure 2.1 shows the scatter plot of price and royalty rate:

Figure 2.1: Price vs. Royalty Rate



Note: Jitters are added to observations for expositional purposes.

Franchisor-owned locations bear no royalty, whereas franchisees have to pay the franchisor 6%, 8%, 8.5%, or 10% of their revenue as franchise royalty payment. The plot shows a general upward trend of price in increasing royalty rate. I statistically test this by running a simple regression of price on royalty rates with product line and time dummies. The regression result in Table 2.2 shows that 10% increase in the royalty rate is associated with \$8.11 increase in the average price, confirming the correlation between the two variables implied by the first-order condition:

Table 2.2: Price vs. Royalty Regression Results

Royalty Rate	81.13*** (2.13)
Constant	161.00*** (1.16)
<u>Dummies</u>	
Product line	Yes
Month	Yes
Observations	34,080
F-stat	1432.24
R-squared	0.77

Robust standard errors in parentheses

\*\*\* p&lt;0.001, \*\* p&lt;0.01, \* p&lt;0.05

Recall that the list of potential customers provides information on the type of consumers and median household income in the area matched to the zip code of the franchise businesses. Figure 2.2 summarizes the data and shows little difference in observed consumer attributes between franchisor-owned locations and franchisee locations. About 60% of the potential customers are repair shops. Close to 20% of the potential customers are new/used car dealers, 10% are auto part shops, and the rest are junkyards, fleets, etc. The mean of median household income is slightly higher for franchisor-owned businesses (\$47,475 vs. \$47,163), but the overall income distributions do not seem to differ much.

Figure 2.2: Comparing Customers by Franchise Ownership Type



## 2.6.2 Parameter Estimates

Tables 2.3 presents parameter estimates. The second column shows the estimates of the full random coefficient model, and the first column lists those of a logit model with instrumental variables by setting  $\beta^u = \beta^u = 0$  in the random coefficient model and removing consumer heterogeneity:

Table 2.3: Parameter Estimates

	Logit with IVs	Random Coefficients with IVs
Demand-side Parameters		
Constant	-2.838*** (0.288)	-1.259* (0.585)
Price (\$00)	-2.137*** (0.265)	-18.615*** (1.177)
Same-day Delivery	1.855*** (0.122)	2.185*** (0.180)
Income (\$00,000)		2.054*** (0.365)
Dealers		15.097*** (0.559)
Repair Shops		13.650*** (0.498)
Auto Part Shops		10.528 (21.964)
Unobserved		-0.009 (0.120)
Supply-side Parameter		
Cost of Effort ( $\lambda$ )	0.026*** (0.004)	0.017* (0.007)

\*\*\* p<0.001, \*\* p<0.01, \* p<0.05

Signs of the estimated parameters of price, same-day delivery, and cost of effort are as expected. The results imply that consumers value low price and a high chance of same-day delivery. A positive  $\lambda$  means that it is costly for franchise businesses to exert additional unit of effort or service for the consumer. In the random coefficient model, a positive coefficient on the income implies that consumers in the area with higher median household income are less price-sensitive. Estimates for consumer type dummies (dealers, repair shops, and auto part shops) indicate that auto dealers and auto repair shops are

significantly less price-sensitive than other types of consumers. The coefficient for the unobserved consumer attribute is not statistically significant. The imputed average marginal cost based on these parameter estimates under random coefficient model is calculated to be \$61.56<sup>20</sup>. Recall that this company is a distributor, not a manufacturer. Its marginal cost mainly consists of the cost of goods, with the remainder arising from storing and delivering an additional unit, which is relatively small in this company. Given the average cost of goods at \$59.23 in the data (Table 2.1), the model estimate suggests that 96% of the imputed marginal cost is accounted by the cost of goods.

### 2.6.3 Effort Measure

Effort level  $e_{ft}$  can be recovered from the data by plugging the estimated parameters into Equation (2.11). If the model is correctly specified, the measured effort should reflect the real-world effort in some ways.<sup>21</sup> I first presented the average effort of all 15 establishments (Table 2.4) to the company chief marketing officer to see whether it is in line with his assessment of business: franchisee 47 is the best-run franchisee in the nation, but controlling for the market size, franchisee 123 has done more than franchisee 47. The recovered effort shows that both franchisees are in the top 3, with franchisee 123 exerting the most per-consumer effort. He also confirmed that the rest of the ranking, including the franchisor-owned location, looks accurate.

Table 2.4: Average Effort Recovered by Company

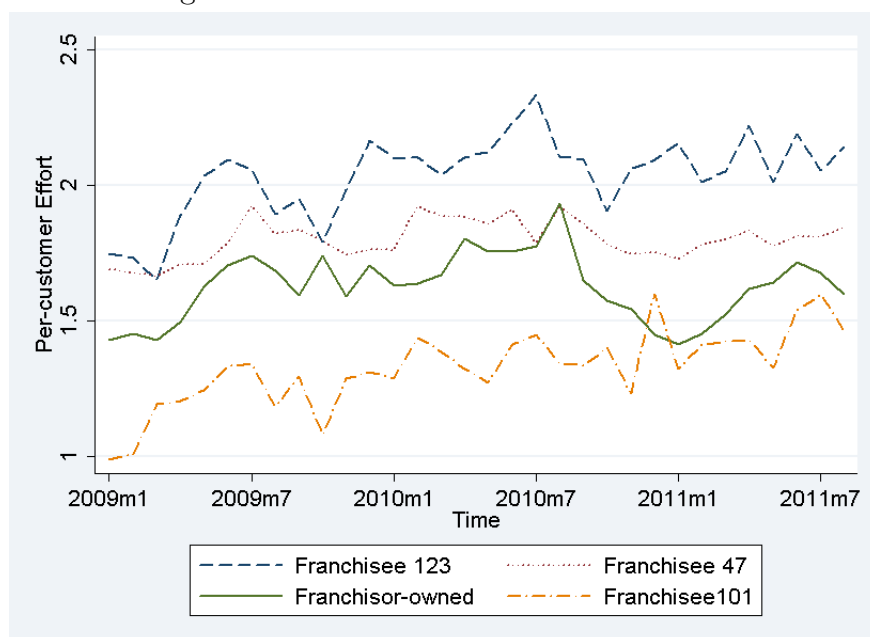
Franchisee ID	Avg. Effort	Franchisee ID	Avg. Effort	Franchisee ID	Avg. Effort
123	2.035	40	1.632	209	1.556
94	1.899	57	1.627	146	1.519
47	1.800	Franchisor-owned	1.626	2	1.431
129	1.794	153	1.608	9	1.381
109	1.745	41	1.594	101	1.328

The franchisor's merger and acquisition history also helps to validate the effort measure. Between August 2010 and January 2011, the franchisor actively leveraged out underperforming franchisees and merged them into franchisor-owned operation. The effort time plot in Figure 2.3 captures this impact of merger and acquisitions:

<sup>20</sup>The price elasticity is 2.77.

<sup>21</sup>The effort used in this section for validity check is recovered using the full random coefficient model.

Figure 2.3: Recovered Per-Customer Effort



The plot shows a significant drop in the franchisor-owned locations' combined effort level during the period of shoring up under-performing franchisees. This is because the overall average market share of franchisor-owned locations is dragged down by that of the under-performers acquired. The decrease in market share in the data is then interpreted as a drop in effort in the model, explaining the patterns in the plot.

Finally, a unique set of data on promotional activities helps validation of the recovered effort. Franchisee owners and sales agents are expected to visit and/or call customers on a regular basis. Sales visits entail finding out customer needs, learning about experience with the company if they previously ordered from the company, and providing them with promotional materials (magnets, candies, coupons, gift cards, etc.). Sales calls involve similar interactions. The company has provided data on the frequencies of these promotional activities at all franchise businesses over time.<sup>22</sup> If the sales visits and calls are good proxies for the unobservable effort, the econometrically recovered effort level is expected to be correlated with them. Regressions of the measured effort (i.e., effort per consumer) on the number of sales calls and/or the number of sales visits per market potential (i.e., total number of customers) allow us to check the correlation between these variables:

<sup>22</sup>These activities are recorded in the CRM. Franchisees and sales agents use the CRM to decide which customers to call or to visit in each day. The CRM even lets the users pick an area to visit and instantly maps the shortest route.

Table 2.5: Effort Regression

Regressor(s)	Calls Only	Visits Only	Calls + Visits	Calls, Visits
Calls/Market Potential	0.003* (0.001)			0.004** (0.001)
Visits/Market Potential		0.001 (0.001)		-0.0006 (0.0008)
(Calls+Visits)/Market Potential			0.001* (0.0004)	
Constant	1.624*** (0.011)	1.628*** (0.013)	1.622*** (0.013)	1.630*** (0.014)
Observations	480	480	480	480
R-squared	0.022	0.003	0.010	0.023

Robust standard errors in parentheses

\*\*\* p&lt;0.001, \*\* p&lt;0.01, \* p&lt;0.05

Results show positive relationship between the recovered effort and the number of calls. The number of visits is not significantly correlated with the recovered effort. Note that the R-squared of these regressions are around 2% or below, meaning that only about 2% of the variation in recovered effort is explained by the variation in these two proxies. This may be attributed to the fact that the regression only captures the quantity of promotional activities. The company executives pointed out that the quality of those activities is also very important, which is not captured in the proxies (regressors). The rest of the variation also may come from other unobservable customer service and effort such as honoring warranties, extended hours of operation, or other unobservable sales tactics. An important part of this study involves investigation of the impact of effort on consumer welfare, so capturing full effort is crucial. Assuming the model specification and assumptions of the utility and profit functions are correct, such low R-squared in the regression supports the approach of micro-modeling unobserved effort over relying on proxies, which would have captured only partial effort by definition. Having the demand model parameters estimated and the effort recovered allows us to run counterfactuals to predict consequences of marketing initiatives or public policies. In this study, the controversial case of resale price ceiling in franchising is investigated to understand how it impacts franchise business optimal effort and consumer welfare.

## 2.7 Policy Evaluation: Resale Price Ceiling

The International Franchise Association defines franchising as “the agreement or license between two legally independent parties which gives a franchisee the right to market a product or service using the trademark or trade name of the franchisor.” The agreement can potentially dictate any aspects of business operation, but pricing agreement between a franchisor and its franchisees has often been the subject of legal scrutiny. Price fixing

in horizontal channel is *per se* (i.e., inherently) illegal because of its antitrust nature that reduces consumer welfare.<sup>23</sup> Extending this judicial interpretation to vertical channel has been controversial, and recently the U.S. Supreme Court reversed its position on resale price ceiling (or maximum resale price) in vertical channel. When *Albrecht*, a newspaper carrier, brought a lawsuit against its publisher, the Herald Company, in 1968 for enforcing resale price ceiling on its carriers,<sup>24</sup> the Court ruled that resale price ceiling is inherently illegal. The Court's decision was partly based on a rationale that "maximum prices may be fixed too low for the dealer to furnish services essential to the value which goods have for the consumer or to furnish services and conveniences which consumers desire and for which they are willing to pay."<sup>25</sup> When a similar lawsuit was filed by *Khan*,<sup>26</sup> a gasoline station owner, in 1997, the U.S. Supreme Court overruled *Albrecht* and made resale price ceiling subject to a rule of reason after 30 years of academic criticism<sup>27</sup> arguing that resale price ceiling lowers price, hence benefiting consumers. This section examines these two competing views of resale price ceiling in vertical channel to investigate their impact on consumer welfare.

Suppose that the franchisor imposes a 5% discount on all the product lines:

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<sup>23</sup>*United States v. Socony-Vacuum Oil Co. (1940)*,

<sup>24</sup>Blair and Lafontaine (2010) discusses why a franchisor wants to impose resale price ceiling on its franchisees in the first place: by expanding output through lowering price, the franchisor cannot increase the total channel profit by reducing the magnitude of double marginalization between two successive firms with market power and/or extract more royalty from franchisees by hurting their profitability.

<sup>25</sup>Albrecht 1968, pp. 152-53. The Court condemns resale price ceiling because it "schemes to fix maximum prices, by substituting the perhaps erroneous judgment of a seller for the forces of the competitive market, may severely intrude upon the ability of buyers to compete and survive in that market," which is a matter of contractual issue rather than an antitrust issue, as Blair and Lafontaine (2010) points out. This counterfactual concerns consumer welfare and focuses primarily on the antitrust aspect of resale price ceiling.

<sup>26</sup>State Oil Company v. Khan 1997. Khan was a gasoline station owner who bought gasoline from State Oil Company. The oil company set the wholesale price to change with the retail price Khan set so that Khan could not make more money even if it charged a higher price, making it effectively a resale price ceiling restraint. More details can be found in Blair and Lafontaine (1999).

<sup>27</sup>Blair and Lafontaine (1999), Blair and Lafontaine (2010), Blair and Lopatka (1998).



Table 2.6: Counterfactual Result

	Current	5% Discount	Change
<u>Market Outcome</u>			
Avg. Price	\$106.08	\$100.78	-5.00%
Avg. Effort	1.64	1.48	-9.91%
Avg. Market Share	10.26%	10.91%	6.42%
<u>Franchisee Profit</u>			
Monetary Profit	\$8.03 M	\$7.63 M	-4.91%
Cost of effort	\$5.25 M	\$4.93 M	-6.03%
Net Profit	\$2.78 M	\$2.70 M	-2.78%
<u>Royalty Payment</u>	\$2.20 M	\$2.29M	4.08%

The counterfactual results in Table 2.6 show that franchise businesses reduce effort level by 9.91% in response to 5% price discount.<sup>28</sup> The intuition comes from Equation (2.10), where optimal effort decreases with a lower margin. The average market size is predicted to increase by 6.42% due to price discount. Examining franchisees' profits also provide insight into a franchisor's potential incentive to impose resale price ceiling and franchisee's opposition towards it. By imposing 5% discount, franchisees' monetary profit, cost of effort decrease, and the net profit for franchisees decrease by varying degrees, but in essence the price discount decreases the franchisees' profit by 2.78%. The predicted royalty payment transfer to the franchisor, which is the franchisor's incentive for imposing resale price ceiling, is predicted to increase by 4.08% (from \$2.20 M to \$2.29 M)<sup>29</sup> Under the current revenue-based royalty scheme, the benefit of reduction in price goes to the franchisor in the form of royalty payment by sacrificing franchisees profit; this provides insight as to why some franchisees filed lawsuits against their franchisors or upstream firms for imposing resale price ceilings.

Change in consumer welfare is measured using change in compensating variation. Table 2.7 summarizes consumer welfare change under the counterfactual:

Table 2.7: Consumer Welfare Change

	Consumer Surplus Change
Due to Price	15.54 %
Due to Effort	-3.80%
Net	11.74 %

Results show that a 5% price reduction increases the net consumer welfare by 11.74%.

<sup>28</sup>The counterfactual is run with the random coefficient model with IVs. Competitors do not react to the price change by this franchise in this model.

<sup>29</sup>Even if imposing resale price ceiling improves profitability, the franchisor may not want to implement it as it can potentially tarnishes the franchisor's reputation, which hampers recruitment of new franchisees.

This net increase can be decomposed into two components: price and effort. Reduction in price alone increases consumer welfare by 15.54%, and 3.8% of it is lost due to lower optimal effort by franchise businesses. Hence, imposing resale price ceiling in this market is consumer welfare enhancing, supporting the recent U.S. Supreme Court's ruling (*Khan*) on changing the status of resale price ceiling from *per se* illegal to rule of reason. However, the argument of *Albrecht* - downstream firm lowering service or effort in response - should not be overlooked in quantifying benefit to the consumer. If one ignores the change of effort level in response to vertically imposed price ceiling in analyzing consumer welfare and calculates it solely based on price change, the welfare increase will be estimated to be 15.54% rather than 11.74%, leading to an overestimation. Hence, the firm's effort level change should be taken into account when vertical pricing is studied, particularly in analyzing consumer welfare in an industry where exerting effort it is an important decision variable of the firm.

## 2.8 Conclusion

Service effort has long been of interest to practitioners and researchers. The literature on a firm's effort (or service) is extensive and diverse; however, there have not been many empirical studies investigating the role of effort in consumer demand. This is because effort, unlike other marketing mix instruments, is not only unobservable to researchers, but also abstract in nature, which makes it difficult to quantify. This paper proposes an empirical framework of effort by micro-modeling it using a demand model of differentiated goods, along with other traditional marketing mix variables. The model defines unobservable service effort in the consumer utility and in the firm profit. In the model, the firm sets the optimal price and the level of effort after incurring a cost of exerting effort. The paper then applies it to a unique data set - sales transaction, customer information, and franchise arrangement - obtained from a franchise network in the car radiator market, where service effort by the franchisee is an important firm decision in determining the market outcome. The set of first-order conditions from the model then helps to recover the unobserved effort level. Once the effort is recovered, it is checked against field evidence for validation.

The estimated model is also applied to provide insight into a much-debated public policy question regarding the impact of resale price ceiling. The legality of resale price ceiling in vertical channels has been controversial. In 1968, the Supreme Court ruled resale price ceiling inherently illegal. The Court argued that the downstream firm might reduce the service effort that the consumer values if it were forced to lower the price by the price ceiling. After 30 years, the U.S. Supreme Court reversed its position and allowed resale price ceiling under reasonable circumstances on the basis of consumer welfare enhancing prospect from lower price.

A policy evaluation result shows that imposing resale price ceiling at 5% below the current price across all products reduces franchisees' profit. On the contrary, it increases

consumer welfare by 11.74% despite welfare loss due to lower service effort exerted by the franchise businesses. This result supports the U.S. Supreme Court's recent decision allowing resale price ceiling. In measuring the size of consumer benefit, however, *Albrecht's* argument on service reduction by the firm should be taken into account as calculating it without change in effort significantly overestimates the amount of consumer welfare gain.

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# Appendix A

## Chapter 1

**Proof of Proposition 1** Under Lemma 1, the optimal level of diversity of the idea pool for each symmetric firm is

$$d_s^* \equiv d_i^* = d_j^* = \frac{6Rt}{DN + 2R^2}$$

Both firms' choice of the diversity of the idea pool  $d_s^*$  decreases in the intensity of competition, in the firm's inability to deal with diverse ideas  $k$ , and in the number of hires  $N$ .

*proof:*

- $\frac{dd_s^*}{dt}$ : We can show  $\text{sgn}[\frac{dd_s^*}{dt}] = \text{sgn}[2R^2 - Q] < 0, \forall N \geq 2$ .
- $\frac{dd_s^*}{dtN}$ :

$$\begin{aligned} \text{sgn}[\frac{dd_s^*}{dN}] &= \text{sgn}[R'DN - RDN' - 2R^2R'] \\ &= -\text{sgn}[1 + N(N+1) \{N + 9tk(N+2)^2(N^3 - 2N - 1)\}] \end{aligned}$$

Using second-order condition, we can show that  $1 + N(N+1) \{N + 9tk(N+2)^2(N^3 - 2N - 1)\} > 1 + N(N+1) \{N + 9\frac{Q(N)}{18N^2}(N+2)^2(N^3 - 2N - 1)\} > 0$  for  $N \geq 2$ . Therefore,  $\frac{dd_s^*}{dtN} < 0$ .

- $\frac{dd_s^*}{dk}$ : Lastly, we can easily see that  $\frac{dd_s^*}{dk} < 0$  since  $DN$  is the only term with  $k$ , which is in the denominator.



**Proof of Proposition 2:** The expected profits of symmetric firms decrease in the intensity of competition (i.e. as  $t$  decreases), but increase in the firm's inability to deal with diverse ideas (i.e. as  $k$  increases).

*proof:*

- $\frac{E\pi_i}{dt} > 0$ .

The expected profit function of firm  $i$  can be written as the following:

$$E\pi_i = \frac{t}{2} + \left[ \frac{1}{9tk(N+1)^2(N+2)} - \frac{1}{2}kN \right] Nd_i^{*2}$$

Taking the first derivative with respect to  $t$ ,

$$\begin{aligned} \frac{E\pi_i}{dt} &= \frac{1}{2} - \frac{(N-1)^2(N+2)}{4N [9tkN(N+1)^2(N+2) - 1]^3} \\ &> \frac{1}{2} - \frac{(N-1)^2(N+2)}{4N \left[ 9 \left\{ \frac{Q+6Rt-2R^2}{18N^2} \right\} N(N+1)^2(N+2) - 1 \right]^3} \\ &> \frac{1}{2} - \frac{(N-1)^2(N+2)}{4N \left[ 9 \left\{ \frac{Q+2R-2R^2}{18N^2} \right\} N(N+1)^2(N+2) - 1 \right]^3} \\ &= \frac{N(N-1)(N+1)(N+3)(N(N+3)+4) - 4}{2(N-1)(N+1)^3(N+2)^2} \end{aligned}$$

where the two inequalities can be established by Lemma 2 and Lemma 1, respectively. The value of the last term in term of  $N$  can be shown that it is strictly positive for  $N \geq 2$ . Therefore,  $\frac{E\pi_i}{dt} > 0$ .

- $\frac{dE\pi}{dk} > 0$

$$\text{sgn}\left[\frac{dE\pi}{dk}\right] = \text{sgn}\left[\frac{3tkN(N+1)^2(N+2) - 1}{(9tkN(N+1)^2(N+2) - 1)^3}\right]$$

Define  $O_N \equiv 3tkN(N+1)^2(N+2) - 1$ ,  $O_D \equiv 9tkN(N+1)^2(N+2) - 1$ . Applying Lemma 2,  $tk > \frac{Q+2R-2R^2}{18N^2}$ , we can easily see that  $O_N, O_D > 0$  for  $N \geq 2$ . Therefore,  $\frac{O_N}{O_D} > 0 \implies \frac{dE\pi}{dk} > 0$ .

# Appendix B

## Chapter 2

## Data Cleaning

The original data contains sales transactions of the top 71 radiator product lines from all franchisor-owned and franchisee businesses. After subtracting 164,170 returned parts, there are 1.4 million sales transactions. Orders without a radiator and more than 3 items are dropped. Among the 2-item orders, if there is a promotion coupon, the coupon discount is subtracted from the sales price. Then orders with multiple quantities are split into single orders, which results in 1.08 million observations. After removing parts with missing information and dropping Canadian locations, data is aggregated to monthly levels in each location. Canadian locations are removed because they have different franchise contracts due to different legislation, tariff and border-crossing supply chains. Most product lines are not substitutable with one another. However, some of them are compatible according to the lookup data. If radiators are looked up for a particular type of car, and the data shows multiple product lines, the substitute products are grouped together.

## Expressions for Market Shares

Derivatives are

$$\frac{ds_{hft}}{dp_{hft}} = \int f_{ihft}(a_{if}, v_{if})[1 - f_{ihft}(a_{if}, v_{if})] \frac{d(\psi_{hft} + \mu_{ihft}(a_{if}, v_{if}))}{dp_{hft}} P(da, dv)$$

$$\frac{\partial s_{hft}}{\partial e_{ft}} = \int f_{ihft}(a_{if}, v_{if})[1 - f_{ihft}(a_{if}, v_{if})] P(da, dv)$$

Assuming the q-th product characteristic is price and random coefficient on price only (i.e.,  $r = 1$ ),

$$\frac{d(\psi_{hft} + \mu_{ihft}(a_{if}, v_{if}))}{dp_{hft}} = \beta_{Price} + a_{if}\beta^o + v_{if}\beta^u$$

Using simple frequency simulators, the above expression can be simulated by

$$\begin{aligned} \hat{s}_{hft}(\psi, \beta^o, \beta^u, \omega) &= \frac{1}{ns} \sum_{i=1}^{ns} f_{ihft}(a_{if}, v_{if}) \\ &= \frac{1}{ns} \sum_{i=1}^{ns} \frac{\exp(\psi_{hft} + \mu_{ihft}(a_{if}, v_{if}))}{1 + \exp(\psi_{hft} + \mu_{ihft}(a_{if}, v_{if}))} \end{aligned}$$

Simulated derivatives are

$$\frac{d\hat{s}_{hft}}{dp_{hft}} = \frac{1}{ns} \sum_{i=1}^{ns} f_{ihft}(a_{if}, v_{if})[1 - f_{ihft}(a_{if}, v_{if})] \frac{d(\psi_{hft} + \mu_{ihft}(a_{if}, v_{if}))}{dp_{hft}}$$

$$\frac{d\hat{s}_{hft}}{de_{ft}} = \frac{1}{ns} \sum_{i=1}^{ns} f_{ihft}(a_{if}, v_{if})[1 - f_{ihft}(a_{if}, v_{if})]$$

## GMM

1. (Initialization) Set initial values for  $(\beta^o, \beta^u, \lambda)$  and take  $ns$  draws of  $(a_i, v_i)$  from the list of potential customers in each market  $f$  and standard normal distributions, respectively.
2. (Outer Loop) Minimize  $m \equiv E[\xi | X, Z]$  over  $(\bar{\beta}, \beta^o, \beta^u, \lambda)$  through non-linear search.
  - Using contraction mapping as in BLP, find  $\psi_{hft}$  such that the observed market share is equal to the predicted market share:  $s_{hft}^N = s_{hft}(\cdot)$
  - Update  $e_{ft}^*(\beta^o, \beta^u, \lambda, \psi; p, c, r, M) = -\frac{1-r_f}{\lambda} \sum_{h=1}^H s_{hft} \frac{\partial s_{hft} / \partial e_{ft}}{\partial s_{hft} / \partial p_{hft}} \frac{M_{hft}}{M_{ft}}$
  - $\xi_{hft} = \psi - \sum_k x_{hft} \bar{\beta}_k - e_{ft}^*(\beta^o, \beta^u, \lambda, \psi; p, c, r, M)$
3. Repeat until it converges

Note that the asymptotic variance of GMM is  $\frac{1}{HFT} \hat{V}$ , where  $\hat{V} = (\hat{d}' \hat{W} \hat{d})^{-1}$ ,  $\hat{d} = \frac{\partial \hat{m}}{\partial \theta'} |_{\hat{\theta}} = Z' \frac{\partial \hat{\xi}}{\partial \theta'} |_{\hat{\theta}}$ . Standard errors can be found by taking the square root of the diagonal elements of the variance covariance matrix.