Introduction to Industrial Organization

Price Dispersion and Search

Jian-Da Zhu

National Taiwan University

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Price Dispersion and Search

- In the competitive markets for homogeneous products, the "law of one price" phenomenon should be predicted by the model.
- For instance, the equilibrium price is equal to the marginal cost in the Bertrand model.
- However, in reality, many empirical studies reveal price dispersion in both online and offline markets.
- Examples: books, CDs, DVDs, prescription drugs, consumer electronics, ...

Price Dispersion in Empirical Literature

Table 1a: Measures of Price Dispersion Reported in the Literature in Offline Markets[1]

Study	Data Period	Product Market	Intervals of Estimated Price Dispersion Measures	Dispersion Measure
Bailey (1998)	1997	Books	13.2%	Standard Deviation
		Books	10.4%	Standard Deviation
		Compact Discs	17.6%	Standard Deviation
		Compact Discs	11.0%	Standard Deviation
		Software	7.1%	Standard Deviation
		Software	8.1%	Standard Deviation
Borenstein and Rose (1994)	1986	U.S. Airline	0.018 - 0.416	Gini coefficient
Carlson and Pescatrice (1980)	1976	Consumer Sundries	3.3% - 41.4%	Coefficient of Variation
Eckard (2004)	1901 - 2001	Baking Powder, Sugar, Salt -- 1901	3.1% - 10.1%	Coefficient of Variation
		Baking Powder, Sugar, Salt -- 2001	0.0% - 13.4%	Coefficient of Variation
Friberg, Ganslandt and Sandstrom (2001)	1999	Books	$54.00 - $122.00	Range
		Books	$21.94 - $76.20	Standard Deviation
		Compact Discs	$20.00 - $40.00	Range
		Compact Discs	$12.91 - $23.86	Standard Deviation
		Books (Sweden)	$19.00 - $58.00	Range
		Compact Discs (Sweden)	$21.00 - $46.00	Range
Lach (2002)	1993 - 1996	Refrigerator (Israel)	4.9%	Coefficient of Variation
		Chicken, Flour, Coffee (Israel)	11.4% - 19.7%	Coefficient of Variation
Marvel (1976)	1964 - 1971	Regular Gasoline	$0.048	Range
		Regular Gasoline	$0.015	Standard Deviation
		Premium Gasoline	$0.048	Range
		Premium Gasoline	$0.017	Standard Deviation
Pratt, Wise and Zeckhauser (1979)	1975	Various Products and Services	4.4% - 71.4%	Coefficient of Variation
		Various Products and Services	11.0% - 567.0%	Range
		Various Products and Services	7.2% - 200.0%	Value of Information
Roberts and Supina (2000)	1963 - 1987	Wood Products	13.8% - 90.2%	Coefficient of Variation
		Fabrics	18.8% - 78.1%	Coefficient of Variation
		Coffee	14.3% - 25.1%	Coefficient of Variation
		Ready-Mixed Concrete	13.2% - 37.2%	Coefficient of Variation
		Newsprint	4.5% - 8.2%	Coefficient of Variation
		Gasoline	6.2% - 11.8%	Coefficient of Variation
		Tinplate Steel Cans	25.0% - 31.0%	Coefficient of Variation
		Pan Bread	26.0% - 49.6%	Coefficient of Variation
		Corrugated Shipping Containers	21.8% - 39.6%	Coefficient of Variation
Scholten and Smith (2002)	1976 - 2000	Consumer Sundries -- 1976	3.3% - 41.4%	Coefficient of Variation
		Consumer Sundries -- 2000	1.6% - 42.0%	Coefficient of Variation
		Consumer Sundries -- 2000	5.7% - 28.4%	Coefficient of Variation
Sorensen (2000)	1998	Prescription Drugs	$13.17	Range
		Prescription Drugs	22.0%	Coefficient of Variation
Stigler (1961)	1953	Anthracite Coal	$3.46	Range
		Anthracite Coal	$1.15	Standard Deviation
	1959	Identical Automobiles	$165.00	Range
		Identical Automobiles	$42.00	Standard Deviation
Villas-Boas (1995)	1985 - 1987	Coffee	21.5%	Coefficient of Variation

[1] Table 1a includes studies comparing offline and online price dispersion.

From Baye, Morgan, and Scholten (2006)

Price Dispersion in Empirical Literature

Table 1b: Measures of Price Dispersion Reported in the Literature in Online Markets Only

Study	Data Period	Product Market	Intervals of Estimated Price Dispersion Measures	Dispersion Measure
Ancarani and Shankar (2004)	2002	Books (Italy)	€4.26 - €4.84	Standard Deviation
		Books (Italy)	€20.00 - €22.88	Range
		Compact Discs (Italy)	€2.29 - €2.79	Standard Deviation
		Compact Discs (Italy)	€11.82 - €14.75	Range
Arbatskaya and Baye (Forthcoming)	1998	Mortgage Interest Rates	> 0.25	Range
Arnold and Saliba (2002)	2001	Textbooks	10.7% - 52.6%	Range
		Textbooks	3.5% - 10.0%	Coefficient of Variation
		Textbooks	0.2% - 12.5%	Price gap
Baye, Morgan and Scholten (2003)	2000 - 2001	Consumer Electronics	$123.88 - $143.15	Range
Baye, Morgan and Scholten (2004a)	2000 - 2001	Consumer Electronics	9.1% - 9.7%	Coefficient of Variation
		Consumer Electronics	3.79% - 5.38%	Gap
Baye, Morgan and Scholten (2004b)	1999 - 2001	Consumer Electronics	57.4%	Range
		Consumer Electronics	12.5%	Coefficient of Variation
Baylis and Perloff (2002)	1999	Camera	$342.00	Range
		Scanner	$106.00	Range
Brynjolfsson and Smith (2000)	1998-1999	Books	33.0%	Range
		Compact Discs	25.0%	Range
Chevalier and Goolsbee (2003)	2001	Books	8.1% - 12.3%	Range
Clay, Krishnan, and Wolff (2001)	1999 - 2000	Books	27.7%	Coefficient of Variation
		Books	$7.62	Range
Clay, Krishnan, Wolff and Fernandes (2003)	1999	Books	10.0% - 18.0%	Coefficient of Variation
Clemons, Hann and Hitt (2002)		Travel	$8.03 - $13.40	Range
Ellison and Ellison (2004)	2000 - 2001	Memory Modules	5.9% - 29.0%	Range
Gatti and Kattuman (2003)	2002	Consumer Electronics (France)	3.0% - 15.3%	Coefficient of Variation
		Consumer Electronics (Italy)	4.3% - 14.2%	Coefficient of Variation
		Consumer Electronics (Netherlands)	5.6% - 20.4%	Coefficient of Variation
		Consumer Electronics (Spain)	2.2% - 13.3%	Coefficient of Variation
		Consumer Electronics (Sweden)	6.6% - 14.0%	Coefficient of Variation
		Consumer Electronics (UK)	3.5% - 16.2%	Coefficient of Variation
		Consumer Electronics (Denmark)	6.3% - 20.2%	Coefficient of Variation
		Consumer Electronics (France)	7.8% - 47.4%	Range
		Consumer Electronics (Italy)	9.3% - 27.8%	Range
		Consumer Electronics (Netherlands)	8.9% - 54.6%	Range
		Consumer Electronics (Spain)	3.8% - 32.4%	Range
		Consumer Electronics (Sweden)	16.4% - 50.4%	Range

From Baye, Morgan, and Scholten (2006)

Price Dispersion in Empirical Literature

		Consumer Electronics (UK)	7.0% - 54.9%	Range
		Consumer Electronics (Denmark)	12.8% - 42.9%	Range
		Consumer Electronics (France)	1.6% - 16.1%	Gap
		Consumer Electronics (Italy)	3.6% - 13.7%	Gap
		Consumer Electronics (Netherlands)	8.9% - 34.6%	Gap
		Consumer Electronics (Spain)	3.7% - 18.0%	Gap
		Consumer Electronics (Sweden)	5.9% - 15.6%	Gap
		Consumer Electronics (UK)	2.5% - 14.5%	Gap
		Consumer Electronics (Denmark)	3.6% - 31.9%	Gap
Hong and Shum (Forthcoming)	2002	Books	$8.19 - 27.05	Range
		Books	6.2% - 8.5%	Coefficient of Variation
Janssen, Moraga-Gonzalez and Wildenbeest (2005)	2004	Market for Keyboards	$6.50 - $91.67	Range
		Market for Keyboards	8.0% - 52.0%	Coefficient of Variation
Pan, Ratchford and Shankar (2002)	2000	Books	15.0%	Coefficient of Variation
		Compact Discs	15.4%	Coefficient of Variation
		DVDs	12.7%	Coefficient of Variation
		PDAs	11.8%	Coefficient of Variation
		Software	11.7%	Coefficient of Variation
		Consumer Electronics	9.6%	Coefficient of Variation
Pan, Shankar and Ratchford (2003)	2000 - 2003	Consumer Electronics and Books	9.8% - 11.7%	Coefficient of Variation
		Books	33.3% - 48.9%	Range
		Compact Discs	22.2% - 51.0%	Range
		DVDs	30.7% - 43.7%	Range
		Computers	15.0% - 34.4%	Range
		Software	19.0% - 35.6%	Range
		Consumer Electronics	22.1% - 45.7%	Range
Smith and Brynjolfsson (2001)	1999	Books	28.0% - 33.0%	Value of Information
		Books	$6.29 - $10.51	Standard Deviation

From Baye, Morgan, and Scholten (2006)

Price Dispersion and Search

- One explanation for price dispersion is that some consumers are better informed than others, which means that consumers need positive search costs to search for the information.
- Search costs in these studies consist of consumers' opportunity cost of time in searching for lower prices (so-called "shoe-leather" costs), plus other costs associated with obtaining price quotes from competing firms (such as the incremental cost of the postage stamps or phone calls used in acquiring price information from firms).

Outline of Price Dispersion and Search

- Theoretical Models
  - Fixed Sample Search
  - Sequential Search
  - Diamond's Paradox
- Empirical Analysis
  - Measuring Price Dispersion
  - Dispersion for "Cheap" versus "Expensive" Items
  - Dispersion and Purchase Frequency
  - Dispersion and the Cost of Search
  - Dispersion and Search Timing

- Reference: Baye, Morgan, and Scholten (2006), "Information, Search, and Price Dispersion", *Handbook on Economics and Information Systems*.

Theoretical Models

General Approaches for Search Models

- To capture the search cost, two types of models are used in the literature:
  1. Assume that it is costly for consumers to gather information about prices.
     - Consumers searching for the best price incur a positive cost of obtaining each additional price quote.
     - Two types of search behavior:
       fixed sample size search, and sequential search.
     - Examples: Stigler (1961), Rothschild (1973), Reinganum (1979), and MacMinn (1980).
  2. Assume that consumers access price information by consulting an "information clearinghouse" (e.g., a newspaper or an Internet price comparison site).
     - A subset of consumers gain access to a list of prices charged by all firms and purchase at the lowest listed price.

Stigler (1961)

- Model settings:
  - Each consumer wishes to purchase $K > 1$ units of the product.
  - Fixed sample search: prior to searching, consumers determine a searching sample size n first, and purchase the product at the lowest price from this sample.
  - The distribution of firms' prices is given by an exogenous cdf $F(p)$ on $[\underline{p}, \bar{p}]$.
- A consumer chooses a fixed sample size, n, to minimize the expected total cost of purchasing K units of the product:

$$E[C] = KE[p_{\min}^{(n)}] + cn,$$

where $E[p_{\min}^{(n)}] = E[\min\{p_1, p_2, ..., p_n\}]$, which is a decreasing function of the sample size, n.

Propositions and Results

- **Proposition 1** Suppose that a price distribution G is a mean preserving spread of a price distribution F. Then the expected transactions price of a consumer who obtains $n > 1$ price quotes is strictly lower under price distribution G than under F.

$\Rightarrow$ Implication: the expected transactions price is lower when prices are more dispersed (in the sense of a mean preserving spread).

Propositions and Results

- **Proposition 2** Suppose that an optimizing consumer obtains more than one price quote when prices are distributed according to F, and that price distribution G is a mean preserving spread of F. Then the consumer's expected total costs under G are strictly less than those under F.

$\Rightarrow$ Implication: the expected total costs inclusive of search costs is lower when prices are more dispersed (in the sense of a mean preserving spread).

- Intuition: In environments where prices are more dispersed, the prospects for price improvement from search are higher because the left tail of the price distribution becomes thicker as prices become more dispersed.

Rothschild Critique

- From Rothschild (1973)
- Two critiques:
  1. The search procedure (fixed sample search) assumed in Stigler's model may not be optimal because it fails to incorporate new information obtained during search.
     - $\Rightarrow$ Sequential search results in an optimal stopping rule such that a consumer searches until she locates a price below some threshold, called the reservation price.
  2. The distribution of prices, F; is exogenously specified and is not based on optimizing firm behavior. Actually, each firm faces exactly the same expected profit function.
     - $\Rightarrow$ The supply side profits maximization problems are needed to create the price dispersion.

Diamond's Paradox

- In Diamond (1971), the model settings and results:
  - Consumers have identical downward sloping demand.
  - Consumers engage in optimal sequential search.
  - A firm acting as a monopoly would optimally charge all consumers the unique monopoly price, p^*.
  - A consumer who is charged the monopoly price earns surplus sufficient to cover the cost of obtaining a single price quote; that is $v(p^*) > c$.
- The unique equilibrium is that all the firms set the monopoly price p^* , and the consumers search only once.
- Implication: If all consumers have positive search costs, all the firms will set price equal to the monopoly price.
- However, there is no price dispersion in the model.

Reinganum Model

- Reinganum (1979) was among the first to show that equilibrium price dispersion can arise in a sequential search setting with optimizing consumers and firms.
- Model settings:
  - Consumers have identical demands.
  - Consumers engage in optimal sequential search with free recall.
  - Firms have heterogeneous marginal costs on $[\underline{m}, \bar{m}]$, with cdf $G(m)$.
  - A consumer who is charged the monopoly price by a firm with the highest marginal cost, $\bar{m}$, earns surplus sufficient to cover the cost of obtaining a single price quote.
- Reinganum shows that, under these assumptions, there exists a dispersed price equilibrium in which firms optimally set prices and each consumer engages in optimal sequential search.

Optimal Sequential Search

- Given the distribution of prices $F(p)$ on $[\underline{p}, \bar{p}]$
- Let $z = \min(p_1, p_2, ..., p_n)$ be the lowest price after n searches.
- By making an additional search, a consumer expects to gain benefits of

$$B(z) = \int_{\underline{p}}^{z} (v(p) - v(z)) dF(p).$$

- Since search is costly, the expected net benefits of an additional search are

$$h(z) = B(z) - c.$$

- If $h(z) > 0$, it is optimal for the consumer to obtain an additional price quote; otherwise, the consumer stop searching and purchase at the lowest price z.

Optimal Search Strategy

- A consumer's optimal sequential search strategy may be summarized as follows:

Case 1 $h(\bar{p}) < 0$, and $\int_{\underline{p}}^{\bar{p}} v(p)dF(p) < c$:
the consumer's optimal strategy is to not search. There is no transaction in the market.

Case 2 $h(\bar{p}) < 0$, and $\int_{\underline{p}}^{\bar{p}} v(p)dF(p) \geq c$:
the consumer's optimal strategy is to search once.

Case 3 $h(\bar{p}) \geq 0$:
consumers search until they obtain a price quote at or below a reservation price r, where $h(r) = 0$.

Firm's Problem and Results

- Firm's problem:
  - Each firm has a marginal cost of production m, drawn from a distribution $G(m)$ with support $[\underline{m}, \bar{m}]$.
  - Each firm anticipates consumers' search strategy and optimal prices set by other firms.
- Solve the firms' optimal prices and calculate the variance of prices, so we can examine how the variance in the distribution of posted (and transactions) prices varies with search costs.
- **Conclusion** In the Reinganum model, a reduction in search costs decreases the variance of equilibrium prices.
- Intuition: lower search costs $\Rightarrow$ lower reservation price r'. Firms with $p \leq r'$ do not change their prices, and firms with $p > r'$ lower their prices to r'. Therefore, dispersion decreases!

MacMinn Model

- MacMinn (1980) investigates whether equilibrium price dispersion can arise in a setting with fixed sample search.
- Model settings:
  - Consumers have unit demand with valuation v.
  - Consumers engage in optimal fixed sample search.
  - Firms have privately observed marginal costs m, from $G(m)$ on $[\underline{m}, \bar{m}]$, where $\bar{m} < v$.
- **Conclusion** In the MacMinn model, a reduction in search costs increases the variance of equilibrium prices.
- Intuition: lower search costs induce consumers to sample more firms before purchasing, so each firm competes with more rivals. The optimal amount of "bid shading" (pricing above marginal cost) is reduced, thus increasing the level of price dispersion.

Empirical Analysis

Measuring Price Dispersion

- Given such a distribution, a standard measure of dispersion is the variance in prices, σ_p^2.
- A number of authors use the sample variance to measure price dispersion; however, the drawback of this measure is apparent when comparing dispersion across products or over time.
- An alternative measure, the coefficient of variation, $CV = \sigma_p / E[p]$, can overcome this problem.
- Another widely used measure of price dispersion is the (sample) range, $R^{(n)} = p_{\max}^{(n)} - p_{\min}^{(n)}$.
- The value of information (VOI), $VOI^{(n)} = E[p] - E[p_{\min}^{(n)}]$, is simply the difference between the average observed price and the lowest observed price, is zero in the absence of any price dispersion but otherwise positive.

Empirical Analysis

- George Stigler provided many hypotheses in Stigler (1961, p. 219).
- Much of this literature tests Stigler's hypotheses by examining whether search intensity is correlated with levels of price dispersion.
- However, there are three challenges:
  1. how to choose a model that closely approximates the "data generating" environment.
  2. how to control for factors outside of the model that might influence levels of dispersion.
  3. the firm optimization is absent in Stiglers model, but is clearly present in the data.
- A number of empirical studies look beyond Stigler's hypotheses to test hypotheses derived from specific search-theoretic or clearinghouse models of equilibrium price dispersion.

Dispersion for "Cheap" versus "Expensive" Items

- The search-theoretic models imply that search intensity depends on the consumer's demand for a product. (parameter K in the Stigler model)
- Stigler (1961) provides evidence in support of his first hypothesis: dispersion is lower for items that account for a large expenditure share of a searcher's consumption bundle ("expensive items") than those that account for a smaller expenditure share ("cheap items").
- Eckard (2004) compares price dispersion for staple products (such as sugar and baking powder) in 1901 and 2001, and reports coefficients of variation in 2001 that are almost twice those based on data from 1901. Eckard argues that those accounted for a much larger share of household budgets in 1901 than in 2001.

Dispersion and Purchase Frequency

- In his second hypothesis, Stigler argues that in markets where there are more repetitive or experienced buyers, the greater is the amount of effective search.
- Sorensen (2000, JPE) uses data from the market for prescription drugs to test this hypothesis.
- The purchase frequency may be objectively measured, based on the typical dosage and duration of therapy for a given prescription drug.
- A consumers' benefit per search is clearly highest for frequently purchased drugs, so Sorensen argues that this should lead to greater search and lower price dispersion.
- After controlling other factors, Sorensen finds that the price range for a drug that must be purchased monthly is about 30 percent lower than if it were a one-time therapy.

Dispersion and Purchase Frequency

- His empirical analysis identifies a strong inverse relationship between purchase frequency and price dispersion.
- The results are qualitatively similar when alternative measures of price dispersion (such as the standard deviation) are are used.

Dispersion and the Cost of Search

- Two challenges:
  - First, the predicted impact of search costs on levels of dispersion depends not only on the model, but also on the metric used for measuring dispersion.
  - Second, search costs are generally unobservable.

Dispersion and the Cost of Search

- Stahl (1989) model predicts that price dispersion is initially an increasing function of the fraction of "shoppers" who enjoy zero search costs, but after a threshold, is a decreasing function of the fraction of shoppers.
- Brown and Goolsbee (2002, JPE) point out that Stahl model closely matches the market for term-life insurance during the 1992-1997 period.
- In their data, internet usage over time or across different groups can be used to proxy the variation of fraction of "shoppers".
- Consistent with the prediction of the Stahl model, price dispersion initially rises as the fraction of shoppers increases, but starts to decline once the fraction of consumers researching insurance online exceeds about 5 percent.

Dispersion and the Cost of Search

- A similar approach is implicit in a number of papers that have compared levels of dispersion in online versus offline markets.
- The basic premise is that search costs are lower in online (search entails clicks) versus offline markets (search entails travel costs). (There are some debates about this view.)
- The results are mixed. For some products, dispersion is lower in online markets; for other products, dispersion is actually higher online.
- Along these same lines, a number of studies compare average prices in online versus offline markets.

Dispersion and the Cost of Search

- An alternative approach is to "recover" search costs using structural parameters from a particular model of price dispersion.
- Hong and Shum (2006, RAND) show how the equilibrium restrictions implied by standard search models can be used to estimate search-cost distributions using price data alone.
- They consider both sequential and non-sequential search strategies.
- They apply this method to online price data for several economics and statistics textbooks.
- They obtain search cost estimates ranging from $1.31 to $29.40 for these items

Dispersion and Search Timing

- Lewis and Marvel (2011), "When Do Consumers Search?"
- By using a measure of Internet traffic for *GasBuddy.com*, a gasoline price aggregator that provides consumers with the opportunity to obtain gasoline prices at individual gasoline stations in their area, they can measure search intensity directly.
- They show that consumers search more as prices rise than they do when prices fall.
- Price dispersion is much greater when prices are falling than when they are rising.
- When consumers are well informed, individual gasoline stations cannot stray far from marketplace norms.
- Falling prices stimulate less search, and so stations are more able to hold back from passing those price declines along at retail.

Average Gasoline Price and GasBuddy Traffic

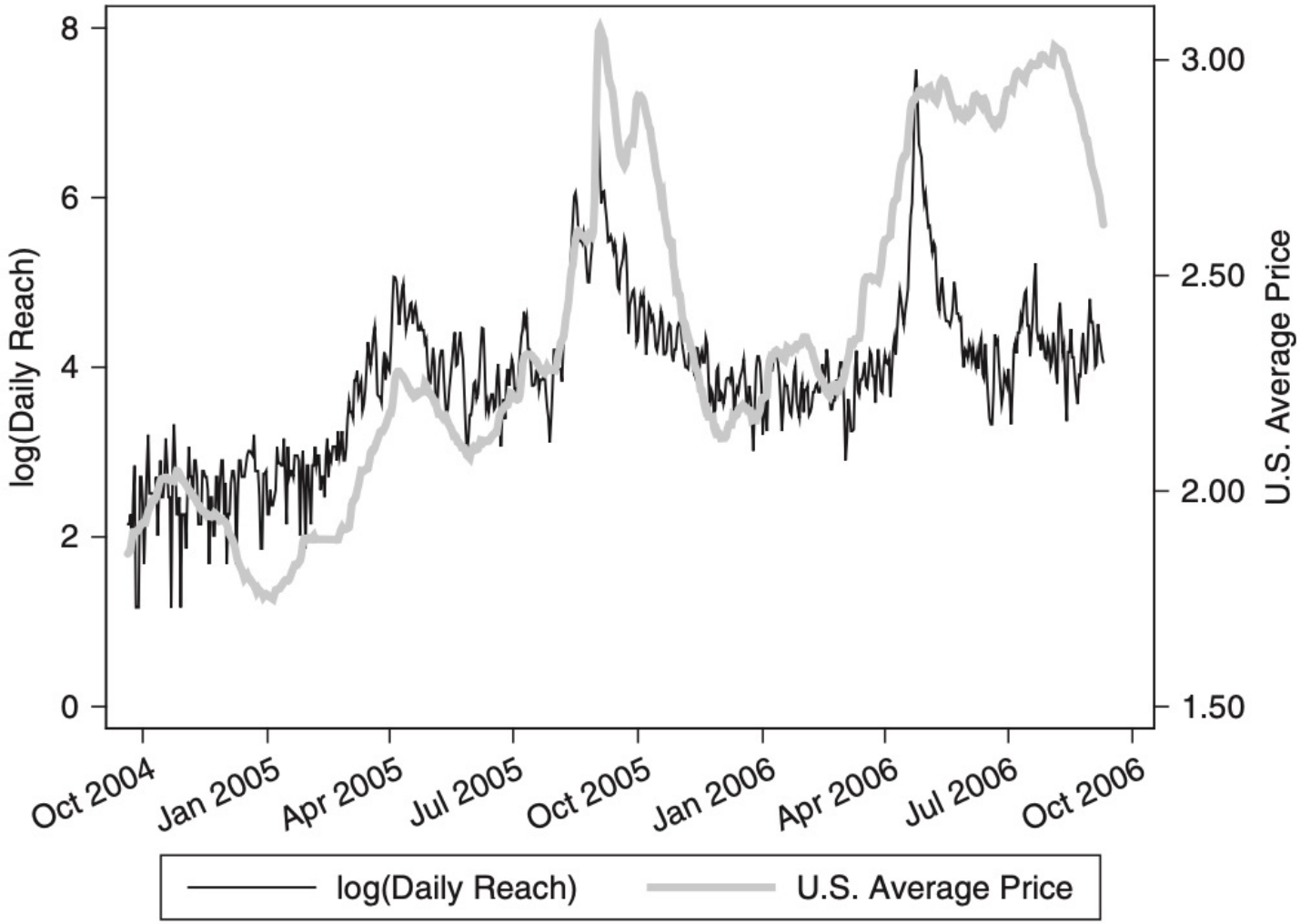

Figure 1
Average Gasoline Price and GasBuddy Traffic, 2004–2006

Note: Figure 1 in Lewis and Marvel (2011).

Homework 7

- Provide one industry/market in which search costs are likely to be important. Do you observe the price dispersion in the market?
- Assume that you have the browsing data on Amazon, and answer the following questions:
  - Within the same (homogeneous) product, can you come up with a measure to proxy the search cost of each user?
  - Across the products, can you come up with a measure to proxy the search cost for each product?
- Note: Actually you can find some browsing data on Kaggle. If you are interested in the empirical analysis, you can directly download the data and construct the measure to see the results. However, this is not required in the homework.