AN ABSTRACT OF THE THESIS OF

Jung Teag Ko for the degree of Master of Science in Economics presented on September 2, 2005.
Title: The Estimation of Sunk Costs in the U.S. Brewing Industry

Abstract approved:

Redacted for Privacy

Victor J. Tremblay

The purpose of this thesis is to provide an estimate of sunk costs in the U.S. brewing industry and analyze the relationships among sunk costs, advertising, and concentration. The estimation procedures involves three steps: (1) estimation of the market value of new and used plant and equipment per barrel of productive capacity, (2) estimation of sunk costs per barrel of productive capacity, and (3) estimation of the total sunk costs of starting a new firm at efficient size. After estimating sunk costs, we investigate the relationships between sunk costs and advertising expenditures and sunk costs and concentration in the U.S. brewing industry. Our Empirical results suggest that sunk costs and advertising expenditures have negative relationship from 1950 to 1975, but have high positive relationship during 1976-2000. Sunk costs and concentration also have high positive correlation from 1950 to 2000 in the U.S. brewing industry.

The Estimation of Sunk Costs in the U.S. Brewing Industry

by
Jung Teag Ko

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 2, 2005
Commencement June 2006

Master of Science thesis of Jung Teag Ko presented on September 2, 2005.

APPROVED:

Redacted for Privacy

Major Professor, representing Economics

Redacted for Privacy

Chair of the Department of Economics

Redacted for Privacy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for Privacy

Jung Teag Ko, Author

ACKNOWLEDGEMENTS

The author expresses sincere appreciation towards Dr. Victor, J Tremblay for his guidance through this thesis work. This thesis could not be completed without his help. I would like to thank Drs. Andrew, Stivers and Carol Horton, Tremblay for serving on my graduate committee. I would also like to thank my fellow graduate students including Natsuko, Yasushi and Mikayel

I am grateful to my wife, Bok Soon, for her patience and prayer during my M.S program. I would like to thank my lovely two sons, Han Byul, John. I want to thank my parents for all their love and support. I want to give thanks to Emily's family and the members at Corvallis Korean Church because of their love and prayer.

I would like to thank GOD who has been guided and will guide my family in USA.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

The Estimation of Sunk Costs in the U.S. Brewing Industry

I. Introduction

The effect of sunk costs on the structure of industry has been one of the most important topics in the field of industrial organization because of their effect on entry and exit to a market, concentration, and competition. Sunk costs are costs that cannot be recovered when a firm exits the industry. Investments in research and development are primarily sunk. For example, investments incurred in research and development are risky and not recoverable if a firm goes out of business. Because of these characteristics, entry may be impeded and concentration may be high in markets with high sunk costs.

The main purpose of this thesis is to estimate sunk costs in the U.S. brewing industry. The estimation of sunk costs is important because they have never been estimated directly, and these estimates can be used to find the relationships between sunk costs and entry, concentration, and competition in the U.S. brewing industry. Sutton (1991 and 1998) and Tremblay and Tremblay (2005) argue that research and development expenditures and advertising expenditures are important sunk costs. After estimating sunk costs, we investigate the links between sunk costs and advertising expenditures and

between sunk costs and industry concentration in the U.S. brewing industry.

The remainder of the thesis is organized as follows: Section II describes the theory of sunk costs and provides a brief summary of the empirical literatures on sunk costs. Section III discusses how sunk costs have been measured in previous studies. We provide a more accurate measure of sunk costs and use it to estimate sunk costs in the U.S. brewing industry. Section IV reports our empirical results and implications, and discusses their relevance to the brewing industry. The final section provides concluding remarks.

II. The Theory of Sunk Costs

Sunk costs affect entry and exit decisions, industry concentration, and the degree of industry competition. Sunk costs represent a barrier to entry and exit. A firm that is considering whether to enter a new market will consider the risk of entering one with high sunk costs, since they are not recoverable if the firm goes out of business. In the case of an export market, sunk costs would include the costs of breaking into foreign markets, analyzing market conditions, and exploring opportunities including upgrading product quality, packing and the establishment of marketing channels. Sutton (1991 and 1998) and Tremblay and Tremblay (2005) argue that expenditures on research and

development and advertising expenditures are important sources of sunk costs. When sunk costs rise, ceteris paribus, Sutton argues that the lower bound on industry concentration will rise.

Sutton (1991) classifies sunk costs into two types: exogenous and endogenous. One type of exogenous sunk costs is that associated with acquiring a single plant of minimum efficient scale. In this case, sunk costs are determined by the nature of technology and are considered exogenously given setup costs. In homogenous goods markets where price competition is tough, the equilibrium number of firms will be greater (i.e. concentration will be lower) as the size of the market grows. In markets with product differentiation and exogenous sunk costs, price competition may be dampened and concentration is lower than in the homogenous goods case. Concentration will still fall, however, as the size of the market expands.

Endogenous sunk costs include expenditures on strategic variables that are not recoverable, such as advertising and research and development. In some markets, the act of entry requires the conversion of liquid assets into advertising capital. Highly specific investment costs, like research and development expenditures, are usually sunk. In this case, endogenous sunk costs affect industry concentration in two ways. First, as in the exogenous case, an increase in the size of the market reduces concentration. Indirectly, however, a larger market increases advertising and R & D expenditures, which increases

sunk costs and concentration. If sunk costs rise with the size of the market, a larger market need not support more firms.

Ideally, sunk costs should be measured as the difference between the cost of all assets minus depreciation and the market value of all assets. In previous research, a number of different measurements are used as proxies for sunk costs. The following is a brief summary of their research.

Kessides (1986) uses advertising as a proxy for sunk costs and a barrier to new competition. His model isolates three separate effects of advertising on entry: the effect on the measured rates of profit, the effect on the irreversible costs of entry, and the effect on the uncertainty underlying the environment faced by potential entrants. Sample data consist of all 266 observations of the 4-digit U. S. manufacturing industries that experienced net entry between the census years 1972 and 1977. The estimated results show that, for the potential entrant, the need to advertise leads to an unrecoverable entry cost in the case of failure, and thus advertising creates a barrier by raising sunk costs.

Roberts and Tybout (1997) develop an econometric model of a firm's decision to export and estimate the quantities of sunk costs to enter an export market using micro panel data in four Columbian manufacturing industries (1981-1989). Sunk costs consist of the costs of packaging, upgrading product quality, establishing marketing channels, and accumulating information on demand sources in the export market. The test looks at

the presence of sunk costs and quantifies the importance of sunk costs to explain export patterns. The results reject the hypothesis that sunk costs are zero. The presence of sunk costs affect whether a firm decides to export or not. They also find that the re-entry costs of firms that have been out of the export market for a year are substantially less than the costs of new entrants. This is consistent with the view that an important source of sunk entry costs for Colombian exporters is the need to accumulate information on market conditions, information that is likely to depreciate over time. The results indicate that sunk costs are significant in export markets.

Ghosal (2002) investigates the impact of uncertainty and sunk costs on firm survival and industry dynamics. To measure sunk costs, he adopts the methodology outlined in Kessides (1990) and Sutton (1991) to quantify sunk costs. He uses proxies for sunk costs such as rental payments on plant and equipment divided by capital stock, expenditures on used plant and equipment divided by total expenditures on new and used plant and equipment, depreciation payments divided by capital stock, and the setup costs divided by industry sales (market size). Ghosal calculates sunk costs for the Census years 1972, 1982 and 1992. Empirical analysis, covering 267 U.S. manufacturing industries over a 30-year period, indicates that higher sunk costs have a negative impact on the survival rate of smaller firms, retard entry and lead to a less skewed firm size

distribution.[1]

Gschwandtner and Lambson (2002) test the hypothesis that intertemporal variability of the number of firms should be lower in industries with higher sunk costs using data that came from 36 different countries. Their proxy for sunk costs is the difference between a cost that a firm must pay to enter an industry and the scrap value that is recouped upon exit. They use the 'the United Nation Industrial Development Organization (UNIDO) Industrial Statistics Database 1999 3-Digit level of the International Standard Classification (ISIC) Code' published by UNIDO. The problem is that entry costs per firm are not available in the UNIDO data set. There are two proxies of entry costs per firm. The first proxy is gross fixed capital formation, defined as the value of purchases and own-account construction of fixed assets during the reference year less the value of the corresponding sales. The second proxy is a measure of each industry's capital-labor ratio by calculating the intertemporal mean of gross fixed capital formation per worker. Because there is no information on the scrap value this variable is ignored. Empirical results that the coefficient on the intertemporal mean number of firms is positive and significant, and that the coefficients of proxies show negative sign and are statistically significant at the 10% level show that sunk costs have a significant, persistent, and predictable effect on the behavior of firms over time.

Klimek (2004) studies the presence of sunk costs in three regional manufacturing

[1] See Ghosal (2002) p. 21-22.

industries: fluid milk (SIC2026), bread and other bakery products (SIC2051), and bottled and canned soft drinks and carbonated waters (SIC2086). The method of estimating sunk costs follows Roberts and Tybout (1997). He describes sunk costs as a function of prior period experience in the industry. There are two kinds of proxies for sunk costs: firm and market characteristics.[2] Using the Census of Manufactures data from 1963 to 1997, Klimek finds that sunk costs are an important factor in a firm's decision to participate in a market.[3]

Bakker (2005) uses the theory of sunk costs and market structure to explain the extraordinary decline of the European film industry.[4] He considers the following costs: outlay on individual film production, outlay on portfolios of films, outlay on sales promotion, outlay on research and development-capacity (studio-complexes), and outlay on national distribution networks. Bakker identifies the first three as sunk costs, and the last two as fixed costs. The outlay on films and film portfolios include four factors, such as the quantity of inputs used, input prices, setup costs, and larger unit sizes (longer

---

[2] The firm characteristics contain log labor productivity, the log ratio of production workers to total employment, log wages, the log ratio of production workers wages to total salaries and wages, the size of firm, an indicator variable for specialization that is equal to 1 if the firm has more than 50 percent of production on the industry and 0 otherwise, and the number of geographic markets. The market characteristics include the costs of operating in market, such as the log of the average production worker wage and of the average price for a kilowatt hour in the market; the number of firms; the sum of total production in the market; Herfendahl index; and the demand in each market. For detailed models they add three variables such as the firm that has production experience in an adjacent market, and the firm that may already be producing in the market in both related and unrelated industries.

[3] See Klimek (2004) for more detail variables explain and results of regression (table 22-24).

[4] Film industry includes production, distribution and marketing of motion picture.

films). He finds that the remarkable decline of the European film industry during the 1910s results from higher sunk costs in spite of the increase in the size of the film market. This supports Sutton's idea that sunk costs affect market structure.

In the Sutton's work (1991 and 1998) we learn that not only exogenous setup costs but also endogenous advertising expenditures and research and development raise sunk costs and increase industry concentration. The implication of Sutton's model is that sunk costs and industry concentration depend on advertising, market size, minimum efficient scale (MES), and the degree of price competition. Tremblay and Tremblay (2005) support the hypothesis that advertising expenditures are important concentration determent in the U.S. brewing industry.[5]

The main goal of this thesis is to provide an accurate estimate of sunk costs and consider directly the link between sunk costs and concentration. This is important because previous studies have used imprecise measure of sunk costs, which makes it difficult to accurately test the relationship between sunk costs and industry concentration.

One of the fundamental characteristics of market structure is industry concentration that characterizes the number and size distribution of firms. Two commonly used methods of measuring industry concentration are the four-firm

[5] See the Regression results (Tremblay and Tremblay Table 3.4, p. 64-65).

concentration ratio (CR_4) and the Herfindahl-Hirschman Index (HHI).[6] If the number of competitors decreases and the variance of market shares increases, then both CR_4 and HHI will rise. CR_4 and HHI can be reparameterized to range from 0 to 1, with higher values indicating greater industry concentration.

III. Estimating Sunk Costs

We can not observe sunk costs directly, so many scholars have tried to measure sunk costs by proxy. Kessides (1986) considers just advertising costs as sunk costs in manufacturing industries. Roberts and Tybout (1997) suggest that sunk costs contain the costs of packaging, upgrading product quality, establishing marketing channels, and accumulating information on demand sources. Ghosal (2002) proxies rental payments on plant and equipment divided by capital stock, expenditures on used plant and equipment divided by total expenditures on new and used plant and equipment, depreciation payments divided by capital stock, and the setup costs divided by industry sales (market

---

[6] The four-firm concentration ratio can be expressed like that $CR_4 = ms_1 + ms_2 + ms_3 + ms_4$ where ms_i =market share of firm i, when i ranges from the largest firm to the fourth largest firm.
The Herfindahl-Hirschman Index (HHI) can be measured as
$HHI = ms_1^2 + ms_2^2 + ms_3^2 + ms_4^2 \cdots + ms_i^2$
$= \frac{1}{N} + Var(ms_i)$, where ms_i^2 = the square of market share of firm i, i is from 1 to n. N is number of firms in industry. $Var(ms_i)$ is a variance of firm market share.

size). Gschwandtner and Lambson (2002) use two proxies for sunk costs. The first proxy is gross fixed capital formation. The second proxy is a measure of each industry's capital-labor ratio. Klimek (2004) uses period production experience, and Bakker (2005) uses costs on the outlay on individual film production, on portfolios of films, and on sales promotion for sunk costs in the European film industry.

These proxies may not provide an accurate estimate of sunk costs. To avoid this measurement error we try to estimate sunk costs directly. To accurately measure sunk costs, we need to estimate the value of new and used plant capacity in the brewing industry because the difference between the two equals sunk costs.

Tremblay and Tremblay (2005) provide estimates of the value of a barrel of new and used plant capacity found in brewing industry trade journals.[7] There are 13 observations for the value of new plant capacity and 19 observations for the value of used plant capacity from 1950 to 2000. The goal of their research is to estimate missing values of new and used plant and equipment for the U.S. brewing industry. This will provide direct estimate of sunk costs.

Let $\widehat{SC}$ represent predicted real total sunk costs. Let $\widehat{Vnb}$ represent the predicted value of a barrel of new plant capacity, $\widehat{Vub}$ represent the predicted value of a barrel of used plant capacity, PPI represent Producer Price Index, and MES represent

[7] See Tremblay and Tremblay (2005) Table 3.2, p. 50.

Minimum Efficient Scale. In this case, the predicted real value of total sunk costs is:

$$\widehat{SC} = \left[\frac{(\widehat{Vnb} - \widehat{Vub})}{PPI} \right] * MES \tag{1}$$

We consider three steps to estimate predicted real total sunk costs in the U.S. brewing industry: prediction of new and used value of a barrel of new and used plant capacity, estimation of predicted real sunk costs per barrel, and estimation of predicted real total sunk costs.

The first step is to predict the value of a barrel of new and used plant capacity from 1950 to 2000. Economic theory suggests that there are four main elements that determine the value of a used plant. The first is the effect of technology. Technological change has made large-scale production more efficient. Tremblay (1987), Kerkvliet, et al (1998) and Xia and Buccola (2003) find that the U.S. brewing industry experienced considerable technological change. We use a time trend (1950 = 1) to control for technological change. The sign on the technological change should be negative because a new technology is likely to lower the value of older used plant and equipment. The second is Producer Price Index for malt beverages (*PPImalt*). This controls for cost shocks in the U.S. brewing industry. It is normalized so that *PPImalt* equals 100 in 1982. The sign on this element should be positive. The third is scale efficiency (SE) that equals market share that a firm must reach to be at MES. SE is expressed as MES divided

by Quantity of production in brewing industry.[8] The sign of SE will be positive. For production efficiency, a firm must reach MES, the size necessary to reach and take advantage of all scale economics. As firms have enough time to adjust all factors of production in the long run, new production facilities will be built large enough to take advantage of all economies of scale. The last factor is firm effects that affect the value of used facilities. This is measured as the average age of the plant and equipment, which should capture embedded technology. So we consider the average age of a plant because an old plant is less valuable than a new plant. The sign on the firm effect will be negative. Equation (2) expresses the simple model used to predict the value of a barrel of used plant capacity in U.S. brewing industry.

(2) $$V_U = f(t, PPImalt, SE, FIRM)$$

where t is a time trend, $PPImalt$ is the Producers Price Index for malt beverages, SE is scale efficiency, and $FIRM$ is the average age of each firm's plant and equipment.

Next, we must estimate the value of a new plant. Assuming markets are reasonably competitive, replacement costs determine the value of new plant and equipment, which are affected by technology and construction costs. As more plant and equipment are demanded in brewing, the costs through the value of a new plant will rise. Our model includes a time trend t, and t^2 to control for non-linearities in technology

[8] Tremblay and Tremblay (2005) estimate MES in the U.S brewing industry. We use their estimated MES.

change. The sign on the time trend will be positive and the sign on the t^2 will be negative. We use two indexes for building and other costs, the Producer Price Index for malt beverages ($PPImalt$) and the Producer Price Index for construction machinery and equipment ($PPIc$). To consider the value of a new plant we have to include construction costs at the year of construction. $PPIc$ reflects construction costs at each year of construction. $PPImalt$ also represents the costs of malt beverage production in the brewing industry. The signs on both will be positive. In this case,

(3) $$V_N = f(t, t^2, PPImalt, PPIc)$$

Following Greene (2003, p. 111) we predict missing values in our data set. To predict missing values, first we apply to the following linear regression models by Ordinary Least Squares:

(4) $$V_U = a_0 + a_1 t + a_2 PPImalt + a_3 SE + a_4 FIRM + e_{ut}$$

(5) $$V_N = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 PPImalt + \beta_4 PPIc + e_{nt}$$

After running regression models we get parameters at each equation. We apply these parameters to our original data set to predict missing values of the dependent variables.

The second step is to find the predicted real sunk costs per barrel. We calculate predicted sunk costs per barrel as the difference between predicted new and used values of a barrel of new and used plant capacity. Each predicted sunk costs data per barrel is expressed in nominal terms. So we need to change to the real value of sunk costs, which

can be expressed by the estimated predicted sunk costs per barrel divided by PPI. By using Producer Price Index (PPI) we can correct inflation effects in the U.S. brewing industry.

The third step is to find the predicted real total sunk costs at the firm level. This equals predicted real value of sunk costs per barrel, multiplied by MES in the U.S. brewing industry. This gives the value of sunk costs for a firm that has a brewing capacity that equals MES.

After finding an estimate of sunk costs, we investigate the relationships between sunk costs versus advertising and between sunk costs versus concentration in the U.S. brewing industry. Sutton (1992) and Tremblay and Tremblay (2005) argue that advertising increases sunk costs and concentration in the U.S. brewing industry.

To better understand the relationship between sunk costs and industry concentration, we run the linear regression model following Tremblay and Tremblay (2005). In this specification, concentration in period t depends on sunk costs in period t and on concentration in period $t-1$. We estimate a model with two different measure of concentration.

(6) $$CR_{4t} = \alpha_0 + \alpha_1 SC_t + \alpha_2 CR_{4t-1} + e_{ct}$$

(7) $$HHI_t = \beta_0 + \beta_1 SC_t + \beta_2 HHI_{t-1} + e_{ht}$$

where CR_{4t} is the four-firm industry concentration in period t, HHI_t is the

Herfindahl-Hirschman Index in period t, and SC is predicted total sunk costs (in 1982 dollars).

IV. Empirical Results

Table 1 describes all data and sources used to estimate sunk costs in section III. Our first goal is to estimate equations (4) and (5) and then use the parameter estimates of those models to predict missing values of new and used plant capacity. With these estimates and estimate of MES, we can estimate predicted real total sunk costs.

The regression results from equation (4) and (5) are reported in Table 2. The results from the value of new plant (Vnb) model imply that the time trend (t) significantly increases the value of new plant at the 10 percent level, and the square time trend (t^2) has a significant negative effect on the value of new plant at the 5 percent level. The Producer Price Index for malt beverages ($PPImalt$) significantly increase the value of new plant at the 5 percent level. The Producer Price Index for construction machinery and equipment ($PPIc$) has a negative, but insignificant effect on the value of new plan. The estimate of the Vub model shows that the Producer Price Index for malt beverages ($PPImalt$) is a significant positive relationship to the value of used plant at the 5 percent level and the firm effect ($FIRM$), the average age of each firm, significantly decreases

the value of used plant at the 1 percent level. Scale efficiency (SE) has a positive effect on the value of used plant.

Table 3-A shows the data used in regression analysis such as the value of new and used plant capacity, time trends (t, and t^2), the Producer Price Index for malt beverages ($PPImalt$), the Producer Price Index for construction machinery and equipment ($PPIc$), the Producer Price Index (PPI), Scale efficiency (SE), and firm effect ($FIRM$).

Table 3-B lists predicted values of new and used plant capacity per barrel ($\widehat{Vnb}$ and $\widehat{Vub}$), predicted sunk costs per barrel of capacity ($\widehat{SC}_b$), predicted real sunk costs per barrel of capacity (Real $\widehat{SC}_b$), predicted real total sunk costs needed to reach MES per each firm ($\widehat{SC}$), four-firm concentration ratio (CR_4), herfindahl-hirschman index (HHI), and real advertising expenditures from 1950 to 2000.

Figure 1 depicts the trend in predicted values of new and used plant capacity in the U.S. brewing industry from 1950 to 2000. Figure 2 depicts the difference between predicted values of new and used plant capacity, which is predicted sunk costs per barrel of capacity. By dividing Producer Price Index (PPI) we calculate the predicted real sunk costs per barrel of capacity (See figure 3.). The predicted real total sunk costs for the U.S. brewing industry are measured as the predicted real sunk costs per barrel of capacity, multiplied by MES from 1950 to 2000.

Figure 4 shows that sunk costs are continuously increased from 1950 to 1985. Tremblay and Tremblay (2005) suggest that higher sunk costs may have been caused by higher advertising and other marketing efforts of the major brewers. To consider this factor in the sunk costs model, we illustrate the trend of advertising in the brewing industry from 1950 to 2000. (See figure 5.)

One of the most important forms of non-price competition in the U.S. brewing industry is advertising. Figure 5 indicates the trend of real advertising in the U.S. brewing industry since 1950. Three major brewers spent about $744 million on advertising; $4.60 per barrel in 2000.[9]

Figure 6 shows the trends of the predicted total sunk costs versus real advertising expenditures in the U.S. brewing industry. The evidence suggests that there are two trends. From 1950 to 1975, the correlation coefficient between sunk costs and advertising expenditures is -0.268, implying negative relationships. From 1976 to 2000, the correlation coefficient of the two is 0.72 that shows the two variables have high positive relationships. This suggests that sunk costs are positively associated with advertising expenditures during this period.

Figure 7 sketches the trend in CR_4 and HHI in the U.S. brewing industry from 1950 to 2000. The data are described in Table 3-B. Both CR_4 and HHI show a

[9] Three major brewers in the U.S Brewing industry are Anheuser-Busch, Miller, and Coors. Source: Tremblay and Tremblay (2005) p171.

continuously increasing concentration pattern. For example, CR_4 has increased from about 22 percent in 1950 to 94 percent in 2000 and HHI has increased from about 2 percent in 1950 to 36 percent in 2000.

Tremblay, Iwasaki and Tremblay (2005) describe that causes for increasing concentration in industry are demand and cost conditions, production efficiency, technological change, individual firm effects, merge, and government actions.[10] There are two factors that influence industry concentration in the U.S. brewing industry: new technologies and sunk costs. New technologies raise MES relative to the size of the market and also increase dramatic industry concentration. Table 4 shows MES, efficient and actual market share, the number of firms needed to reach MES and the production of the average firm in the industry from 1950 to 2000. In the case of sunk costs, we find that the relationship between sunk costs and concentration is very high. The correlation of sunk costs and HHI is 0.85 and the correlation of sunk costs and CR_4 is 0.93. The evidence show that rising sunk costs contributed to increased concentration in the brewing industry from 1950 to 2000.

Table 5 reports the regression estimates of industry concentration with sunk costs from equation 6 and equation 7. The results from equation 6, which measures

[10] Government policy such as the antitrust is also contributed to the concentration in the brewing industry (See Schmalensee 2004).

concentration as CR_4, imply that sunk costs increases concentration but it is insignificant. The effect of lagged concentration is positive and significant at the 1 percent level. The results from equation 7, which measures concentration as HHI, shows that sunk costs significantly increases concentration at the 5 percent level. The effect of lagged concentration is also positive and significant at the 1 percent level. The evidences are sensitive to the measurement of concentration, a result that is consistent with Tremblay and Tremblay (2005).[11]

V. Conclusion

Costs that have been incurred and cannot be recovered are called sunk costs. Following Sutton (1991), sunk costs can be exogenous or endogenous. Exogenous sunk costs are costs needed to enter a new business such as setup costs. Endogenous sunk costs are costs that increase a consumer's willingness to pay for firm's product offerings such as advertising and R & D. In the previous studies, scholars have used proxy variables to measure sunk costs because it is difficult to calculate sunk costs directly. Thus, many previous estimates of sunk costs may be measured with error. To avoid this problem, we

[11] See Tremblay and Tremblay (2005) Table 3.4, p. 64. They estimate that concentration in period t depends on advertising expenditures in period t, on concentration in period t-1, and on scale efficiency.

directly estimate sunk costs using estimated new and used values of a barrel of new and used plant capacity. We have some missing value problems in our data set. We apply a prediction method of estimated new and used values of plant and equipment.

The results show that sunk costs have been continuously increasing from 1950 to 1985. Real advertising expenditures do not have a same pattern. The correlation between sunk costs and advertising expenditures is a negative relationship from 1950 to 1975, a high positive relationship after 1976. Since 1976 advertising expenditure increases have led to sunk costs increases, and sunk costs increasing has caused increasing concentration in the brewing industry. The results suggest that sunk costs are positively correlated with concentration in the U.S. brewing industry but very sensitive according to the type of concentration. Empirical findings have been consistent with Sutton's theory from 1976 to 2000 and Tremblay and Tremblay (2005).

We need to study the relationship between sunk costs and internationalization of the U.S. brewing industry in future research because sunk costs will affect not only market structure but also import and export competition in the U.S. brewing industry (Tremblay, Iwasaki and Tremblay, 2005).

References

Bakker, Gerben (2005), "The Decline and Fall of the European Film Industry: Sunk Costs, Market Size, and Market Structure, 1890-1927", *Economics History Review*, VIII, 2, 310-351.

Baumol, William J., John C. Panzar, and Robert D. Willig (1982), *Contestable Markets and the Theory of Industry Structure*, San Diego: Harcourt Brace Jovanovich.

Cabral, Luis (1995), "Sunk Costs, Firm Size and Firm Growth," *The Journal of Industrial Economics*, 43, 161-172.

Colombo, Massimo G.., and Delmastro Marco (2000), "A Note on the Relation between Size, Ownership Status and Plant's Closure: Sunk Costs vs. Strategic Size Liability," *Economics Letters,* 69, 421-427.

Garella, Paolo G and Richelle Yves (1999), "Exit, Sunk Costs and the Selection of Firms," *Economic Theory,* 13, 643-670.

George, Symeonidis (2000), "Price Competition, Non-Price Competition and Market Structure: Theory and Evidence from the UK," *Economica* 67, 437-456.

Ghosal, Vivek (2003), "Impact of Uncertainty and Sunk Cost on Firm Survival and Industry Dynamics," CIC Working Papers with number SP II 2003-12, Wissenschaftzentrum Berlin (WZB), Research Unit: Competitiveness and

Industrial Change (CIC).

Giorgetti, Letizia Maria (2003), "Lower Bound Estimation-Quantile Regression and Simplex Method: An Application to ITALIAN Manufacturing Sectors," *The Journal of Industrial Economics,* 51, 113-120.

Greene, H. William (2003), *"Econometric Analysis"*, Fifth Edition, Prentice Hall.

Gschwandtner and Lambson (2002), "The Effects of Sunk Costs on Entry and Exit: Evidence from 36 Countries," *Economics Letters* 77, 109-115.

Kerkvliet, Joe R., William Nebesky, Carol Horton Tremblay, and Victor J. Tremblay (1998), "Efficiency and Technological Change in the U.S. Brewing Industry," *Journal of Productivity Analysis*, 10, 271-288.

Kessides, Ioannis N (1986), "Advertising, Sunk Costs and Barriers to Entry," *The Review of Economics and Statistics,* 68, 84-95.

_____ (1990), "Market Concentration, Contestability, and Sunk Costs," *The Review of Economics and Statistics*, 72, 614-622.

Klimek, Shawn D (2004), "Exit, Sunk Costs and Geographic Diversification in Selected U.S. Manufacturing Industries," The Pennsylvania State University.

Lambson, Val E (2000), "Sunk Costs, Entry, and the Timing of Cost-Reducing Investment," *International Journal of Industrial Organization,* 18, 1067-1084.

Lambson,Val E and Jensen F., (1995) "Sunk Costs and Firm Value Variability: Theory

and Evidence", *The American Economic Review*, Vol. 88, No. 1. (Mar., 1998), pp. 307-313.

Martin, Stephen (2002), "Sunk Cost and Entry," *Review of Industrial Organization,* 20, 291-304.

Matraves, Catherine (2002), "European Integration and Market Structure in the Soft Drinks Industry," *International Journal of the Economics of Business*, 9, 295-310.

Roberts, Mark J and Tybout James R (1999), "An Empirical Model of Sunk Costs and the Decision to Export," *Policy Research Working Paper Series,* 1436, The World Bank.

Robinson, William. T and Chiang Jeongwen (1996), "Are Sutton's Predictions Robust?: Empirical Insights into Advertising, R&D, and Concentration," *The Journal of Industrial Economics*, 44, 389-408.

Scherer, F.M., and David Ross (1990), *Industrial Market Structure and Economics Performance*, Houghton Mifflin.

Schmalensee, Richard (2004), "Sunk Costs and Antitrust Barriers to Entry", Working Paper 4457-04, MIT Sloan School of Management.

Stoneman, Paul and Kwon Myung Joong (1996), "Technology Adoption and Firm Profitability," *The Economics Journal*, Vol. 206, no.437, 952-962.

Sutton, John (1991). *Sunk Costs and Market Structure,* Cambridge, MA: MIT Press.

_____(1998). *Technology and Market Structure*, Cambridge, MA: MIT Press.

Tremblay, Victor J., and Carol Horton Tremblay (2005), *The U.S. Brewing Industry- Data and Economic Analysis*, Cambridge, MA: MIT Press.

Tremblay, Victor J., Natsuko, Iwasaki and Carol Horton Tremblay (2005), "The Dynamics of Industry Concentration for U.S. Micro and Macro Brewers," *Review of Industrial Organization* 20, 307-324.

Xia, Yin, and Steven Buccola (2003), "Factor Use and Productivity Change in the Alcohol Beverage Industries," *Southern Economics Journal* 70, no. 1: 93-109.

Table 1: Variable Name and Data source and Explain

Variable Name	Description, and Data Source
Vnb	Estimated value of a barrel of new plant capacity, dollars
Vub	Estimated value of a barrel of used plant capacity, dollars
t, t^2	Time Effect that reflects technology effect from 1950(t = 1) to 2000 (t = 51)
PPImalt	Producer Price Index for Malt Beverages (1982 = 100) Source: Bureau of Labor Statistics
PPIc	Producer Price Index for Construction Machinery and Equipment (1982 = 100) Source: Bureau of Labor Statistics
PPI	Producer Price Index (1982 = 100) Source: Bureau of Labor Statistics
SE	Scale Efficiency that equals market share which a firm must reach to be at MES: Minimum Efficient Scale (MES) divided by beer industry production. Measured in percent.
FIRM	Firm Effect : Average old year of each firm
$\widehat{Vnb}$	Predicted new value of a barrel of new plant capacity, dollars
$\widehat{Vub}$	Predicted used value of a barrel of used plant capacity, dollars
$\widehat{SC}_b$	Predicted Sunk Costs per Barrel of capacity, dollars.
Real $\widehat{SC}_b$	Predicted Real Sunk Costs per Barrel of capacity(= $\widehat{SC}_b$ divided by PPI), dollars
$\widehat{SC}$	Predicted Real Total Sunk Costs (=Real $\widehat{SC}_b$ multiplied by MES), million dollars
CR_4 (%)	Four-Firm Concentration ratio
HHI (%)	Herfindahl-Hirschman Index
Real Advertising	Total advertising expenditures divided by PP I/100, millions dollars

Source: Tremblay and Tremblay (2005), *The U. S. Brewing Industry Data and Economic Analysis*, Appendix A, p.286-289.

Table 2: Regression Estimates of the Values of New and Used Plant Capacity

Indepent Variables	Depent Variable	
	Value of New Plant per Barrel(Vn)	Value of Used Plant per Barrel(Vu)[12]
Intercept	-15.21654	22.07342***
	(1.05)	(5.49)
t	0.64978	0.16657
	(1.53)	(0.67)
t^2	-0.01*	-
	(2.20)	
$PPImalt$	1.00603**	0.01313**
	(2.47)	(2.14)
$PPIc$	-0.34347	-
	(1.25)	
SE	-	0.78108
		(0.74)
$FIRM$	-	-0.81413***
		(5.01)
F-Statistic	23.22***	7.39***
R-Square	0.9207	0.6786
Observation	13	19

The absolute values of t-statistics are in parentheses.
*** Significant at 0.01 level (two-tail test)
** Significant at 0.05 level (two-tail test)
* Significant at 0.10 level (two-tail test)

[12] We do not include t^2 in the model of the value of the used plant. When t^2 is included in the model, its parameter is small and insignificant and the estimates of sunk costs are unaffected.

Table 3-A: Data and Predicted Values (1950 – 2000)

Year	*Vnb*	*Vub*	*t*	t^2	PPImalt	PPIc	PPI	SE(%)	FIRM
1950			1	1	39.9	15.9	27.3	0.12	
1951	25.0	10.0	2	4	42.2	17.6	30.4	0.22	11
1952			3	9	44.8	17.9	29.6	0.32	
1953			4	16	45.8	18.4	29.2	0.42	
1954			5	25	47.8	18.7	29.3	0.54	
1955			6	36	47.8	19.5	29.3	0.64	
1956			7	49	48.4	21.1	30.3	0.75	
1957			8	64	49.7	22.7	31.2	0.86	
1958			9	81	50.0	23.6	31.6	0.96	
1959	30.0	10.0	10	100	50.5	24.5	31.7	1.03	16
1960			11	121	50.2	25.0	31.7	1.13	
1961			12	144	50.4	25.4	31.6	1.89	
1962			13	169	50.2	25.4	31.7	2.61	
1963			14	196	50.3	25.9	31.6	3.28	
1964	28.6		15	225	50.5	26.5	31.6	3.82	
1965		12.7	16	256	50.6	27.2	32.3	4.43	20
1965		16.7	16	256	50.6	27.2	32.3	4.43	18
1966	30.0	15.0	17	289	50.8	28.1	33.3	4.91	18
1967			18	324	51.7	29.1	33.4	5.40	
1968			19	361	52.4	30.7	34.2	5.78	
1969	40.0		20	400	53.3	32.1	35.6	6.13	12
1969		37.1	20	400	53.3	32.1	35.6	6.13	
1970			21	441	54.8	33.7	36.9	6.42	
1971			22	484	57.1	35.4	38.1	6.94	
1972			23	529	57.2	36.5	39.8	7.49	
1973			24	576	57.6	38.0	45	7.83	
1974			25	625	63.0	44.3	53.5	8.14	
1975	40.0	20.0	26	676	70.5	53.8	58.4	8.64	15
1976	40.0	4.25	27	729	71.8	57.8	61.1	9.19	36
1977			28	784	73.2	62.1	64.9	9.42	
1978			29	841	77.0	67.7	69.9	9.67	
1979		8.68	30	900	84.3	74.5	78.7	9.37	34
1979		22.7	30	900	84.3	74.5	78.7	9.37	12
1980		3.18	31	961	91.5	84.2	89.8	9.06	40
1981			32	1024	96.7	93.3	98.0	8.92	
1982	59.59	19.3	33	1089	100.0	100.0	100.0	8.94	17
1983	50.0	17.5	34	1156	105.1	102.3	101.3	8.88	19
1984			35	1225	108.7	103.8	103.7	8.99	
1985	62.5		36	1296	111.1	105.4	103.2	8.98	40
1985	60.0	4.44	36	1296	111.1	105.4	103.2	8.98	
1986		21.6	37	1369	114.1	106.7	100.2	8.81	35
1987		15.4	38	1444	113.6	108.9	102.8	8.83	17
1988			39	1521	114.4	111.8	106.9	8.81	
1989		17.9	40	1600	116.6	117.2	112.2	8.73	20
1990			41	1681	116.2	121.6	116.3	8.48	
1991			42	1764	122.3	125.2	116.5	8.73	
1992			43	1849	124.8	128.7	117.2	8.89	
1993		23.3	44	1936	123.4	132.0	118.9	8.99	19
1994			45	2025	121.1	133.7	120.4	9.07	
1995	51.0		46	2116	125.2	136.7	124.7	9.27	
1996		29.0	47	2209	128.9	139.8	127.7	9.35	21
1997			48	2304	129.2	142.3	127.6	9.54	
1998			49	2401	129.3	145.2	124.4	9.68	
1999			50	2500	132.5	147.2	125.5	9.74	
2000			51	2601	137.3	148.6	132.7	9.90	

Table 3-B: Data and Predicted Values (1950 – 2000)

Year	$\widehat{Vnb}$	$\widehat{Vub}$	$\widehat{SC}_b$	Real $\widehat{SC}_b$	$\widehat{SC}$	$CR_4(\%)$	$HHI(\%)$	Real Advertising
1950	20.10613	22.04294	-1.93681	-7.0946	-0.70946	22.0334	2.03671	423.2418
1951	22.4348	22.32099	0.1138	0.37435	0.071126	23.1788	2.22695	442.9901
1952	25.53306	22.6007	2.93236	9.90662	2.773853	24.3614	2.42884	495.1385
1953	26.89985	22.85711	4.04273	13.845	5.122643	22.9626	2.32553	547.8288
1954	29.31398	23.14508	6.1689	21.0543	9.68496	21.8384	2.32987	653.942
1955	29.52839	23.38642	6.14197	20.9623	11.52929	22.1217	2.49132	658.3311
1956	30.02709	23.64336	6.38373	21.0684	13.48378	22.8914	2.62761	649.4224
1957	31.21122	23.91395	7.29727	23.3887	17.07373	23.9711	2.71728	671.484
1958	31.59664	24.16697	7.42967	23.5116	19.27953	25.1430	2.92679	663.9019
1959	32.17593	24.39283	7.7831	24.5524	22.34265	26.1481	3.27104	681.8644
1960	32.02893	24.63192	7.39701	23.3344	23.33441	26.969	3.43296	711.0315
1961	32.38618	25.39806	6.98812	22.1143	37.5943	27.4076	3.58748	712.3101
1962	32.44244	26.12226	6.32018	19.9375	47.84991	29.4763	3.90384	702.5804
1963	32.6243	26.81124	5.81306	18.3957	57.02682	31.2713	4.17822	774.3386
1964	32.82213	27.4029	5.41924	17.1495	65.16803	32.0403	4.31855	807.057
1965	32.86909	28.05098	4.81811	14.9168	67.12541	34.4786	4.86608	815.0186
1965	33.02277	28.21755	4.80522	14.8769	66.94586	34.4786	4.86608	815.0186
1966	33.0383	28.75713	4.28117	12.8564	66.85317	36.8942	5.29156	786.7658
1967	33.70205	29.32197	4.38008	13.114	77.3726	39.0669	5.75251	748.515
1968	33.89678	29.79534	4.10143	11.9925	79.15049	41.6135	6.44009	697.9649
1969	34.34548	30.24471	4.10077	11.519	84.08881	41.1399	6.39656	698.0421
1969	34.35655	30.41128	3.94527	11.0822	80.90017	41.1399	6.39656	698.0421
1970	35.28829	30.82797	4.46032	12.0876	96.7006	44.2633	7.09531	661.8916
1971	36.95454	31.42679	5.52775	14.5085	130.5767	47.2864	7.65170	592.8688
1972	36.57477	32.02342	4.55135	11.4356	114.3556	50.7743	8.57298	560.0226
1973	36.34923	32.46552	3.88371	8.63046	94.93505	53.6230	9.52140	442.0489
1974	39.48066	32.94125	6.53941	12.2232	146.6784	56.5677	10.5649	343.0598
1975	43.55534	33.59909	9.95625	17.0484	221.6289	57.8397	11.1366	334.0205
1976	43.2801	34.20998	9.07012	14.8447	207.826	58.1888	10.4923	362.9673
1977	42.98077	34.57659	8.40418	12.9494	194.2415	62.1461	11.9731	454.8798
1978	44.59912	34.99025	9.60888	13.7466	219.9457	65.1984	13.4462	561.093
1979	49.31335	35.01508	14.2983	18.1681	290.6892	66.7161	14.8766	542.0013
1979	48.98033	35.18165	13.7987	17.5333	280.5324	66.7161	14.8766	542.0013
1980	52.546	35.2045	17.3415	19.3113	308.9801	66.5736	15.5566	718.7628
1981	54.2497	35.32866	18.921	19.3072	308.9149	68.6214	16.9757	502.0898
1982	54.83316	35.5479	19.2853	19.2853	308.5641	75.8437	19.0846	586.43
1983	58.71136	35.73955	22.9718	22.677	362.8321	77.6528	19.5510	644.6298
1984	61.33937	36.03517	25.3042	24.4013	390.4215	79.8550	21.0803	830.0878
1985	62.68411	36.23014	26.454	25.6337	410.139	81.0743	22.4151	899.5649
1985	62.15086	36.39671	25.7541	24.9556	399.289	81.0743	22.4151	899.5649
1986	64.15322	36.46789	27.6853	27.6301	442.081	82.2863	23.5940	1085.751
1987	62.27508	36.64065	25.6344	24.9362	398.9794	84.1892	25.3491	1046.867
1988	61.47418	36.80312	24.6711	23.0786	369.2582	85.6352	26.4852	1086.03
1989	61.16419	36.93576	24.2284	21.594	345.5034	86.4787	27.0733	760.7317
1990	58.53457	36.90349	21.6311	18.5994	297.59	87.5977	28.5261	722.9948
1991	62.72303	37.34329	25.3797	21.7852	352.92	88.1925	29.0703	690.3897
1992	63.27386	37.67369	25.6002	21.8431	358.2277	88.0488	29.4517	810.8788
1993	59.94248	37.89373	22.0488	18.5439	307.8295	87.8883	29.6596	732.2212
1994	56.23072	38.09537	18.1353	15.0626	253.0513	88.0054	29.9012	675.7757
1995	58.48365	38.46872	20.0149	16.0505	272.858	87.8214	29.9925	652.8011
1996	60.24097	38.74673	21.4942	16.8318	289.5074	92.0576	31.6172	640.7064
1997	58.80801	39.06873	19.7393	15.4697	269.172	91.9399	32.1275	651.5892
1998	56.96328	39.34534	17.6179	14.1623	249.257	93.0305	33.6887	701.851
1999	58.52185	39.59973	18.9221	15.0774	268.3775	95.2187	35.2645	727.9814
2000	61.86019	39.95309	21.9071	16.5087	297.1573	94.4967	36.1790	783.8335

Table 4: MES, Market Share, and Number of Firms in the U.S. Brewing Industry

Year	MES	Market Share		Number of Firms		Actual Average scale
		Efficient	Actual	Efficient	Actual	
1950	0.1	0.12%	0.29%	829	350	0.24
1960	1.0	1.13%	0.59%	88	175	0.52
1970	8.0	6.42%	1.28%	15	82	1.59
1980	16.0	9.06%	2.90%	11	42	5.11
1990	16.0	8.48%	3.49%	12	29	6.59
2000	18.0	9.90%	4.52%	11	24	8.23

MES is an estimate of minimum efficient scale (millions of barrels). The efficient market share is market share needed to reach MES. The efficient number of firms is an estimate of the cost minimizing number of firms. The actual average scale equals total beer production divided by the number of mass-producing beer companies (millions of barrels). Source: Tremblay and Tremblay (2005), Tremblay, Iwasaki and Tremblay (2005)

Table 5: Regression Estimates of Industry Concentration with Sunk Costs

Indepent Variables	Depent Variable	
	CR_4	HHI_t
Intercept	1.67767***	0.19903
	(2.64)	(1.63)
SC	0.00383	0.00237**
	(0.97)	(2.46)
CR_{4t-1}	0.98135***	-
	(45.7)	
HHI_{t-1}	-	0.99927***
		(80.59)
F-Statistic	7428.75***	11829.1***

The absolute values of t-statistics are in parentheses.
*** Significant at 0.01 level (two-tail test)
** Significant at 0.05 level (two-tail test)
* Significant at 0.10 level (two-tail test)

Figure 1: Predicted Value of New and Predicted Value of Used plant capacity per Barrel

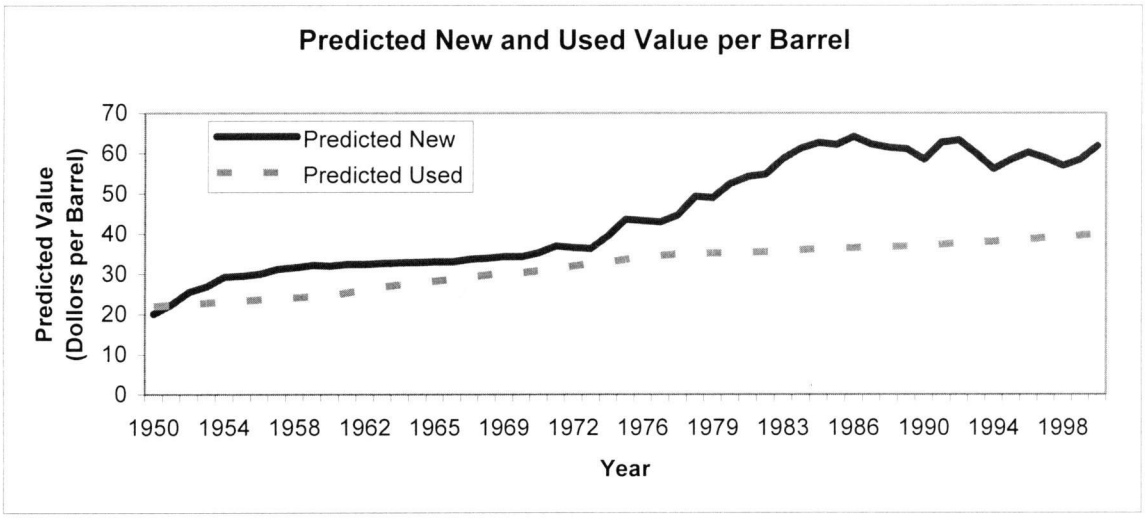


Figure 2: Predicted Sunk Costs per Barrel of Capacity

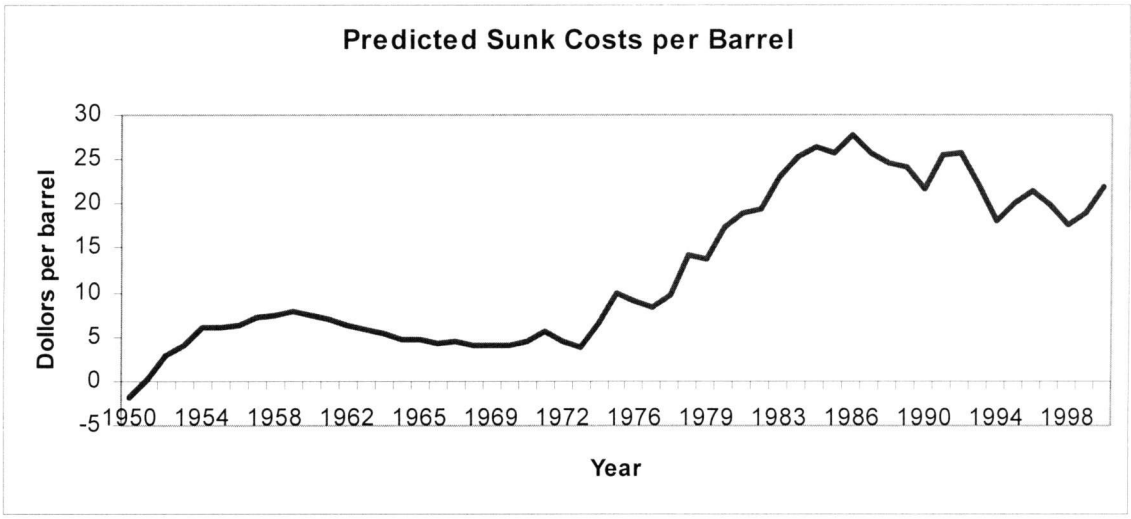


Figure 3: Predicted Real Values of Sunk Costs per Barrel of Capacity

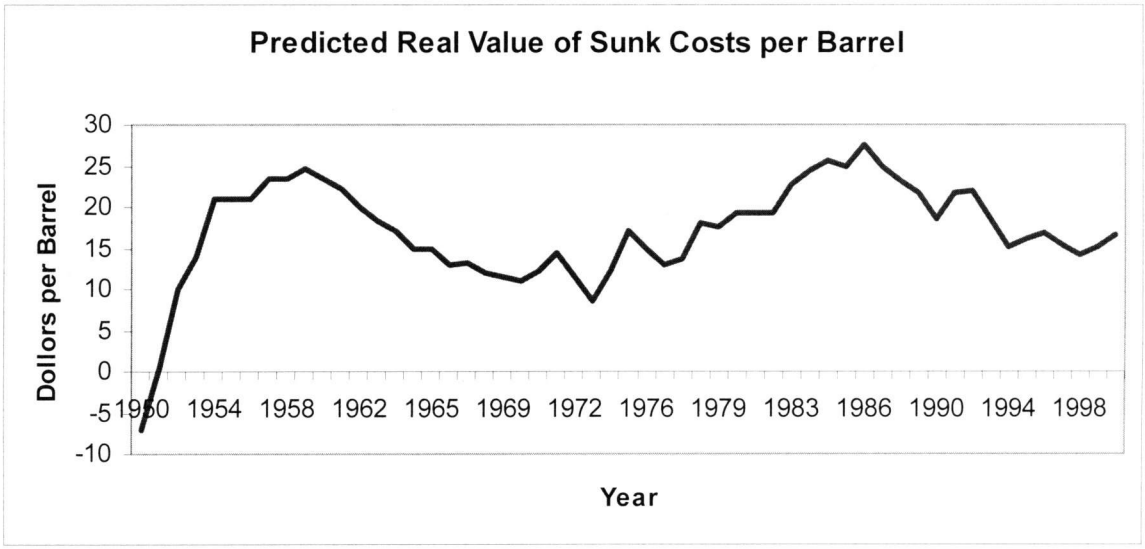


Figure 4: Predicted Real Total Sunk Costs for the U.S Brewing Industry from 1950 to 2000

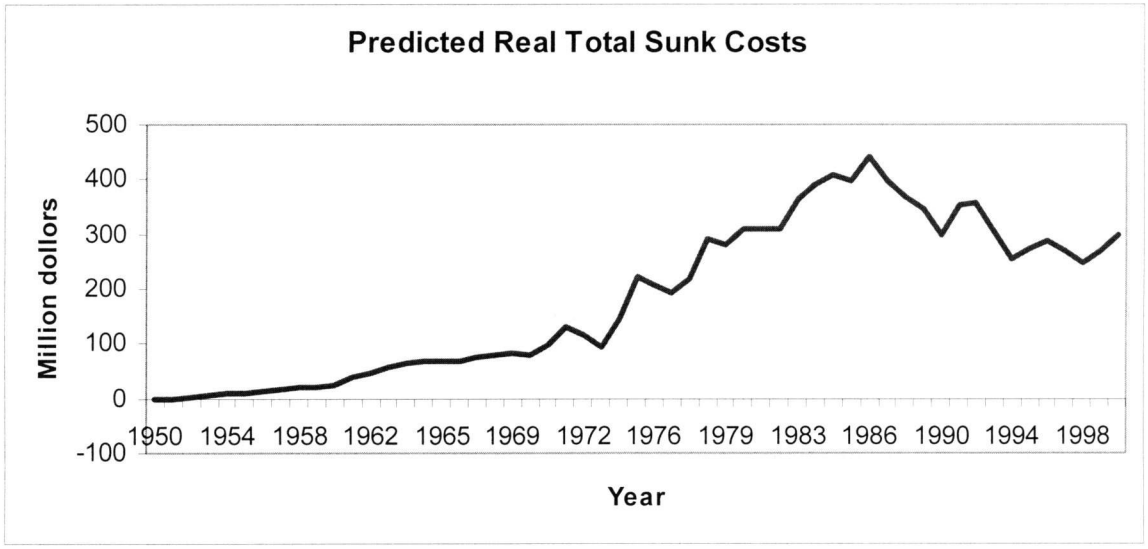


Figure 5: Real Advertising in the U.S. Brewing Industry from 1950 to 2000

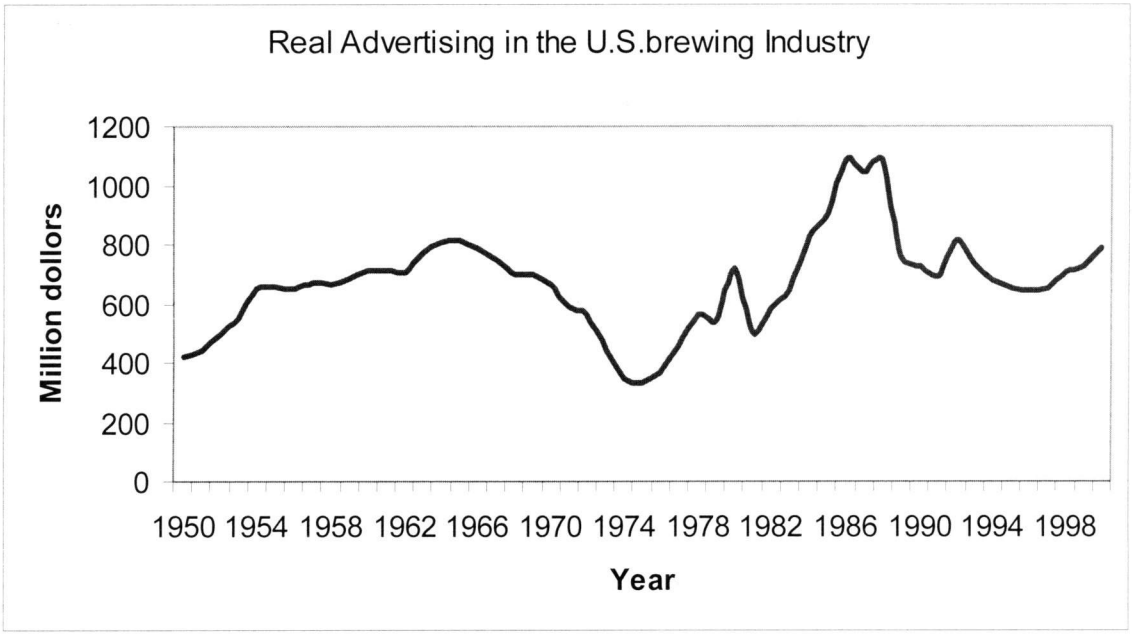


Figure 6: Predicted Real Total Sunk Costs Vs Real Advertising Expenditures in the U.S. Brewing Industry from 1950 to 2000

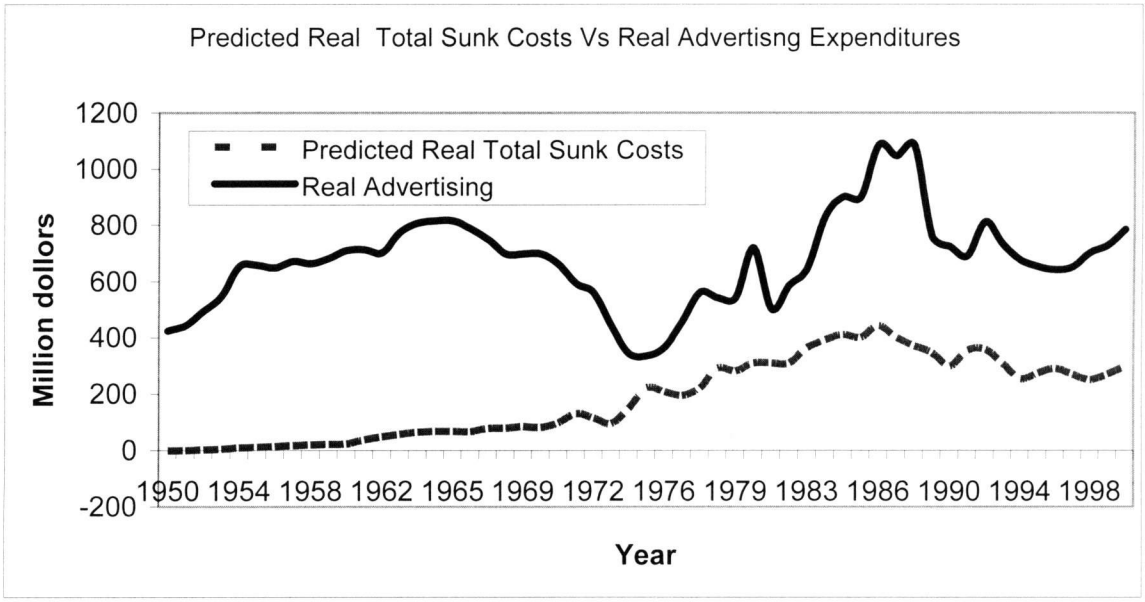
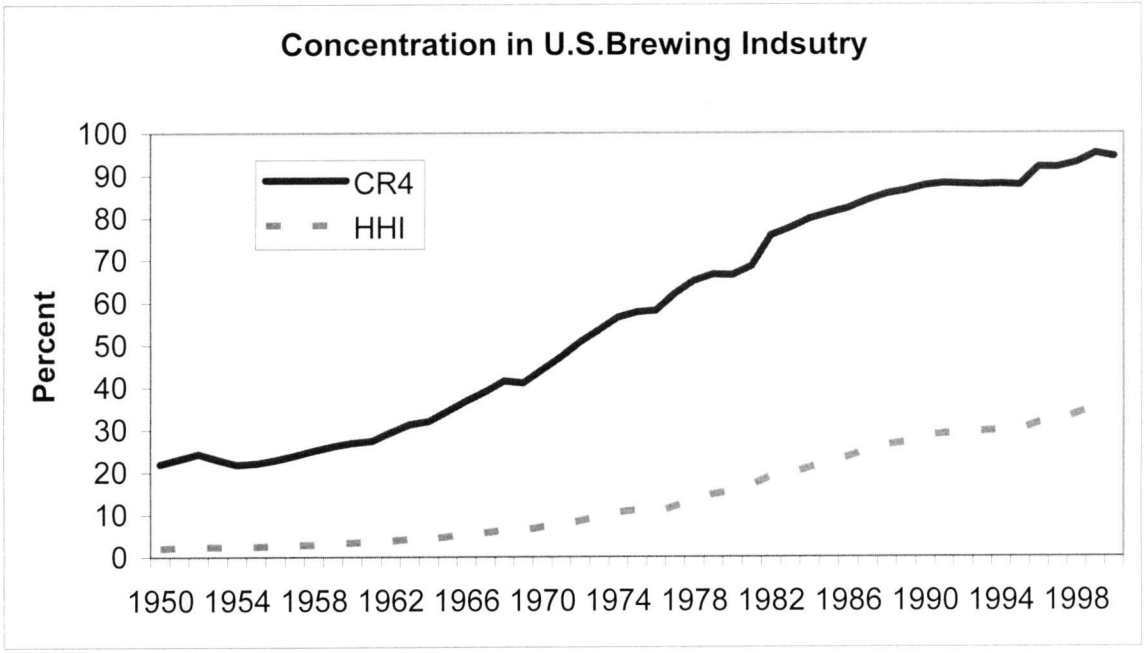


Figure 7: Concentration in the U.S. Brewing Industry, 1950-2000



Source: Tremblay and Tremblay (2005) Appendix A.