J Prod Anal (2009) 32:41–54
DOI 10.1007/s11123-009-0134-x

The effect of marketing regulations on efficiency: LeChatelier versus coordination effects

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Published online: 21 March 2009

Abstract Government regulations designed to promote social welfare can have unintended consequences on efficiency. According to the LeChatelier Principle, regulations that effectively limit substitution possibilities among inputs will reduce firm and industry-wide efficiency. In imperfectly competitive markets, however, government constraints on a strategic variable can facilitate coordination. An advertising restriction, for example, would improve efficiency if it enables firms to produce the same level of sales with less advertising spending. We use data envelopment analysis to estimate the effect of marketing regulations on efficiency in the U.S. cigarette industry. Unlike previous studies, we do not assume that marketing and production technologies are separable. Our results demonstrate that coordination effects dominate LeChatelier effects. Cigarette producers have benefited from advertising restrictions, a result consistent with the capture theory of regulation.

Keywords Efficiency · Advertising regulations · LeChatelier principle · Coordination in advertising · U.S. cigarette industry

JEL Classification D61 · L51 · M37

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1 Introduction

In order to reduce smoking and the negative externalities associated with cigarettes, the federal government has imposed severe marketing restrictions on the U.S. cigarette industry.[1] The most important restrictions come from the Broadcast Advertising Ban and the National Tobacco Settlement. In 1971, the Broadcast Advertising Ban outlawed cigarette advertising on television and radio. On November 23 of 1998, the tobacco industry and the attorney's general of 46 states agreed to the National Tobacco Settlement, which further restricted the marketing of cigarettes to youth.[2] For example, the Settlement prohibits

[1] Cigarette smoking is the leading cause of mortality in the U.S., resulting in about 400,000 deaths annually, and imposes an annual social cost of $104 billion (Sloan et al. 2006).

[2] In response to lawsuits designed to recover states' tobacco-related health care costs, the cigarette industry agreed to the National Tobacco Settlement. Four other states (Florida, Minnesota, Mississippi, and Texas) previously settled their lawsuits against the cigarette industry. As well as marketing restrictions, the Settlement included cash payments to states, funds that could be used to pay for these health-care expenses and to develop smoking-prevention programs. The settlement required the industry to pay $2.4 billion annually from December 1998 through 2003) and an additional $183.177 billion over a 25 year period, beginning in 2000. In 2000 and 2001 the payment was $4.5 billion annually, and it was $6.5 billion in 2002. The industry is also required to contribute $325 million annually to the National Foundation and National Public Education Fund, 1999 through 2003. The Settlement requires that the payments be inflation adjusted, based on 3% or the Consumer Price Index, whichever is greater. Consequently, after adjusting for the inflation, the payments are calculated as $2.4 billion (1998), $2.8 billion (1999), $7.6 billion (2000), $8.6 billion (2001) and $11 billion (2002). For further discussion of the Settlement, see the Appendix, Nader (1998), Shapiro (1998), Teinowitz (1998), Wilson (1999), Center for Disease Control and Prevention (2002), The U.S. Federal Trade Commission (2002), and Sloan and Trogdon (2004).

all outdoor advertisements, the use of cartoon characters in marketing, and the distribution of clothing that carries a cigarette logo.

The net effect of regulations such as these is ambiguous, however. On the one hand, regulations that effectively constrain marketing or production activities will limit a producer's ability to adjust to changing market conditions. Milgrom and Roberts (1996) generalization of the LeChatelier Principle demonstrates that effective restrictions will limit long-run substitution possibilities among inputs and reduce the allocative efficiency of regulated firms. On the other hand, the capture theory associated with Stigler (1971) and Peltzman (1976) indicates that industry performance will improve when regulations emerge in response to the interests of producers. Industry demand for regulation may be especially strong in imperfectly competitive industries like cigarettes where the coordination of a strategic variable is difficult to sustain without government help.

Regarding advertising, a government restriction may benefit an industry when competition induces firms to advertise more than would maximize joint profit. To illustrate, consider a market where advertising is purely predatory or combative. This occurs when one firm's advertising steals customers from rival firms and attracts no new customers to the market (Bagwell 2005). If behavior is non-cooperative, each firm will ignore the negative externality that its own advertising inflicts on its rivals, and the Nash equilibrium level will exceed the joint profit-maximizing level of advertising (Stivers and Tremblay 2005). In this setting, firms face a prisoners' dilemma: each firm's dominant strategy is to advertise more than is jointly profit maximizing. If a government fiat effectively limits advertising spending, efficiency will improve because each firm produces and sells the same level of output with less advertising.[3]

The empirical evidence is mixed regarding the effect of the Broadcast Advertising Ban on performance in the U.S. cigarette industry. Consistent with the capture theory, Eckard (1991) finds that the Ban led to a significant increase in industry profits. Mitchell and Mulherin (1988) reach a similar conclusion using the event study technique. In follow-up studies using the event study approach, however, Johnson et al. (1991) and Lamdin (1999) find evidence that the Ban did not raise industry performance, measured by tobacco stock returns.[4] Tauras et al. (2006) investigate the effect of the National Tobacco Settlement on the market share of the leading brands of cigarettes, but the effect of the Settlement on economic performance has yet to be examined.

The main purpose of our study is to investigate the effect of the Broadcast Advertising Ban and the National Tobacco Settlement on the industry's ability to use its production and marketing inputs efficiently. Because they directly affect the mix of marketing inputs, such restrictions are likely to have a larger effect on allocative efficiency than on technical efficiency. The Ban, for example, will decrease allocative efficiency if it induces firms to adopt a sub-optimal mix of marketing and/or production inputs, as the LeChatelier Principle suggests. Efficiency will rise, however, if the primary effect of the Ban is to facilitate coordination in marketing.[5] Coordination is likely to be important, because recent evidence suggests that broadcast advertising was primarily combative in the U.S. cigarette industry (Farr et al. 2001; Nelson 2003).

Our data and empirical approach do not require us to assume that production and marketing technologies are separable, as in previous research. The numerous studies of efficiency in production ignore the marketing side of the firm, implicitly assuming that production and marketing are separable.[6] Studies of marketing efficiency have just begun (Färe et al. 2004; Tremblay and Tremblay 2005; Vardanyan and Tremblay 2006), but they likewise ignore the production side of the firm. The separability assumption may be reasonable in mature markets where product characteristics are well established and marketing is designed to promote product goodwill. In this case, the marketing division's goal is to promote a positive image at lowest cost, and the production division's goal is to produce output at lowest cost.

[3] Of course, if advertising is constructive (i.e., it benefits both the firm and its rival), then firms will advertise less than is jointly profit maximizing and an advertising restriction might lower the marketing efficiency of both firms, ceteris paribus. The effect of an advertising restriction is even more complex when firms compete in both price and advertising. See Stivers and Tremblay (2005), Tremblay and Tremblay (2005), and Iwasaki et al. (2008) for further discussion of the price effect of advertising.

[4] An important concern with these studies is that other factors may influence profit rates and stock returns over time. The ceteris paribus assumption is less likely to be a concern in our study, however, because we estimate the effect of a marketing restriction on efficiency. For example, if all firms are profit maximizers and all demand and cost shocks are anticipated, then only government regulations affect efficiency. Thus, a comparison of efficiency estimates over time is appropriate, since the ceteris paribus assumption would hold. Nonetheless, in Sect. 3 we relax the assumption that all demand and cost shocks are anticipated.

[5] This is admittedly an indirect test of a prisoners' dilemma in advertising. A direct test is very difficult to perform, however, because one must test the hypothesis that a firm's profit increases when the firm increases advertising from the cartel level, assuming all other firms hold advertising at the cartel level. Because such outcomes are inconsistent with Nash and subgame perfect Nash equilibria, they are generally not observed.

[6] See Schmidt (1985–1986) for a review of the literature. For more recent applications, see Goh and Yong (2006) and McEachern and Paradi (2007).

Production and marketing need not be separable in markets where firms constantly introduce new products, however. Chaloupka (2007) documents that during our sample period, cigarette producers introduced a several new products, including brands that contain menthol, have low levels of acidity, and are "safer" (e.g., cigarettes that are low in tar, have charcoal filters, and emit little cigarette smoke). In this case, the marketing division must work closely with the production division to assure that consumers are adequately informed of new product introductions. A delayed marketing campaign may lead to greater demand uncertainty and unexpected increases in inventories, causing inefficiency in production. In addition, because the broadcast advertising Ban was so dramatic, it may have enabled management to divert attention from marketing to production, affecting production as well as marketing efficiency. Given these facts about the cigarette industry, we do not assume separability.[7]

In the sections that follow, we use data envelopment analysis (DEA) to estimate allocative, technical, and overall cost efficiency scores from 1963 to 2002. We compare efficiency scores before and during each advertising restriction.[8] Our results show that coordination effects dominate LeChatelier effects, as marketing restrictions generally have a positive effect on allocative efficiency. Although the Broadcast Advertising Ban had its greatest effect on marketing efficiency, it also affects efficiency in production.

2 Production and marketing technology

In a consumer goods industry like cigarettes, both production and marketing are important to sales. We consider a technology with both components, as in Bresnaham (1984), Seldon et al. (2000), Färe et al. (2004), and Vardanyan and Tremblay (2006). These studies assumed that production and marketing technologies are separable, producing the following full (production and marketing) cost function:

$$C(y, w_p, w_m) = \min_{x_p}\{w_p x_p : x_p \text{ can produce } y\} + \min_{x_m}\{w_m x_m : x_m \text{ can produce } y\}, \quad (1)$$

where y is output, x_p is a vector of production inputs, w_p is a vector of production input prices, x_m is a vector of marketing inputs, and w_m is a vector of marketing input prices. That is, the cost minimization process is done separately by the production and marketing divisions. The problem with this approach is that someone in management must decide y. If spending more time managing production means less time managing marketing, then the full cost function will not be separable and can be written as

$$C(y, w) = \min_{x}\{wx : x \text{ can produce } y\}, \quad (2)$$

where y is output, x is a vector of both production and marketing inputs, and w is a corresponding vector of production and marketing input prices.

In our application, we describe technology with an input requirement set, which is described as follows:

$$L(y) = \{x : x \text{ can produce } y\}. \quad (3)$$

This provides a convenient way of defining efficiency (inefficiency). To illustrate, consider the technology describe in Fig. 1 with two inputs, x_1 and x_2, where input combination A is used to produce y. Production is technically inefficient, since fewer inputs could be used to produce the same output. If we follow Farrell (1957) and contract toward the origin (0), then technical efficiency can be measured by the distance 0B/0A. This is sometimes called a technical efficiency score. Production is technically inefficient when the score is less than 1 (i.e., A > B)

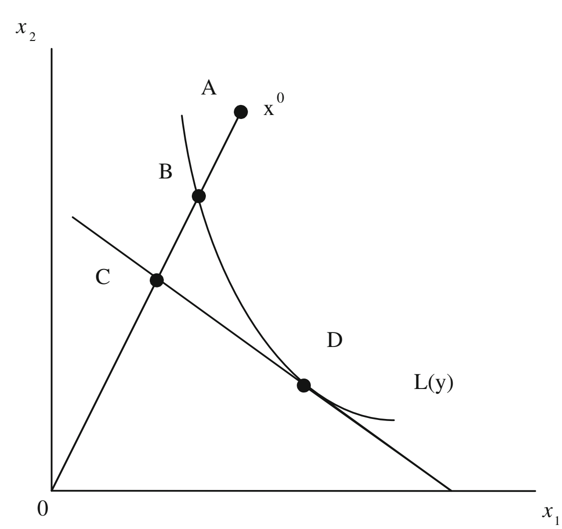

Fig. 1 Cost efficiency decomposition for two inputs

[7] The limited research on advertising by medium has focused on the issues of substitutability among media and scale economies of advertising. Bresnaham (1984) develops a method for estimating the demand for different advertising media. Silk et al. (2002) apply this method by estimating the market demand for media by national advertisers and find that there is weak substitutability and complementarity among media. On the other hand, Seldon et al. (2000) estimate a cost function for advertising in various media using a translog cost model. They find a high degree of substitutability among television, radio, and print advertising in the U.S. brewing industry. If input substitutability is high in the U.S. cigarette industry, then the Broadcast Advertising Ban would not be excessively costly to producers, because they could mitigate the effect of the Ban by reallocating expenditures from broadcast to unrestricted media.

[8] For a discussion of other welfare issues involving advertising restrictions in the U.S. cigarette market, see Farr et al. (2001) and Iwasaki et al. (2006).

and is efficient when the score equals 1 (i.e., A = B). If the isocost function associated with cost minimization is represented by the line CD, then the economically efficient point is D. By contracting toward the origin once again, allocative efficiency can be measured by the distance 0C/0B. Production becomes more allocatively efficient as B approaches C and is allocatively efficient when the score equals 1. Likewise, overall cost efficiency is measured as 0C/0A (or 0B/0A times 0C/0B). When overall efficiency is reached, points A, B, C, and D coincide, and all efficiency scores equal 1.

In our application, it is more convenient to use *in*efficiency scores, which derive directly from efficiency scores. In the example in Fig. 1, technical inefficiency is measured as 1 − 0B/0A or AB/0A; allocative inefficiency equals 1 − 0C/0B or BC/0A; overall cost inefficiency equals 1 − 0C/0A or AC/0A. In this case, overall efficiency is reached when all inefficiency scores equal zero.

Activity analysis is used to estimate a DEA frontier of the input requirement set and inefficiency scores.[9] An advantage of this approach is that it avoids imposing a specific functional form on technology. In this approach, the input requirement set for a particular observation τ, given $t = 1, 2, 3,\ldots, T$ observations and $n = 1, 2, 3,\ldots, N$ inputs, is defined as follows:

$$L(y_\tau) = \left\{ \begin{array}{ll} (x_1,\ldots,x_N) : \sum_{t=1}^{T} z_t y_t \geq y_\tau, & \\ \sum_{t=1}^{T} z_t x_{tn} \leq x_n, & n = 1,\ldots,N \\ z_t \geq 0, & t = 1,\ldots,T \\ \sum_{t=1}^{T} z_t = 1 & \end{array} \right\}. \tag{4}$$

In our application, the τ subscript represents a particular time period. We impose strong disposability of output and inputs by the inequalities in the first and second lines, respectively. Strong input disposability implies that output does not decrease if any or all feasible inputs are increased.[10] The third and fourth lines are conditions for the intensity variables, z_t; one is defined for each observation. The derived value of this variable can be interpreted as the extent to which a particular observation is involved in the production of potential outputs. The restriction that $\sum_{t=1}^{T} z_t = 1$ allows the technology to exhibit variable returns to scale: increasing, constant, or decreasing returns.

To measure technical efficiency/inefficiency, we apply the Farrell (1957) index with respect to the following linear programming model,

$$\begin{array}{lll} F_i(y_\tau, x^\tau) = \min \lambda : & \sum_{t=1}^{T} z_t y_t \geq y_\tau, & \\ & \sum_{t=1}^{T} z_t x_{tn} \leq \lambda x_{n,\tau}, & n = 1,\ldots,N \\ & z_t \geq 0, & t = 1,\ldots,T \\ & \sum_{t=1}^{T} z_t = 1. & \end{array} \tag{5}$$

where λ is an efficiency index. With this notation, x^τ represents a vector in N inputs at time period τ. In the example in Fig. 1, this measure equals 0B/0A, the minimum distance from the observed input combination (point A) to the frontier of the input requirement set (point B), divided by the distance 0A.

To determine overall cost efficiency, we must compute the minimum total cost of producing a given output for each τ. This is derived from the following model,

$$\begin{array}{lll} C^*(\tau) = C^*(y_\tau, w) = \min\limits_{x^\tau} \sum_{n=1}^{N} w_n x_n & & \\ \quad s.t. \quad \sum_{t=1}^{T} z_t y_t \geq y_\tau, & & \\ \quad\quad \sum_{t=1}^{T} z_t x_{tn} \leq x_n, & n = 1,\ldots,N & \\ \quad\quad z_t \geq 0, & t = 1,\ldots,T & \\ \quad\quad \sum_{t=1}^{T} z_t = 1. & & \end{array} \tag{6}$$

The solution to this linear programming problem gives us the lowest cost of producing a given output holding input prices fixed at time τ, $C^*(\tau)$. Overall cost efficiency is defined as the ratio of minimized cost to observed cost:

$$C^*(t) \Big/ \sum_{n=1}^{N} w_{t,n} x_{t,n} \quad t = 1, \ldots, T. \tag{7}$$

Hence, the observed cost is minimized when this ratio equals 1. Overall cost efficiency requires both allocative and technical efficiency.

A measure of allocative inefficiency can be obtained by comparing the observed input share with the optimal input share. This is described below:

[9] For a more detailed discussion of activity analysis and DEA, see Färe and Grosskopf (2004).

[10] If this is strictly equal, then it imposes the weak disposability of inputs and output and, in this case, output can be increased only when all feasible inputs increase proportionally.

$$\left[w_{t,n} x_{t,n} \Big/ \sum_{n=1}^{N} w_{t,n} x_{t,n} \right] - \left[w_{t,n} x^*_{t,n} / C^*(t) \right] \qquad n = 1, \ldots, N \qquad t = 1, \ldots, T, \tag{8}$$

where x^*_{tn} denotes the level of input n at time t that minimizes cost. The first ratio in (8) is the observed share, and the second ratio is the optimal share. Equation 8 equals zero when the industry optimally allocates its expenditure on the input (i.e., there is no allocative inefficiency). It is positive when the industry spends too much on the input category and negative when the industry spends too little.

Finally, we impose no a priori restrictions on returns to scale. In a reasonably competitive market, individual firms would be scale efficient in the long run, and technology would exhibit constant returns. If firms operate in the region of increasing (decreasing) returns, overall scale efficiency would improve if there were fewer (more) firms and each firm produced more (less) output. Figure 2 illustrates the Färe and Grosskopf (1985) measure of scale efficiency for a production function with a single input. If the production frontier is ABCDE for $y \in [y', y'']$ and actual production occurs at point B, then production takes place in the region of increasing returns. Constant returns occurs at point C. At point B, the Färe and Grosskopf measure of scale inefficiency is $x_F/x_B \leq 1$. Scale inefficiency diminishes as this measure gets closer to 1. It is useful to define scale economies (SE) as the Färe and Grosskopf measure minus 1 and take the absolute value of this measure when there are scale economies. In this case, SE = 0 for constant returns, SE > 0 for increasing returns, and SE < 0 for decreasing returns.[11]

3 Efficiency estimation results

Annual observations from 1963 through 2002 are used to estimate the production-marketing technology for the U.S. cigarette industry.[12] Production inputs include labor, capital, and materials. Marketing inputs include broadcast (television and radio), print, and other marketing messages. Variable definitions and data sources are discussed in the Appendix. Before the Ban, broadcast advertising accounted

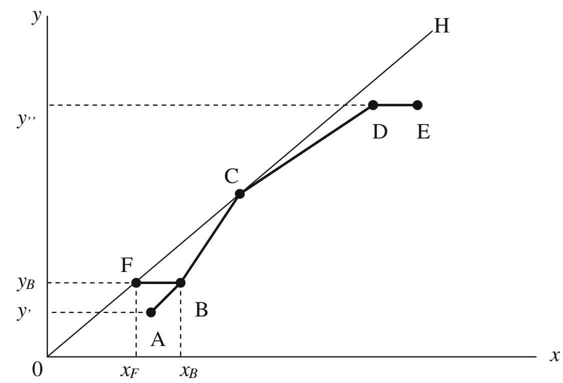

Fig. 2 Scale efficiency for single input production function

for about 70% of total advertising messages. The "other" category, primarily promotional allowances to retailers and discount coupons to consumers, became the dominant form of marketing by the 1980s.[13]

Given the extent of government regulation and the history of marketing activity in the U.S. cigarette industry, we focus our discussion on four regimes. The first regime, 1963–1970, is the pre-Ban period when broadcast advertising was dominant. The second, 1971–1986, is the period immediately following the Broadcast Advertising Ban. We break at 1986 because this is when the U.S. Surgeon General announced that second-hand smoke causes health problems in non-smokers, leading to stricter state and local clean indoor air laws (Chaloupka 1992; Chaloupka and Saffer 1992; Ross and Chaloupka 2004). The 1987–1998 delineation corresponds to a time when the industry invested more heavily in promotional marketing activity and was not yet subject to the National Tobacco Settlement. The final period, 1999–2002, marks the Settlement era.

Figure 3 plots the pattern of per-capita cigarette sales and identifies the four regimes. It shows that per-capita smoking reached a peak just before the U.S. Surgeon General's Report in 1964, the first official pronouncement that cigarette smoking causes lung cancer. The per-capita smoking rate rose slightly after the Broadcast Advertising Ban but has shown a general pattern of decline since reaching a peak in 1963.

We begin by investigating how allocative *in*efficiency changes over the sample period. Estimates of allocative inefficiency scores for each production and marketing input are displayed in Fig. 4. For clarity, we separate these out for production inputs in Fig. 5 and for advertising inputs in Fig. 6. Recall that allocative efficiency is reached when the inefficiency score equals zero, and a positive (negative)

[11] We do not discuss this issue in subsequent sections of the paper, because the focus of our study is on allocative, technical, and overall cost inefficiency. In any case, our mean estimate of scale efficiency (SE) is about 0.02, implying that the industry has operated at close to constant returns to scale during our sample period.

[12] One potential concern with using time series data is technological change (Lynde and Richmond 1999). If technological change were important, our inefficiency scores would decline over time, but our estimates reveal no such trend.

[13] Promotional activity also includes the sponsorship of local public events and the distribution of free samples.

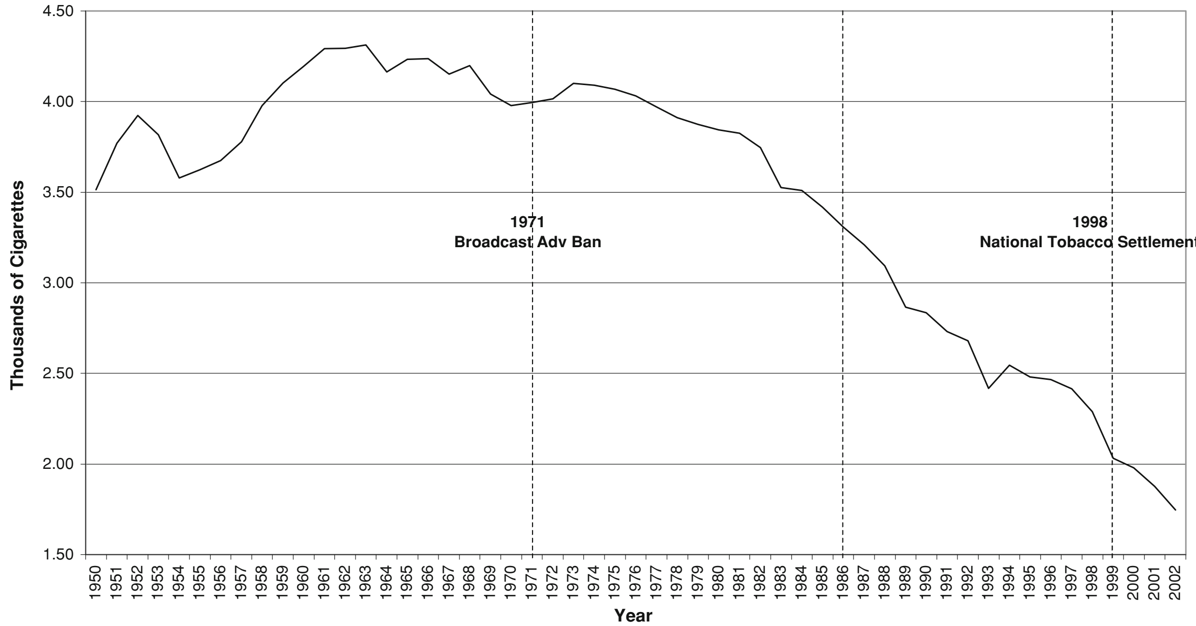

Fig. 3 Per-capita cigarette consumption

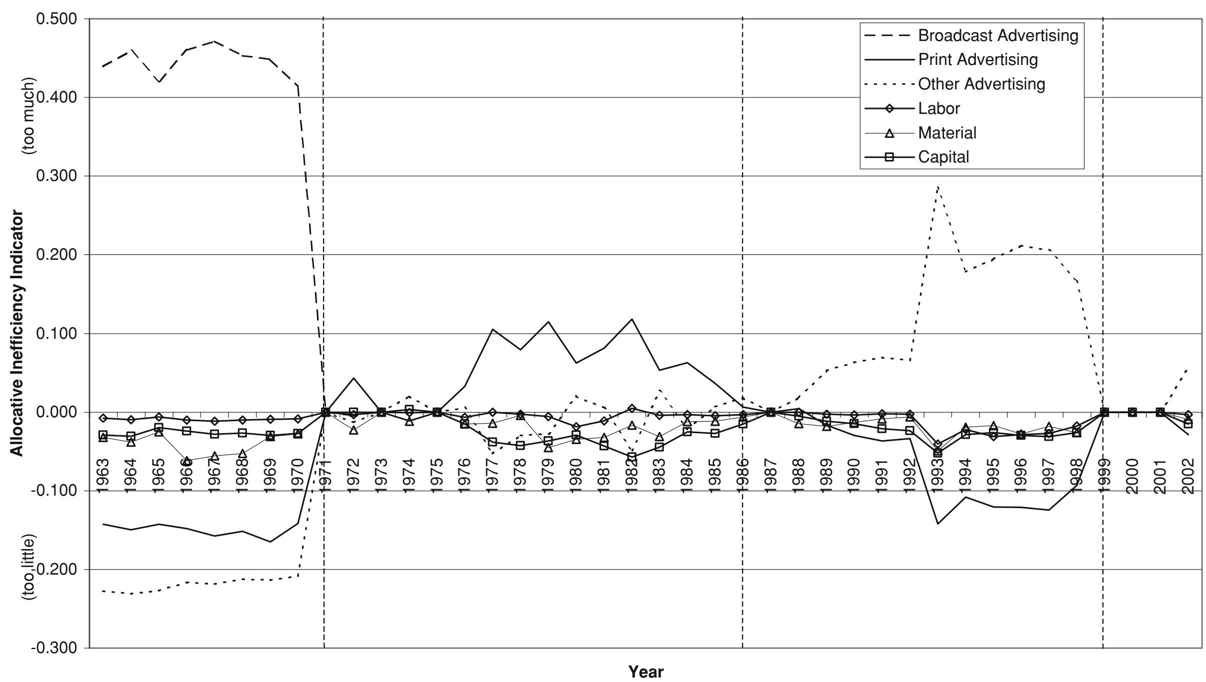

Fig. 4 Allocative inefficiency indicator for all inputs (efficient when indicator = 0)

score implies that too much (little) of the input is being used. Inefficiency scores for the production inputs (labor, materials, and capital) are all close to zero and appear to be unaffected by advertising restrictions. If true, this would imply that the production and marketing divisions are separable, as assumed in previous studies.

The marketing inefficiency scores, however, are much more volatile and indicate that the Broadcast Advertising Ban substantially reduced allocative inefficiency in advertising. Before the Ban, the industry invested too heavily in broadcast advertising and too little in print and other advertising media. After the Ban, the broadcast inefficiency

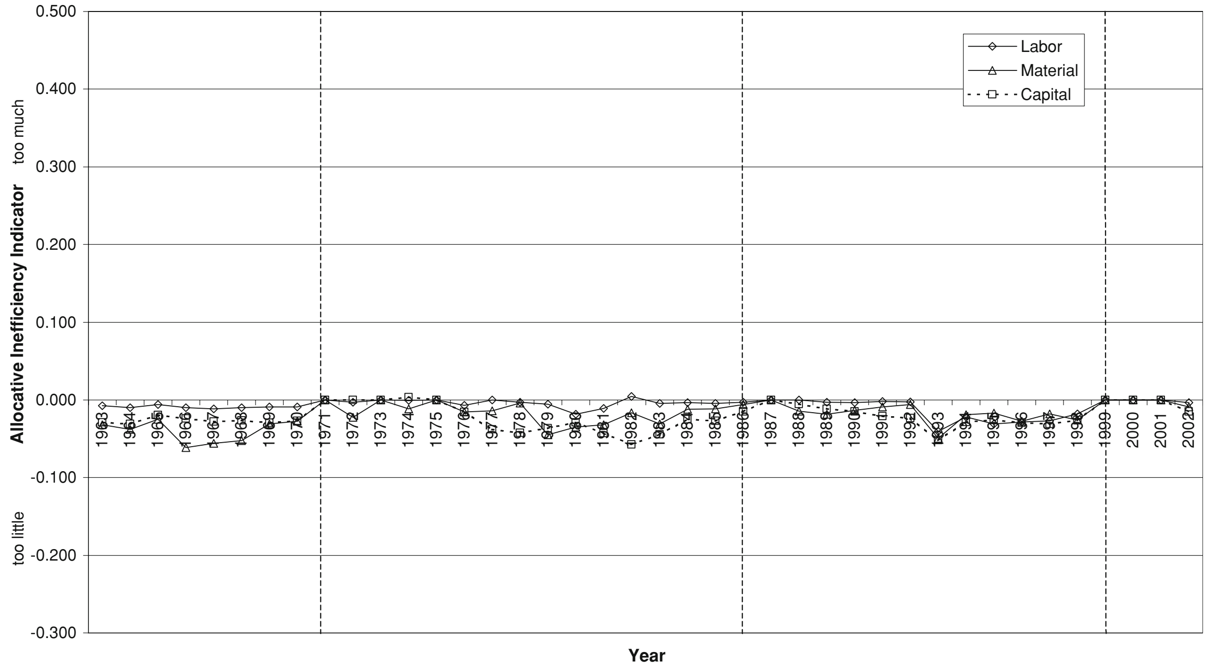

Fig. 5 Allocative inefficiency indicator of production inputs (efficient when indicator = 0)

Fig. 6 Allocative inefficiency indicator of marketing inputs (efficient when indicator = 0)

score fell to zero in every subsequent period, providing strong evidence that the optimal amount of broadcast advertising at the industry level is zero.

This can occur if the efficient point is a corner solution, as illustrated in Fig. 7. Ignoring technical inefficiency for the moment, the allocatively efficient combination of inputs is at point D, where no broadcast advertising is used to market cigarettes. For strategic reasons, however, firms operate at point A. This is consistent with the argument that cigarette producers were forced into a prisoners' dilemma

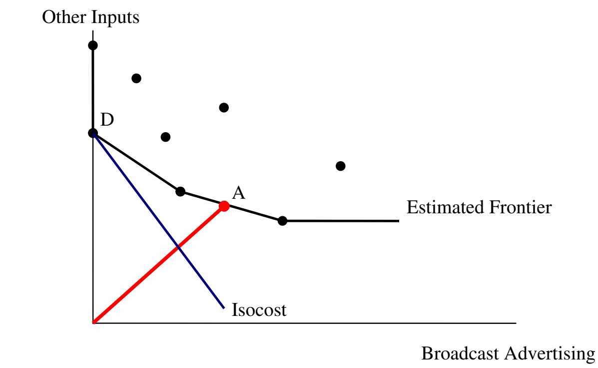

Fig. 7 Illustration of Corner Solution where the efficient allocation of broadcast advertising is zero

in broadcast advertising because cigarette advertising is predatory. Even though the cartel level of broadcast advertising is zero, cigarette producers chose their dominant strategy, which was to invest heavily in broadcast advertising before the Ban. Thus, the Broadcast Advertising Ban facilitated coordination.[14]

Although somewhat less striking, the inefficiency estimates in Figs. 4, 5, 6 also suggest that the National Tobacco Settlement led to lower allocative inefficiency in marketing. During the mid 1990s, firms competed heavily in price promotions and discounts. This is consistent with our finding that firms over-invested in the "other advertising" category during this period. For further discussion of marketing activity after the Settlement, see Tauras et al. (2006).

The upper three sections of Table 1 provide the minimum, median, maximum, mean, and standard deviation (SD) of our estimates of allocative inefficiency. Given that our sample is relatively small, standard errors are obtained by bootstrapping with one thousand trials.[15] Because the process generating allocative inefficiency in production and marketing may be different, we evaluate them separately as well as jointly.[16] The data verify that the allocative-inefficiency scores fell dramatically after the Ban (regime 1–2) and after the Settlement (regime 3–4). For example, mean scores for aggregate allocative inefficiency (marketing plus production) fell by about 89% after the Ban and by about 87% after the Settlement. The Ban's effect on marketing inefficiency is most dramatic, as the range of scores after the Ban for regime 2 (9.2E-08 to 0.0532) is well below those before the Ban for regime 1 (0.211 to 0.2622).[17]

In order to more formally evaluate the effect of advertising restrictions on allocative inefficiency, we perform a Mann–Whitney–Wilcoxon non-parametric test for distributional differences across regulatory regimes (Wackerly et al. 2001, pp. 724–730). These results are reported in Table 2. The distributions of allocative inefficiency scores are significantly different at conventional levels of significance when comparing regime 1 with 2 and regime 3 with 4. These results support the conclusion that cigarette producers invested too heavily in broadcast advertising before the Ban and that the marketing restrictions of the Ban and Settlement led to less allocative inefficiency in both marketing and production. This suggests that marketing and production technologies are not separable.

Next, we investigate the effect of marketing restrictions on technical and overall cost inefficiency. We expect these effects to be relatively small. Although an advertising restriction has a direct effect on the mix of marketing inputs (i.e., allocative efficiency), it need not induce firms to waste (conserve) inputs and raise (lower) technical inefficiency. In addition, advertising typically accounts for less than 20% of total costs before and after the Ban. Thus, a marketing restriction is likely to have a smaller effect on overall cost (allocative plus technical) inefficiency than on allocative inefficiency.

The lower two sections of Table 1 provide information about our estimates of technical and overall cost (allocative plus technical) inefficiency. As expected, the Ban and

[14] This can occur, for example, if broadcast advertising is highly combative compared to print advertising. From the industry perspective, firms will over-invest in broadcast advertising if it generates negative externalities on rival firms (i.e., it is combative) and will under-invest in print advertising if it generates positive externalities (i.e., it is constructive). This is consistent with Gallet (1999), who found that cigarette advertising became less combative after the Ban.

[15] Because allocative efficiency scores are unbounded, we use a naïve bootstrapping method to generate standard errors. This involves constructing one thousand bootstrapped samples of the efficiency scores, each of which is obtained by random sampling with replacement from the original data set. Then, we calculate standard deviations from the one thousand bootstrapped samples. Because technical and overall cost efficiency are bounded by 1, we use a bootstrap method proposed by Simar and Wilson (1998). We used a method developed by Sheather and Jones (1991) to obtain the efficient bandwidth by regime.

[16] The marketing allocative-inefficiency score is measured as the sum of the absolute values of the weighted allocative-inefficiency scores for broadcast, print, and other advertising. Weights are media share of total cost. The production allocative-inefficiency score is calculated as the sum of the absolute values of the weighted allocative-efficiency scores for labor, materials, and capital. Weights are the input shares of total cost.

[17] For the interested reader, ANOVA tests for differences in mean allocative-inefficiency scores reject the hypothesis that the means are the same in all four regimes at the 1% level of significance for marketing, production, and both marketing and production. ANOVA tests also confirm that the Ban (regimes 1 and 2) led to a significant decrease in all allocative inefficiency categories. Comparing regimes 3 and 4, the Settlement also led to a decrease in allocative inefficiency, but the difference in means in production is insignificant. These tests are suspect, however, because an ANOVA test is valid only for random variables that are normally distributed.

Table 1 Descriptive statistics on inefficiency estimates

Regime[a]	Minimum	Median	Maximum	Mean	SD
Allocative inefficiency (marketing)					
Regime 1	0.2111	0.2434	0.2622	0.2393	0.0078
Regime 2	9.2E-08	0.0204	0.0532	0.0216	0.0063
Regime 3	1.1E-07	0.0955	0.2328	0.0998	0.0412
Regime 4	5.2E-08	7.3E-08	0.0516	0.0129	0.0150
Allocative inefficiency (production)					
Regime 1	0.0083	0.0110	0.0161	0.0118	0.0016
Regime 2	4.7E-06	0.0051	0.0117	0.0054	0.0011
Regime 3	2.8E-06	0.0032	0.0080	0.0036	0.0007
Regime 4	2.6E-07	4.2E-07	0.0009	0.0002	0.0003
Aggregate allocative inefficiency (marketing plus production)					
Regime 1	0.2204	0.2554	0.2434	0.2511	0.0094
Regime 2	4.8E-06	0.0256	0.0612	0.0270	0.0075
Regime 3	2.9E-06	0.0993	0.2408	0.1034	0.0419
Regime 4	3.2E-07	5.0E-07	0.0525	0.0131	0.0148
Technical inefficiency					
Regime 1	0	0	0	0	0
Regime 2	0	0	0.1300	0.0319	0.0105
Regime 3	0	0.0158	0.0800	0.0158	0.0058
Regime 4	0	0	0	0	0
Overall cost inefficiency (technical plus allocative)					
Regime 1	0.1400	0.1950	0.2600	0.1988	0.0191
Regime 2	0	0.0800	0.3000	0.1031	0.0256
Regime 3	0	0.2050	0.5100	0.2258	0.0563
Regime 4	0	0.0500	0.2000	0.0500	0.0464

[a] Regime 1 represents the Pre-Ban era, 2 the Ban era, 3 the Pre-Settlement era, and 4 the Settlement era

Settlement had little effect on technical inefficiency. That is, even though the industry did not use the allocatively efficient mix of marketing and production inputs, it did not waste inputs. Overall cost inefficiency, was more pronounced, however. The mean overall cost inefficiency score fell by about 48% after the Ban and by about 78% after the Settlement.[18] Except for technical inefficiency in regimes 3 and 4, the distributions across regimes are significantly different (Table 2). These results indicate that marketing restrictions lowered overall cost inefficiency by lowering allocative inefficiency, a result that is consistent with hypothesis that coordination dominates LeChatelier effects.

To further analyze the effect of marketing restrictions, we develop a truncated regression model of inefficiency determination. Of the many possible sources of inefficiency identified in the literature, two are most relevant to the cigarette industry.[19] First, inefficiency may result from demand and input price uncertainty. For example, Perrakis (1980) shows that input price uncertainty can lead to allocative inefficiency (i.e., use too little of the risky input), even when firms are risk neutral. Second, government regulations can have favorable or unfavorable effects on industry performance. This is the central issue of our study, the LeChatelier vs. coordination effects of marketing restrictions.

We explore these issues by estimating individual regression models for technical inefficiency, overall cost inefficiency, and allocative inefficiency in marketing,

[18] Estimates of overall inefficiency after the Settlement should be interpreted with caution, however, because the Settlement required financial payments to state governments as well as tighter marketing restrictions. Financial stress caused by these payments may have induced belt tightening and may partially explain the lower inefficiency scores after the Settlement.

[19] After reviewing the literature, Färe, Grosskopf, and Lovell (1985) identify nine different causes of inefficiency in production. The only other possibility that readers might be concerned with is market power that can lead to X-inefficiency (Leibenstein 1966). This is unlikely to be important in the cigarette industry, however, because industry concentration has remained stable over the sample period.

Table 2 Mann–Whitney–Wilcoxon tests for distributional differences between regulatory regimes

Inefficiency estimators		Smallest rank sum
Regime 1 vs. Regime 2 (Ban)		
Allocative inefficiency:	Marketing	36*
	Production	46*
Aggregate allocative inefficiency (marketing plus production)		36*
Technical inefficiency		28*
Overall cost inefficiency (allocative and technical)		56***
Regime 3 vs. Regime 4 (Settlement)		
Allocative inefficiency:	Marketing	16**
	Production	11*
Aggregate allocative inefficiency (marketing plus production)		17**
Technical inefficiency		26
Overall cost inefficiecny (allocative and technical)		16***

* Statistically significant at 1%

** Statistically significant at 5%

*** Statistically significant at 10%

production, and both marketing and production.[20] To control for uncertainty, independent variables include the annual percentage change in per-capita consumption (%Δpcq) and the percentage change in total cost (%ΔCost).[21] These changes will have efficiency effects if unanticipated. If a positive demand shock is unanticipated by cigarette producers, for example, it could lessen financial pressure and lead to greater managerial slack and inefficiency. Given sufficient adjustment time, however, anticipated changes in demand and costs should have no effect on inefficiency.

To evaluate the effect of marketing restrictions imposed by government, we use dummy variables to control for the Ban and the Settlement. D_{71} represents the Ban, which equals 1 from 1971 to 2002 and 0 otherwise; D_{99} represents the Settlement, which equals 1 from 1999 to 2002 and 0 otherwise. The Ban and the Settlement would reduce inefficiency if the coordination effect dominates but would increase inefficiency if the LeChatelier effect dominates.

One concern is that the dependent variables (inefficiency scores) are truncated at zero. To account for truncation, we use an estimation technique developed by Simar and Wilson (2007). This is a two-stage approach that corrects for bias using maximum likelihood estimation in the second stage of estimation. Truncated regression estimates are provided in Table 3. They indicate that in many cases the effects of the control variables (%Δpcq and %ΔCost) are insignificant, suggesting that demand and cost shocks were generally anticipated by the industry.

Consistent with the analysis above, marketing restrictions generally increased efficiency. The Ban had a negative and significant effect on allocative inefficiency in marketing, in production, and in both marketing and production. In addition, the Settlement had a negative effect on allocative inefficiency, but the results are significant only for production. To put these estimates into perspective, they indicate that the Ban caused allocative inefficiency in marketing to fall by approximately 71%, allocative inefficiency in production to fall by 84%, and aggregate allocative inefficiency (marketing plus production) to fall by 82%. These effects are similar to those found in Table 1, and together they provide strong evidence that the Broadcast Advertising Ban led to a substantial increase in allocative efficiency in marketing.

4 Concluding remarks

We evaluate the effect of marketing restrictions on inefficiency in the U.S. cigarette industry. In an imperfectly competitive market like cigarettes, the effect of a regulation on a strategic variable such as advertising is uncertain. On the one hand, the LeChatelier Principle indicates that if a regulation effectively limits the use of an important input, then allocative efficiency will fall. On the other hand, restrictions that reduce a combative strategy like broadcast advertising may facilitate coordination, causing an improvement in allocative efficiency.

We use DEA to estimate the degree of allocative, technical, and overall cost inefficiency for the U.S. cigarette industry. Unlike previous studies, we do not assume that marketing and production technologies are separable, and the evidence suggests that they are not separable. A comparison of inefficiency estimates before and after a regulation allows us to analyze the efficiency effects of the Broadcast Advertising Ban and the National Tobacco Settlement. The bulk of our empirical evidence shows that the Ban and the Settlement led to efficiency gains at the industry level.

The strongest evidence involves the effect of the Ban on efficiency. All of the empirical evidence supports the

[20] For ease of interpretation, we continue to focus our discussion on inefficiency rather than efficiency scores. To illustrate, overall cost efficiency scores (CE) range from 0 to 1, with a value of 1 meaning that there is no inefficiency. In this case, overall cost inefficiency is defined 1 − CE, with a value of 0 meaning that there is no inefficiency.

[21] We also estimate models with a variable to control for changes in clean indoor air regulations, but the main empirical results remain the same.

Table 3 Truncated regression results for allocative, technical and overall cost inefficiency[a]

Independent variable	Dependent variable				
	Allocative inefficiency in			Technical inefficiency	Overall cost inefficiency
	Marketing	Production	Mkt. & Prod.		
Constant	0.2000*	0.011*	0.1853**	0.4469	0.0964
	(0.0563)	(0.0018)	(0.0834)	(0.4152)	(0.3486)
%Δpcq	−0.8585	−0.0296	−0.9896	−5.6959**	−2.0554
	(0.6675)	(0.0308)	(0.6751)	(2.5361)	(1.9317)
%ΔCost	−1.9418***	0.0255	−1.1278	3.0023**	−1.3940
	(1.1662)	(0.0181)	(0.7735)	(1.5224)	(1.5575)
D_{71}	−0.1693**	−0.0099*	−0.2047***	−0.1497	−0.0894
	(0.0723)	(0.0024)	(0.1051)	(0.1546)	(0.3465)
D_{99}	−0.1021	−0.0155**	−0.1023	−0.2363	0.2919
	(0.067)	(0.0068)	(0.0812)	(0.2005)	(0.2471)

* Statistically significant at 1%, two-tailed test

** Statistically significant at 5%, two-tailed test

*** Statistically significant at 10%, two-tailed test

[a] Numbers in parentheses are standard errors

hypothesis that the Broadcast Advertising Ban improved allocative efficiency in marketing. This is clear from Fig. 4, which shows that the efficient amount of broadcast advertising is zero. Before the Ban, the industry spent about 70% of its marketing dollars on broadcast advertising, which was far in excess of the efficient amount. In addition, all other empirical evidence supports the hypothesis that the Ban increased marketing efficiency in the industry. Taken as a whole, the results are consistent with a prisoners' dilemma in broadcast advertising.

Using a different approach from prior research, our findings help resolve the debate concerning the economic consequences of the Broadcast Advertising Ban. Like Eckard (1991) and Mitchell and Mulherin (1988), our results indicate that the U.S. cigarette industry benefited from the Ban. This may explain why U.S. cigarette producers did not vigorously oppose this restriction (Hamilton, 1972). Although our finding that the Ban benefited producers is consistent with the capture theory of regulation, it does not preclude the possibility that regulators intended to promote the public interest. That is, the primary reason for the Ban and Settlement may have been to reduce demand and the social cost of smoking. Whether intended or unintended, however, our evidence demonstrates that marketing restrictions facilitated coordination in the U.S. cigarette industry.

Acknowledgements We wish to thank Rolf Färe, Shawna Grosskopf, James F. Ragan Jr., Barry Seldon, Robin Sickles, Carol Tremblay, Dennis Weisman and two anonymous referees for their helpful comments on an earlier version of the paper.

Appendix

The data include 40 annual observations from 1963 through 2002. Table 4 lists variable definitions and data sources, and Table 5 provides summary statistics. For each year, data are available for broadcast advertising, print advertising, and advertising in all other media. Broadcast advertising includes expenditures on television and radio. Print includes advertising expenditures on newspapers and magazines. The "all other"category includes expenditures on outdoor advertising, transit advertising, direct mail advertising, commercial endorsements, testimonials by celebrities, advertisements posted at retail locations, and advertising on any medium of electronic communication. It also includes promotional expenses such as promotional allowances, public entertainment, coupons, free samples, specialty items, and price promotions. The quantity of an advertising message by media is obtained by dividing advertising expenditures by the price of advertising for the appropriate medium. That is, the quantity of print advertising is defined as the expenditures on print advertising divided by the price of print advertising. The price is defined as the average cost of reaching an audience of one thousand, the cost-per-thousand (CPM) for each medium. These price data are obtained from Robert J. Coen, a marketing executive at Universal McCann, New York Office.

Regarding production, data are available for the number of all employees, payroll of all employees, the cost of materials, and the value of depreciable assets. Because stemmed tobacco leaf is the major material expense, we

Table 4 Variable descriptions and data sources

Name	Definition and data source
x_{t1}	Number of television and radio advertising messages, obtained by dividing advertising expenditures on television and radio by the Cost-per-Thousand (CPM) index of network TV and network radio [1, 6]
x_{t2}	Number of newspaper and magazine advertising messages, obtained by dividing advertising expenditures on newspaper and magazines by the CPM index of newspaper and magazines [1, 6]
x_{t3}	Number of advertising messages sent by all other marketing media, obtained by dividing the advertising expenditures on other media by CPM index for the other category. It includes the following media (available years in parentheses): Outdoor (1975–2002), Transit (1975–2002), Point-of-Sale (1963–2002), Endorsement & Testimonial (1963–2002), Direct Mail (1963–2002), Audio-visual (1963–2002), Promotional Allowances (1975–2002), (Retail, Wholesale, Other), Public Entertainment (1975–2002), Coupons & Retail value added (1985–2002), Sampling (1975–2002), Specialty item (1975–2002), Price discount (2002). Missing observations are estimated using ordinary least squares [1, 6]
x_{t4}	Quantity of labor input, defined as the number of all production and non-production employees (thousands) [3]
x_{t5}	Quantity of material input, defined as the Total Cost of Materials divided by PPI of farm product/tobacco leaf.[a] In 1997, 40% of material cost expenditures were on stemmed leaf tobacco, 8% on manmade fibers, staple and tow. The rest included expenditures on other materials, containers, ingredients and supplies (millions) [3, 5]
x_{t6}	Quantity of capital input, defined as the value of depreciable assets divided by PPI of capital equipment. Depreciable assets excludes inventories and intangible assets (millions) [3, 5][b]
w_{t1}	Price of broadcast advertising messages, defined as the CPM of Network TV and Network Radio, by the PPI of all commodities [5, 6]
w_{t2}	Price of print advertising messages, defined as the CPM of Newspapers and Magazines, deflated by the PPI of all commodities [5, 6]
w_{t3}	Price of other advertising messages, defined as the CPM of other national and local advertising, deflated by the PPI of all commodities [5, 6]
w_{t4}	Price of labor inputs, defined as the full payroll (i.e., salaries, benefits, and pensions) of all employees divided by number of all employees, deflated by the PPI of all commodities (thousands) [3]
w_{t5}	Price of material inputs, defined as the PPI of farm products for 1963–1984 and of tobacco (stemmed) leaf for 1985–2002, deflated by the PPI of all commodities [5]
w_{t6}	Price of capital inputs, defined as the PPI of capital equipment, deflated by the PPI of all commodities [5]
y_t	Quality adjusted output, defined as total production multiplied by output price (before tax), deflated by the CPI of all items (tens of millions) [1, 2]
pcq_t	Per-capita consumption of cigarettes, defined as total cigarette consumption divided by the U.S. population over 17 years of age (thousands) [1, 4]
$Cost_t$	Total cost, which includes the cost of materials, labor, capital and advertising, deflated by the PPI of all commodities (millions) [3, 5]
PCM_t	Price-Cost Margin defined as the ratio of the profit to total revenue [1, 2, 3, 4, 5]
D_{71}	Broadcast Advertising Ban Dummy = 1 for 1971–2002; = 0 otherwise
D_{98}	National Tobacco Settlement Dummy = 1 for 1998–2002; = 0 otherwise

Sources:

[1] "Federal Trade Commission Cigarette Report," Federal Trade Commission (2002)

[2] "The Tax Burden on Tobacco," Tobacco Institute (1985, 1992, 1995, 1997) and "Tobacco Briefing Room," USDA/ERS, U.S. Department of Agriculture, at http://www.ers.usda.gov/Briefing/Archive/Tobacco/

[3] *Census of Manufacturers, Industry Series on Tobacco*, U.S. Department of Commerce (1972, 1977, 1982, 1995a, 1996, 1998, 2004)

[4] *Statistical Abstract of the U.S.*, U.S. Department of Commerce (various issues)

[5] Bureau of Labor Statistics, U.S. Department of Labor, at http://www.bls.gov/bls/inflation.htm

[6] Universal McCann, New York Office (see the Appendix)

[a] The base year for all indices is 1982

[b] U.S. cigarette companies do not grow their own tobacco but buy leaf tobacco from farmers or cooperatives. Cigarette companies use three types of physical capital in the production of cigarettes: tobacco aging facilities, processing facilities (that cut and blend the tobacco), and cigarette making machines, and packaging machines. For more information on cigarette production, go to http://www.philipmorrisinternational.com/PMINTL/pages/eng/outbus/Production.asp

approximate the price of materials by the producer price index of leaf tobacco. This index is only available from 1985 to 2002, and we use the producer price index of farm products in earlier years. The price of capital is approximated by the producer price index of capital equipment.

The price of cigarettes is the producer price (i.e., the market price minus state and federal taxes per unit). Following Spence (1980), we define the quality adjusted quantity of cigarettes as the real dollar value of total sales, as quality improvements increase cigarette prices. In differentiated goods markets, this implies that profit maximizing

Table 5 Data Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Quality adjusted output	1793.2372	479.9569	1110.9807	2821.3854
Quantity of inputs (x_i)				
Broadcast	1344.7419	433.6302	0	7746.1841
Print	3067.0229	2167.6068	523.45	7689.25
Other advertising	15156.0136	12616.4199	1591.4344	45813.8097
Capital	28.7610	12.5820	12.7341	47.9673
Labor	31.9917	8.2936	15.1900	42.3000
Material	38.4170	7.2151	23.8143	52.2755
Price of inputs (w_i)				
Broadcast	1.2590	0.3246	0.7567	2.0738
Print	1.3344	0.3061	0.9260	1.9994
Other advertising	1.2986	0.3639	0.8376	2.2220
Capital	105.0428	4.4816	94.3925	111.3787
Labor	31.3638	12.1369	16.2672	51.6739
Material	107.7862	21.1185	74.9812	161.5556
Per-capita consumption	3.4519	0.7740	1.6562	4.3122
Total cost	7519.2467	521.8640	6175.1626	8574.1898
Price-cost margin	0.67043	0.2353	0.3012	0.1407

firms will minimize the cost of reaching a given level of sales. To avoid biasing our inefficiency estimates, total cost includes all production and marketing expenses but does not include National Tobacco Settlement expenses.

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