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# AN EMPIRICAL ANALYSIS OF CIGARETTE ADDICTION

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## ABSTRACT

We use a framework suggested by a model of rational addiction to analyze empirically the demand for cigarettes. The data consist of per capita cigarettes sales (in packs) annually by state for the period 1955 through 1985. The empirical results provide support for the implications of a rational addiction model that cross price effects are negative (consumption in different periods are complements), that long-run price responses exceed short-run responses, and that permanent price effects exceed temporary price effects. A 10 percent permanent increase in the price of cigarettes reduces current consumption by 4 percent in the short run and by 7.5 percent in the long run. In contrast, a 10 percent increase in the price for only one period decreases consumption by only 3 percent. In addition, a one period price increase of 10 percent reduces consumption in the previous period by approximately .7 percent and consumption in the subsequent period by 1.5 percent. These estimates illustrate the importance of the intertemporal linkages in cigarette demand implied by rational addictive behavior.

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states also might decide to quit. The existence of unstable steady states means that some people who smoke a lot will be the "marginal" smokers with respect to changes in cigarette prices and other variables.

## VIII. Monopoly and Addiction

Both the demand for cigarettes and the organization of the cigarette industry have been studied frequently (on the latter, see, for example, Bain 1968; Sumner 1981; Appelbaum 1982; Geroski 1983; and Porter 1986). Yet neither type of study has highlighted the habitual-addictive side of smoking, even though cigarette smoking has long been recognized as a habit that is among the most difficult to break.

The cigarette industry in the U.S. is highly concentrated. Two companies (R.J. Reynolds and Philip Morris) account for about 70 percent of output, and the studies just cited conclude in general that cigarette companies have significant monopoly power. The analysis in previous sections shows that the habitual aspects of cigarette smoking significantly alter estimates of its response to changes in prices and other variables, and addiction affects optimal monopoly pricing and other policies.

To illustrate the relation between pricing and addiction, we consider monopoly pricing when there are only two periods. Quantities demanded in each period are given by the Cobb-Douglas functions[10]

(23) $$q_1 = a_1 p_1^{-\epsilon_1} p_2^{*-g\gamma}$$

(24) $$q_2 = a_2 p_2^{-\epsilon_2} q_1^{\gamma} ,$$

where $\epsilon_1$, $\epsilon_2 > 0$, $0 < g < 1$, $0 \leq \gamma < 1$ with a reinforcing but stable habit and

$p_2^*$ is the price expected in period 2 by consumers in period 1. Note that the price elasticities in equations (23) and (24) pertain to the individual firm, while the estimated price elasticities at sample means in Sections V and VII pertain to the market. Theoretically and empirically, the former elasticities are larger in absolute value than the latter (for example, Sumner 1981; Appelbaum 1982).

The present value of profits over the two periods is (with a zero interest rate)

$$\pi = p_1 q_1 + p_2 q_2 - c_1 q_1 - c_2 q_2 , \tag{25}$$

where $c_1$ and $c_2$ are the constant costs in each period inclusive of excise taxes. Substituting for $q_1$ and $q_2$ gives profits as a function of prices alone:

$$\pi = a_1 p_1^{1-\epsilon_1} p_2^{*-g\gamma} + a_2 a_1^{\gamma} p_2^{1-\epsilon_2} p_1^{-\epsilon_1 \gamma} p_2^{*-g\gamma^2}$$
$$- c_1 a_1 p_1^{-\epsilon_1} p_2^{*-g\gamma} - c_2 a_2 a_1^{\gamma} p_2^{-\epsilon_2} p_1^{-\epsilon_1 \gamma} p_2^{*-g\gamma^2} .$$

The firm chooses $p_1$ and $p_2$ to maximize $\pi$. The first-order condition for $p_1$ is

$$\frac{1 - \epsilon_1}{\epsilon_1} \; p_1 + c_1 = a_1^{\gamma-1} a_2 \gamma p_1^{\epsilon_1(1-\gamma)} p_2^{-\epsilon_2} p_2^{*\, g\gamma(1-\gamma)} (p_2 - c_2) . \tag{26}$$

We hold $p_2^*$ constant when differentiating with respect to $p_1$ because rational expectations of $p_2$ are not affected by changes in $p_1$ with these demand functions. This reduces to the familiar condition that marginal revenue equals marginal cost $[p_1(1 - 1/\epsilon_1) = c_1]$ when either $\gamma = 0$ (no addictive effects of consumption) or when $p_2 = c_2$ (competitive pricing in the second period). However, marginal revenue is less than marginal cost in period 1 if $p_2 > c_2$ and if consumption is addictive. The reason is that profits in periods 2 are higher when $q_1$ is larger ($p_1$ is smaller) because an increase in $q_1$ raises $q_2$ (when $\gamma > 0$). As it were, a monopolist may lower price to get more consumers "hooked" on the addictive good. Note that, if the monopolist can engage in price discrimination, he may have an incentive to offer lower prices to persons who currently do not consume the good. This can explain why cigarette companies distributed free cigarettes on college campuses in the past. In effect college students were being offered a zero current price but a positive future price once they became addicted.

The right-hand side of equation (26) shows that the optimal marginal revenue in period 1 is lower relative to marginal cost when the good is more addictive (the larger is $\gamma$), demand in period 2 is stronger (the larger is $a_2$), demand in period 1 is weaker (the smaller is $a_1$), and when $p_2$ minus $c_2$ is bigger. With a sufficiently large positive effect on $q_2$ of a lower $p_1$, a monopolist might choose a $p_1$ that is less than $c_1$, or a $p_1$ that is in an inelastic region of demand ($\epsilon_1 < 1$).[11]

The choice of an optimal $p_2$ depends on whether the monopolist can precommit $p_2$ to consumers in period one. With precommitment, a decline in $p_2$ stimulates $q_1$ by lowering $p_2^*$. But without precommitment, actual changes in $p_2$ do not affect $p_2^*$, and hence do not affect $q_1$. Without precommitment, rational consumers simply anticipate that the monopolist chooses $p_2$ to maximize profits in period 2, given the level at that time of $q_1$. With rational expectations, $p_2^* = \hat{p}_2$ (the optimal $p_2$), and a monopolist who cannot precommit takes both $q_1$ and $p_2^*$ as given when choosing $p_2$.

The first-order condition for $p_2$ to a monopolist who cannot precommit is

$$(27) \qquad a_2(1-\epsilon_2)p_2^{-\epsilon_2}q_1^{\gamma} = a_2c_2(-\epsilon_2)p_2^{-\epsilon_2-1}q_1^{\gamma}$$

or

$$(28) \qquad \frac{\epsilon_2-1}{\epsilon_2}\, p_2 = c_2 \; .$$

This is the usual condition that marginal revenue equals marginal cost. In particular, a monopolist who cannot precommit would never choose $p_2$ in the inelastic region of the demand curve in period 2 ($\epsilon_2 > 1$) because $p_2$ cannot influence $q_1$ without precommitment. Without going into details of the case where precommitment is possible, it should be clear that a precommitted $p_2$ would be below the $p_2$ given by equation (38) because a precommitted lower $p_2$ reduces $p_2^*$, and hence raises $q_1$ and profits in period 1 (assuming $p_1 > c_1$).

When $p_2$ is not precommitted, equations (37) and (38) can be substituted into the first-order condition for $p_1$ to get

$$(29) \qquad c_1 - a_2a_1^{\gamma-1}\, \gamma\epsilon_2^{-1}\, p_1^{\epsilon_1(1-\gamma)}\hat{p}_2^{1+g\gamma(1-\gamma)-\epsilon_2} = (1 - \frac{1}{\epsilon_1})p_1 \quad .$$

If $1 < \epsilon_2 > 1 + g\gamma(1 - \gamma)$, which follows if $\epsilon_2 > 5/4$, then an increase in $\hat{p}_2$ raises $p_1$.[12]

This analysis is helpful in understanding the rise in cigarette prices in recent years. Much of the drop in demand for cigarettes since 1981 documented by Harris (1987) and others is due to greater information about health hazards, restrictions imposed on smoking in public places, and the banning of cigarette advertising on radio and television. Equation (29) shows that $p_1$ increases when demand falls by the same percentage in both periods ($a_1$ and $a_2$ fall by the same percentage); $p_1$ increases even more when future demand is expected to fall by a larger percentage than current demand. A rise in $p_1$ with $c_1$ fixed raises profit and profit margin (the difference between price and average cost) in period 1.

Several studies have commented about the apparent paradox that cigarette companies have been posting big profits while smoking is declining, and have documented the faster rise in cigarette prices than in apparent costs (Harris 1987; Dunkin, Oneal, and Kelly 1988). Indeed, according to Adler and Freedman (1990, p. 1), "...One of the great magic tricks of market economics...[is] how to force prices up and increase profits in an industry in which demand falls by tens of billions of cigarettes each year." Incorporation of the addictive aspects of smoking into the analysis resolves this paradox if cigarette companies have some monopoly power. Since $p_1$ increases, cigarette companies' profits rise in the short run precisely because of the decline in smoking. An event study of the common stock prices of cigarette companies could detect whether they fell relative to a risk-adjusted index of stock prices as the price of cigarettes rose during the 1980s.[13]

If consumers and producers know that an excise tax on cigarettes will be imposed next period, and if the cigarette industry were competitive with constant costs, present prices would not change and future prices would rise by the size of the tax. If the industry were oligopolistic but if cigarettes were not addictive, present prices still would not change, while future prices would rise by the same percentage as tax-inclusive future costs (with a constant elasticity of demand). Since price exceeds costs under monopoly, future monopolistic prices would rise by a greater amount than the excise tax.

The rise in cigarette prices does usually exceed the rise in cigarette taxes, which is evidence that the industry is not fully competitive (Sumner 1981).

Incorporation of the addictive aspects of smoking leads to a further test of whether the cigarette industry is fully competitive. If smokers are addicted, and if the industry is oligopolistic, an expected rise in future costs due to future taxes induces a rise in current prices [if $\epsilon_2$, the price elasticity of demand for one of the oligopolists, in equation (28) exceeds 5/4], even though current demand ($q_1$) falls when future prices are expected to increase. A higher federal excise tax on cigarettes was widely expected to go into effect at the beginning of 1983. Cigarette prices increased sharply not only in 1983 but also prior to the tax increase during 1982. The price increase in 1982 has been taken as evidence that "the tax increase served as a focal point [or coordinating device] for an oligopolistic price increase" (Harris 1987, p. 101). That is possible, but an increase in 1982 would have occurred even if cigarette producers had no such coordinating problems. An oligopolistic producer of an addictive good would raise prices prior to an anticipated increase in the tax on his product.

## FOOTNOTES

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[1]State-specific education and divorce measures were available for the Census of Population years of 1950, 1960, 1970, and 1980; and state-specific religion measures were available for the years 1952, 1971, and 1980. Values for other years were computed using state-specific exponential growth rates. Hence, differences in education, divorce, or religion are almost fully "explained" by the state and time variables. The algorithm also had to be applied to estimate the unemployment rate during the early years of the time series, and it is highly collinear with the set of state and time dummies.

[2]In the regressions in columns 3 and 4, the first observation on the dependent variable pertains to 1956 or to the second year in which both consumption and price are reported, and the last observation pertains to 1984. Fewer than 102 observations are lost because 65 of 1,581 cases have missing data in the regressions in columns 1 and 2, while 58 of 1,479 cases have missing data in the regressions in columns 3 and 4. Nine states have missing sales in 1955 and other years. Two of these states, Alaska and Hawaii, also

have missing prices. For these two states price is missing every year that sales are missing and in the first year in which sales are reported. Consequently, the number of cases with missing data falls by 7 rather than by 9 when one lag and lead of price are included in the regressions.

[3]Another bias arises because the dependent variable pertains to purchases rather than to consumption. If cigarettes can be stored, current purchases will rise in response to an increase in future or past price. This causes an underestimation of the absolute values of the future and past price coefficients. Thus, the negative and significant cross price effects in columns 3 and 4 may be even larger and more significant than they appear. To the extent that cigarettes spoil if they are stored for a period as long as a year, the bias just discussed is not important.

[4]The F tests are performed by estimating regressions with and without past and future price using 1,421 observations in each case.

[5]According to the solution of the second-order difference equation (6) or (22), consumption at any point in time depends on the current value and on <u>all</u> past and future values of a given exogenous variable [see equation (10)]. Clearly, not all these variables can be used to predict $C_{t-1}$ and $C_{t+1}$. Therefore, both these variables are regressed on $P_{t-1}$, $P_t$, $P_{t+1}$, and $X_t$ (a vector of the additional exogenous variables at time t). This procedure is followed because the set of exogenous variables should not vary among reduced form equations. Note that no past prices of $C_{t-1}$ ($P_{t-j}$, $j > 1$) appear in the reduced form regression for $C_{t-1}$, and no future prices of $C_{t+1}$ ($P_{t+j}$, $j > 1$) appear in the reduced form regression for $C_{t+1}$.

[6]The residuals from several of the models in Table 3 were examined for autocorrelation. The algorithm assumed a common time-series error structure

among states, and no autocorrelations for lag lengths greater than 10. The first ten autocorrelation coefficients were obtained and were used to compute a variance-covariance matrix of regression coefficients (var) of the form

$$\text{var} = (\hat{Z}'\hat{Z})^{-1}\ \hat{Z}'V\hat{Z}(\hat{Z}'\hat{Z})^{-1},$$

where V is the variance-covariance matrix of the disturbance term and

$$\hat{Z} = [\hat{Y}X_1] \ .$$

The last equation specifies a matrix of the predicted values of the endogenous variables ($\hat{Y}$) and exogenous variables ($X_1$) in the structural demand function for current consumption. Standard errors of regression coefficients based on this algorithm (available on request) were very similar to those that did not correct for autocorrelation. In most cases the corrected standard error was smaller than the corresponding uncorrected standard error. The same comment applies to the estimates in Table 6. The regression residuals also were examined for cross-sectional heteroscedasticity due to averaging over an unequal number of people in each state. This analysis suggested that there were no efficiency gains to weighting by the square root of the state population.

[7]The above computations assume that consumption this period, last period, and next period are approximately equal.

[8]Note that a Granger (1969) causality test of the relationship between cigarette consumption and the excise tax is not helpful in the context of our model. Suppose that the current tax rate was regressed on the lagged tax rate and on lagged consumption. Significant lagged consumption coefficients would

not necessarily indicate causality from consumption to the tax because lagged consumption should respond to the current tax given rational addiction.

[9]Frank Chaloupka kindly supplied us with the above estimates.

[10]These demand functions have constant price elasticities, while the demand functions estimated in Sections V and VII have constant slopes. We use the constant elasticity form in this section for analytical convenience and indicate how our conclusions would differ if the demand functions were linear.

[11]Of course, we assume that the demand function for current consumption has a constant price elasticity. In this context the constant value could be smaller than one. More generally, if the demand function did not have a constant elasticity, the monopolist might choose to operate in the inelastic segment of it.

[12]The term $\gamma(1 - \gamma)$ takes on a maximum value of 1/4 when $\gamma$ equals 1/2. Since g is less than one, the condition in the text is sufficient but not necessary.

[13]Most of the results just obtained hold in certain cases with linear demand functions. In particular, price could rise in period 1 in response to parallel downward shifts in the demand functions in both periods. The results in this section suggest that it may not be entirely appropriate to treat price as an exogenous variable in fitting cigarette demand functions for reasons other than those mentioned in Section V and note 9. We reemphasize, however, that market demand functions are estimated in Sections V and VII, while the demand functions discussed in this section pertain to individual firms. Moreover, in the context of a non-addictive model, Porter (1986) reports little difference between cigarette market demand functions that treat price as exogenous and demand functions that treat price as endogenous.

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