Section II
Analytics of tobacco use

5
The economics of addiction

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Non-technical summary

This chapter reviews economic models of addiction and their empirical applications to cigarette smoking and other tobacco use. These models can help in understanding the impact of prices and tobacco-control policies on individuals' smoking behavior, including their decisions to start, continue, reduce, quit, or re-start smoking. The discussion of economic models is technical and assumes some knowledge of economics. Here we provide a summary for the reader interested in the key implications from the various models.

Introduction. Economic theory assumes that individuals demand goods or services to maximize their happiness (or 'utility' in economic terms), taking into account prices, income, and other factors. For most products, consumption decisions at a given point in time are independent of past choices. Cigarettes and other tobacco products, unlike nearly all other consumer goods, are highly addictive, implying that decisions regarding their consumption at any moment depend on previous choices. In other words, a consumer who is addicted to a particular product, such as cigarettes, must by definition have bought the product before and will require the same or larger quantities as before to maintain the addiction. Likewise, the consumer will suffer significant adjustment costs if consumption is stopped or reduced.

Different models of addiction. Economic models in the past either ignored addiction or treated it as an irrational behavior not subject to basic laws of economics. Thus, for example, many assumed that higher prices for an addictive product would not, in fact, reduce its consumption.

Over the past few decades, economists have increasingly examined addictive behaviors, including smoking, in theoretical and empirical models. These models differ largely in the assumptions made about the extent of rationality among consumers of addictive products. Three groups of these models are discussed in this chapter.

The first approach models addiction as an imperfectly rational behavior. In these models, individuals' preferences are not consistent over their life-cycle. Some, for example, assume that people have two competing sets of preferences: one for good health and long life; and the other for the pleasure of smoking. This leads people to choose different actions at different ages. For example, people may prefer to smoke at one age with the intention of quitting later, but then change their mind later in life. These models have not been applied empirically to smoking or other addictions.

The second approach models addicts as myopic. These models generally assume that people know that their current smoking is based on their past smoking (i.e. that smoking

is addictive), but do not take account of the future consequences of their addiction when making current choices. Empirical applications of this model in several high-income countries have confirmed that cigarettes are addictive in an 'economic' sense; that is, current cigarette smoking is increased by past consumption. These studies also confirm that higher prices reduce smoking.

The third approach models addiction as a fully rational behavior. That is, addicts are both aware of the dependence of current choices on past behavior (as in the myopic-addiction models) and consider the future implications of their addictions when making current choices. This model has generated considerable debate both within and outside of economics. Several empirical applications of the rational-addiction model confirm that smoking is an addictive behavior and that increases in cigarette prices lead to reductions in cigarette smoking. The evidence is mixed, however, when it comes to the 'rationality' of cigarette smoking.

These models, particularly the rational-addiction model, have been criticized for not fully taking into account some aspects of addictive behavior. One frequently criticized feature of the rational-addiction model is that it assumes perfect foresight, implying that people fully understand the future implications of decisions concerning the consumption of addictive products. The reality, however, is that most addictions begin in adolescence, and young people have, at best, a limited understanding of addiction. Recent extensions of the rational-addiction model attempt to account for this, concluding that this lack of information for some individuals will lead many to regret becoming addicted. Other extensions of the economic models of addiction attempt to explain cessation behavior, such as the use of nicotine-replacement therapies, and focus on the 'adjustment costs' associated with overcoming withdrawal. This approach suggests that aging, by raising the immediacy of the health consequences of smoking, will result in some people quitting, and suggests that, in economic terms, it may be easier for the heaviest smokers to quit 'cold-turkey'. Finally, other recent models have examined the impact of differing approaches to modeling time-preferences, and suggest that youth onset is heavily influenced by a desire for immediate gratification and lack of self-control. These models, however, have only begun to be empirically tested.

Policy implications. These models have important implications for policy. Most importantly, because of the dependence of current consumption on past consumption, they indicate that the effect of a permanent change in price will be greater in the long-run than in the short-run, suggesting that permanent real price increases and strong tobacco-control efforts, which raise the actual and perceived costs of smoking, can be effective in significantly reducing smoking. By nature, the economic models of addiction will tend to simplify what are, in reality, very complex decisions about starting to smoke, continuing, quitting, or re-starting. Moreover, this research is at a relatively early stage and interesting theoretical developments remain to be tested empirically. Further research is likely to yield even more policy-relevant answers on smoking and addiction.

5.1 Introduction

Whether a commodity conforms to the law of diminishing or increasing return, the increase in consumption arising from a fall in price is gradual; and, further, habits which have once grown up around the use of a commodity while its price is low are not so quickly abandoned when its price rises again (Marshall 1920, appendix H, section 3, p. 807).

Standard economic theory implies that the demand for any product will depend on its price, the prices of other products, incomes, tastes, and other factors. For years, however, the conventional wisdom was that the basic principles of economics did not apply to addictive products, such as cigarettes and other tobacco products (which, because of the nicotine contained in them, are highly addictive; see Chapter 2 and Chapter 12). As the quotation from Marshall above indicates, the impact of addiction on demand is something that economists have considered for many years. However, they have largely either ignored the addictive nature of goods such as cigarettes when estimating demand or have assumed that behaviors such as smoking were irrational and could not be analyzed in the rational, constrained utility maximizing framework of economics.

Many theoretical and empirical studies from the past three decades, however, explicitly address the unique dimensions of the consumption of addictive goods. In economic analyses of addiction, the consumption of a good is considered addictive if an increase in the past consumption of that good leads to an increase in current consumption. Most analyses of addictive consumption have focused on the use of harmful substances, including tobacco products, alcohol, and illicit drugs. However, applications of the economic models of addiction are not limited to harmful consumption, but can also include more ‘positive’ addictions, including those to jogging, classical music, religion, and more that do not impose harm on others and that may yield future benefits (Becker and Murphy 1988; Grossman *et al.* 1998). These models clearly indicate that addiction has important implications for the impact of price and other control efforts on the demands for tobacco, alcohol, drugs, and other addictive substances.

This chapter provides an overview of economic models of addiction, their empirical applications to tobacco use, and recent innovations in the economic modeling of addiction. The chapter begins with a brief discussion of the physiological and psychological aspects of nicotine addiction, followed by a review of the most widely used economic models of addiction. Economic models of addiction can be divided into three basic groups: imperfectly rational models of addictive behavior; models of myopic addictive behavior; and models of rational addictive behavior. Each of these is discussed, along with a selected review of their empirical applications to cigarette smoking. This is followed by a discussion of several recent theoretical developments in the economic modeling of addictive behavior that focus on the initiation of addiction, the role of adjustment costs, and the time inconsistency of addictive behavior. Finally, several conclusions are provided.

5.2 Physiological and psychological dimensions of nicotine addiction

Over the past several decades, extensive biomedical, pharmacological, psychological, and other research have clearly demonstrated that cigarettes and other tobacco products are addictive, primarily because of the nicotine contained in them (US

Department of Health and Human Services/USDHHS 1988; Food and Drug Administration/USFDA 1996). The presence of three key factors—tolerance, reinforcement, and withdrawal—are often used to distinguish addictive consumption from the consumption of other goods and services (for more detailed reviews see: Ashton and Stepney 1982; Chaloupka 1988; USDHHS 1988). Other definitions are also employed that emphasize compulsive consumption, intoxication, and impairment of control (Hughes and Bickel 1999).

Tolerance reflects the body's adaptation to taking a drug. In the case of most drugs, tolerance implies that a given level of consumption yields less satisfaction as cumulative past consumption is higher. In other words, more of the drug must be consumed to achieve the same level of satisfaction from drug taking. Tolerance is exhibited somewhat differently in the case of cigarettes and other tobacco products. In part, tolerance reflects the overcoming of the initially unpleasant physical reactions to early consumption experiences. Moreover, in the case of tobacco use, tolerance does not result in a continuing escalation of use, but rather in the maintenance of a plateau.

Reinforcement reflects the learned responses to consumption and the rewards associated with it. In the case of cigarette smoking, reinforcement may be positive or negative (Ashton and Stepney 1982). Positive reinforcement comes from the pleasure or satisfaction that results from consuming cigarettes, including the pharmacological effects produced by nicotine and the psychological benefits associated with the act of smoking. Negative reinforcement is reflected by cigarette smoking to avoid a negative stimulus, such as smoking to avoid stress, weight gain, or nicotine withdrawal.

Finally, withdrawal reflects the negative physical reactions to the cessation, interruption, or reduction of consumption. In the case of cigarette smoking, these include increased irritability, inability to concentrate, increased anxiety, elevated blood pressure and heart rate, and much more, with a craving for tobacco the most common. As Ashton and Stepney (1982, p.61) describe it, the presence of withdrawal leads to the evolution from 'taking the drug in order to feel better to taking it in order to avoid feeling worse'.

The risk that the consumption of tobacco products can lead to nicotine addiction is exacerbated by the fact that most tobacco use begins at an early age (see Chapter 2) and that most young users are likely to underestimate their potential for addiction (see Chapter 7 and Chapter 8). In the United States, for example, surveys of youth indicate that most young smokers do not expect to be smoking regularly in the future; in follow-up surveys 5 years later, however, fewer than two out of five who expected to quit have actually done so (USDHHS 1994).

Over the past several decades, significant advances have been made in understanding the neuropsychological, pharmacological, and genetic mechanisms underlying nicotine addiction (see, for example, the proceedings from the National Institute on Drug Abuse's 1998 conference *Addicted to Nicotine* (Swan and Balfour 1999) for an excellent collection of multidisciplinary reviews of the state of the science on nicotine addiction). In contrast, economic models of addiction are at a relatively earlier stage of their development and are the subject of much debate among economists and others.

5.3 Economic models of addiction

For years, most economists treated the consumption of addictive goods no differently from other consumption even though the factors discussed above that are unique to addictive consumption were well known. These aspects of consumption were ignored, in part, because addiction was considered an irrational behavior not subject to standard economic analysis. As a result, many thought that the consumption of addictive substances, including tobacco products, was not subject to the same laws of economics that guided the consumption of other goods and services. That is, many thought that increases in prices and changes in other costs associated with the consumption of addictive goods would have little or no impact on their use. This is in contrast to the use of a typical consumer good that falls as prices and other costs associated with use rise.

However, over the past three decades, economists have begun to apply the standard framework of rational, constrained utility maximization to the study of the consumption of addictive substances. The economists who have studied addictions have made differing assumptions concerning the rationality of addictive behavior, where rationality in the context of these models largely reflects the degree to which the addict considers the future implications of current addictive consumption decisions. This chapter groups these studies into three basic categories depending on their assumptions about rationality: imperfectly rational addiction models, myopic-addiction models, and rational-addiction models. Other approaches that rely on more unusual approaches to modeling utility or the technology associated with addictive production are not discussed here (e.g. Barthold and Hochman 1988; Michaels 1988).

5.3.1 Imperfectly rational addiction models

Elster (1979), McKenzie (1979), Winston (1980), and Schelling (1978, 1980, 1984a, 1984b) best exemplify the economic models of imperfectly rational addictive behavior. These models generally assume stable but inconsistent short-run and long-run preferences. This is seen, for example, in Schelling's (1978, p. 290) description of a smoker trying to 'kick the habit':

> Everybody behaves like two people, one who wants clean lungs and long life and another who adores tobacco. . . . The two are in a continual contest for control; the 'straight' one often in command most of the time, but the wayward one needing only to get occasional control to spoil the other's best laid plan.

Thus, the farsighted personality may enroll in a smoking-cessation program, only to be undone by the short-sighted personality's relapse in a weak moment. Winston (1980) formally modeled this behavior and described how this contest between personalities leads to the evolution of what he called 'anti-markets', which he defined as firms or institutions that individuals will pay to help them stop consuming (e.g. smoking cessation programs or pharmaceutical companies producing nicotine-replacement products).

Strotz (1956) was the first to develop a formal model of such behavior, describing the constrained utility-maximization process as one in which an individual chooses a future consumption path that maximizes current utility, but later in life changes this plan 'even though his original expectations of future desires and means of consumption are verified' (p. 165). This inconsistency between current and future preferences arises when a non-exponential discount function is used (this is discussed further below). Strotz went on to suggest that rational persons will recognize this inconsistency and plan accordingly, by pre-committing their future behavior or by modifying consumption plans to be consistent with future preferences when unable to pre-commit.

Pollak (1968) went one step further, arguing that an individual may behave naively even when using an exponential discount function. Thaler and Shefrin (1981) described the problem similarly, referring to an individual at any point in time as both a 'far-sighted planner and a myopic doer' (p. 392), with the two in continual conflict. While these models present interesting discussions of some aspects of addictive behavior, they have not yet been applied empirically to cigarette smoking or other addictions.

5.3.2 Myopic-addiction models

The naive behavior described in some of the imperfectly rational models of addiction is the basis for many of the myopic models of addictive behavior. As Pollak (1975) observed, behavior is naive in the sense that an individual recognizes the dependence of current addictive consumption decisions on past consumption, but then ignores the impact of current and past choices on future consumption decisions when making current choices. Many of these models treat preferences as endogenous, allowing tastes to change over time in response to past consumption (Gorman 1967; Pollak 1970, 1976, 1978; von Weizsacker 1971; El-Safty 1976a, 1976b; Hammond 1976a, 1976b). These models are similar in spirit to those in which tastes change in response to factors other than past consumption, including advertising (Galbraith 1958, 1972; Dixit and Norman 1978) and prices (Pollak 1977).

In some implementations of these models, past consumption affects current consumption through an accumulated stock of past consumption (e.g. Houthakker and Taylor 1966, 1970). These models are comparable to those of the demand for durable consumer goods that use a stock adjustment process (e.g. Chow's (1960) model of the demand for automobiles, and Garcia dos Santos' (1972) analysis of the demands for household durables). As Phlips (1983) noted, however, the distinction between models with endogenous tastes and those with stable preferences within a household production framework is purely semantic, since the underlying mathematics of the two are the same.

The earliest theoretical models of demand in the context of myopic addiction can be traced to the irreversible demand models (Haavelmo 1944; Duesenberry 1949; Modigliani 1949; Farrell 1952). Farrell, for example, described an irreversible demand function as one in which current demand depends on all past price and income combinations. As a result, price and income elasticities are constant, but may differ for increases and decreases in price and income. Farrell tested this model empirically, using data from the United Kingdom on the demands for tobacco and beer from 1870 through 1938, in a model that included not only current price and income, but also price, income, and consumption in the prior year. In general, his estimates were inconclusive, although he did find limited evidence of habit formation for tobacco use.

The notion of asymmetric responses to price and income reappeared in Scitovsky (1976) and was applied to cigarette demand by Young (1983), using US data from 1929–73. The basic notion was that the response to a price increase or drop in income will be smaller in absolute value than the response to a comparable price reduction or increase in income. Young asserted that this was due to the addictive nature of cigarette smoking. Young's empirical model included separate variables for price increases, price reductions, income increases, and income reductions, as well as a variety of other factors affecting demand. Using Ridge regression methods, Young obtained estimates consistent with his hypotheses. His estimated price elasticity of demand for price increases (–0.33) was slightly more than half of his estimate for price decreases (–0.61), with a comparable relationship for income (income elasticity of 0.30 for increases and 0.15 for reductions). Pekurinen (1989) took the same approach to estimating cigarette demand in Finland, concluding that Finnish smoking was almost twice as responsive to price reductions (elasticity of –0.94) as it was to price increases (elasticity of –0.49).

In the Young and Pekurinen models, myopic behavior is captured by the asymmetric responses to changes in price and income. In contrast to the earlier work by Farrell (1952), these models are essentially atheoretical and ignore the effect of past consumption on current consumption that is emphasized in most theoretical models of addiction. As Godfrey (1989) noted, this mis-specification of demand is likely to produce biased estimates of the effect of price on cigarette demand.

Most empirical applications of myopic models of addiction are based on the pioneering work by Houthakker and Taylor (1966, 1970). They formally introduced the dependence of current consumption of an addictive good on its past consumption by modeling current demand as a function of a 'stock of habits':

$$C(t) = a + \beta S(t) + \mathbf{X}(t)\Gamma, \tag{5.1}$$

where C(t) is consumption of the addictive good at time t, $\mathbf{X}(t)$ is a vector of factors influencing demand, and S(t) is the stock of habits at time t, defined as:

$$S(t) = C(t-1) + (1-\delta)S(t-1), \tag{5.2}$$

where δ is the rate of depreciation. This stock of habits, or 'addictive stock,' represents the depreciated sum of all past consumption of the addictive good and explicitly captures the dependence of current consumption on past consumption. Making appropriate substitutions, Houthakker and Taylor derived the following demand equation:

$$C(t) = \pi + \tau C(t-1) + [\mathbf{X}(t) - \mathbf{X}(t-1)]\varphi + \mathbf{X}(t)\theta. \tag{5.3}$$

Thus, after simplification, the addictive nature of demand is captured by making current consumption dependent on past consumption. Houthakker and Taylor predicted that τ will be positive for addictive or habit forming goods like tobacco products. Houthakker and Taylor estimated alternative versions of eqn 5.3 for a number of goods, including cigarettes, using annual aggregates for the US and several Western

European countries. Their estimates provided considerable support for their hypothesis of habit formation in demand, with positive estimates of the structural stock coefficient (β) for almost all of the non-durable consumer goods, including cigarettes, they examined.

Mullahy (1985) took a similar approach in his empirical examination of cigarette demand using US survey data. In his model, the stock of past cigarette consumption has a negative impact on the production of commodities such as health and the satisfaction received from current smoking. Mullahy used a two-part model to estimate cigarette demand, as well as instrumental variables methods to account for the unobserved individual heterogeneity likely to be correlated with the stock of past consumption. Mullahy found strong support for the hypothesis that cigarette smoking is an addictive behavior, as shown by the positive and significant estimates he obtained for the addictive stock in both the smoking participation and conditional demand equations. His estimates for price are quite similar to those obtained by Lewit and Coate (1982), with the overall price elasticity of demand centered on –0.47. In addition, Mullahy estimated that men were more price-responsive than women (total price elasticities of –0.56 and –0.39, respectively). Finally, using an interaction between the addictive stock and price, Mullahy concluded that more-addicted smokers (defined as those with a larger addictive stock) were less responsive to price than their less-addicted counterparts.

Using an approach that combined aspects of the Houthakker and Taylor model with Deaton and Muellbauer's (1980) Almost Ideal Demand System, Jones (1989) explicitly modeled the acquired tolerance characteristic of addictive consumption. Tolerance, in his model, is captured by replacing the money prices of addictive goods, including cigarettes, with their shadow prices, which include a variety of other costs associated with addictive consumption, including future health consequences and reduced productivity. Jones used quarterly data from the UK to estimate this model for cigarettes and various other goods, as well as an alternative model that ignores the addictive or habitual nature of cigarette demand. He found that the more conventional model, with an own-price elasticity of cigarette demand of –0.29, provided a better statistical fit than the habit model, with an own-price elasticity of –0.60. Nonetheless, Jones concluded that addiction was an important factor in cigarette smoking, speculating that the effects of withdrawal are more important than those of tolerance.

In a model reminiscent of the partial adjustment process described by Marshall (1920), Baltagi and Levin (1986) estimated cigarette demand using a time-series of annual state-cross-sections for the period 1964–80. In their model, changes in cigarette consumption over time depend on the divergence between 'desired' cigarette consumption and actual consumption, where desired consumption depends on prices, income, current and lagged advertising, and other factors. They estimated a coefficient on lagged cigarette consumption of 0.9, which they interpret as evidence of addiction, while estimating an own-price elasticity of cigarette demand of –0.22.

5.3.3 Rational-addiction models

Several researchers have modeled addiction as a rational behavior. In this context, rationality simply implies that individuals incorporate the interdependence between past, current, and future consumption into their utility-maximization process. This is in contrast to the assumption, implicit in myopic models of addictive behavior, that future implications are ignored when making current decisions. In other words, myopic behavior implies an infinite discounting of the future, while rational behavior implies that future implications are considered, while not ruling out a relatively high discount rate. Several of the rational-addiction models, including those of Lluch (1974), Spinnewyn (1981), and Boyer (1983), assume that tastes are endogenous. These models build on the significant contributions of Ryder and Heal (1973), Boyer (1978), and others in the optimal growth literature who have developed endogenous taste models with rational behavior.

Spinnewyn (1981) and Phlips and Spinnewyn (1982) argued that incorporating rational decision-making into models of habit formation results in models that are 'formally equivalent to models without habit formation' (Spinnewyn 1981, p. 92). This observational equivalence is obtained by redefining wealth and the cost of current consumption, so as to account for the additional costs associated with the addictive stock. The demand equations that result are equivalent to those obtained from myopic models of addictive behavior. Thus, they argue, assuming rationality only leads to unnecessary complications.

This assertion was challenged by Pashardes (1986) in his empirical test of the myopic versus rational models in the context of the Almost Ideal Demand System. In his model, myopic and rational demand equations are the limiting cases of a more general model. In the context of his general model, Pashardes derived demand equations for a rational consumer in which current consumption is determined by past consumption and current preferences with full knowledge about the impact of current decisions on the future costs of consumption. He then tested for rational and myopic behavior using British data for nine groups of commodities, including tobacco products, alcohol, food, and others, for the period 1947–80. Pashardes found considerable evidence to support the hypothesis of rational behavior in general, as well as evidence that cigarette smoking is an addictive behavior. Finally, he noted that expectations concerning the future price and other costs of consumption played an important role in consumer behavior.

Becker and Murphy (1988) similarly rejected the notion that myopic behavior is empirically indistinguishable from rational behavior in their theory of rational addiction. They assumed that individuals consistently maximize utility over their life-cycle, taking into account the future consequences of their choices. At any point in time t, an individual's utility, U(t), depends on current addictive consumption, C(t), current consumption of a composite of non-addictive consumption, Y(t), and the stock of past consumption, S(t):

$$U(t) = U[C(t),\ Y(t),\ S(t)]. \tag{5.4}$$

They assumed that U(t) is a strongly concave function of C, Y, and S, and that the lifetime utility function is separable over time in C, Y, and S, but not in C and Y alone. Tolerance is incorporated by assuming that the marginal utility of the addictive stock is negative. Reinforcement is modeled by assuming that an increase in the addictive stock raises the marginal utility of current addictive consumption. Finally, eqn 5.4 captures withdrawal, since total utility falls with the cessation of addictive consumption.

Becker and Murphy define the stock accumulation process as:

$$\partial S(t)/\partial t = C(t) - \delta S(t) - h[D(t)]. \tag{5.5}$$

This is comparable to the stock accumulation process described in other models of addiction, with the exception of the D(t) term representing endogenous attempts to reduce the addictive stock.

Maximizing lifetime utility subject to an appropriate budget constraint and the stock accumulation process described by eqn 5.5 yields the following first order condition for the addictive good:

$$U_C(t) = \mu\pi_C(t), \tag{5.6}$$

where μ is the marginal utility of wealth and $\pi_C(t)$ is the full price of the addictive good, which depends on the money price of the good and the future utility costs (or shadow price) of the addictive stock. For harmful addictions, the full price of addictive consumption exceeds its money price due to the effects of tolerance and the health consequences of consumption, for example. Moreover, the full price is lower as depreciation on the addictive stock is faster or as the rate of time-preference is higher.

Becker and Murphy (1988) and Becker *et al.* (1991) developed several hypotheses from this basic model. First, addictive consumption displays 'adjacent complementarity'; that is, due to reinforcement, the quantities of the addictive good consumed in different time periods are complements. As a result, current consumption of the addictive good will be inversely related not only to the current price of the good but also to all past and future prices. Consequently, the long-run effect of a permanent change in price will exceed the short-run effect. In addition, price responsiveness varies with time-preference: addicts with higher discount rates will be relatively more responsive to changes in money price than those with lower discount rates. The opposite will be true with respect to the effects of information concerning the future consequences of addictive consumption. Thus, the model suggests that younger, less educated persons and those on lower incomes will be relatively more responsive to changes in the money price of cigarettes, while older, more educated persons and those on higher incomes will be relatively more responsive to new information on the health consequences of cigarette smoking.

Strong adjacent complementarity, reflecting strong addiction, can lead to unstable steady states in the Becker and Murphy model. This is a key feature of their rational addiction theory, helping to explain the binge behavior and 'cold turkey' quit behavior observed among addicts. Furthermore, these unstable steady states imply that there will be a bimodal distribution of consumption, again something that is observed for many addictive goods. In addition, Becker and Murphy's model implies that temporary events, including price reductions, peer pressure, or stressful events, can lead to permanent addictions.

Given a quadratic utility function (which has the useful property that the first order conditions for each of the arguments are linear), and the individual's rate of time-preference, σ, being equal to the market interest rate, a structural demand function for the consumption of the addictive good is derived as:

$$C(t) = \alpha_0 + \alpha_1 P_C(t) + \alpha_2 P_C(t-1) + \beta\alpha_2 P_C(t+1) + \alpha_3 C(t-1) + \beta\alpha_3 C(t+1), \quad (5.7)$$

where β is a discount factor that depends on the rate of time-preference ($\beta = 1/(1 + \sigma)$). Equation 5.7 is the basis for most of the empirical applications of the rational-addiction model. In this equation, current consumption of the addictive substance is inversely related to its current price, but positively related to past and future prices. As Becker *et al.* (1994) noted, the positive past and future price effects seem contradictory, given the discussion of adjacent complementarity. However, eqn 5.7 holds past and future consumption constant, eliminating the mechanism through which past and future prices affect current consumption. If past consumption did not change as past prices rose, then some other factor must have led to an increase in past consumption, offsetting the decrease caused by the price increase. This increase in past consumption is what causes current consumption to be positively related to past price when past and future consumption are held constant.

For addictive goods, eqn 5.7 implies that current consumption is positively related to past consumption, with the degree of addiction reflected by α_3. Similarly, given the assumption of rational behavior and the symmetry present in the model, future consumption has a positive impact on current consumption. Finally, the effects of future consumption and future price on current consumption are expected to be smaller than those of past consumption and price by a factor that depends on the rate of time-preference.

The demand equation given by eqn 5.7 allows for direct tests of addiction and rationality. If a good is not addictive, in the sense that its past consumption has no impact on current consumption, then α_2 and α_3 will be equal to zero. Similarly, if a good is addictive, but individuals behave myopically ($\sigma \to \infty$), then past consumption and price will have a positive impact on current consumption, but future consumption and price should have no effect, and the resulting demand equations would be comparable to those estimated by Mullahy (1985) and others described above. Clearly, the demand equations obtained when rationality is assumed are not observationally equivalent to those resulting from the alternative assumption of myopic behavior.

Given the endogeneity of past and future consumption in eqn 5.7, ordinary least squares estimation would lead to biased estimates of the key parameters. Fortunately, the theoretical model provides a solution to this problem. In the full reduced form, addictive consumption at any point in time is a function of all past, current, and future prices, while in the structural demand equation, it is a function of the current, once lagged, and once led price. Thus, further leads and lags of price are appropriate instruments for past and future consumption. In addition, many empirical applications of the Becker and Murphy rational-addiction model impose the additional assumption that the depreciation rate on the addictive stock is equal to one. When this assumption is imposed, $\alpha_2 = 0$, and current consumption is a function of the current price only, as well as past and future consumption.

The Becker and Murphy rational-addiction model has several interesting implications with respect to the effects of price on demand for an addictive good that can be obtained from the solution to the second-order difference equation given in eqn 5.7. For one, the effect of an anticipated price change is expected to exceed that of an unanticipated change in price, while the effect of a permanent price change will exceed that of a temporary change. Perhaps most interestingly, the Becker and Murphy model predicts that the long-run effect of a permanent change in price will exceed its short-run effect. Moreover, the ratio of the long-run to short-run price effects rises as the degree of addiction rises (Becker *et al.* 1991, 1994).

Chaloupka (1988, 1990, 1991, 1992) was the first to use individual level data to estimate cigarette demand equations derived from the Becker and Murphy rational-addiction model. His data were taken from the Second National Health and Nutrition Examination Survey for the United States conducted in the late 1970s. Although a cross-sectional survey, information on past cigarette consumption was collected retrospectively, which enabled Chaloupka to construct measures of past, current, and future cigarette consumption for all survey respondents ages 18 years and older. In addition to estimating a version of eqn 5.7, Chaloupka estimated an alternative version that replaced the past consumption and price variable with the stock of past cigarette consumption. In all of the estimated models, past cigarette consumption had a significant positive impact on current consumption, consistent with the notion that cigarette smoking is an addictive behavior. Similarly, consistent with the hypothesis of rational behavior, future cigarette consumption had a significant positive effect on current consumption. The relatively low rates of time-preference implied by these estimates are also consistent with the hypothesis of non-myopic or rational behavior.

Chaloupka's (1991) estimates of the long-run price elasticity of demand fell in the range from –0.27 to –0.48, larger than the elasticities obtained from conventional demand equations using the same data. In addition to estimating the rational addiction demand equations for the full sample, Chaloupka also explored the implications of the Becker and Murphy model with respect to the rate of time-preference by estimating comparable demand equations for subsamples based on age and educational attainment. Chaloupka's (1991) estimates were generally consistent with the hypothesis that less educated or younger persons behave more myopically than their more educated or older counterparts. In addition, less educated persons were more price responsive, with long-run price elasticities ranging from –0.57 to –0.62, than were more educated persons, who were generally unresponsive to price. Chaloupka (1990) also estimated separate demand equations for subsamples based on gender, concluding that men behaved more myopically and were relatively more responsive to price (long-run price elasticity centered on –0.60) than women (statistically insignificant effect of price on demand).

Becker *et al.* (1994) estimated a version of eqn 5.7 that assumed a depreciation rate of 1 on the stock of past cigarette consumption, as well as a comparable myopic demand equation, using a pooled time-series of annual US state cross-sections for the period 1955–85. They also found clear evidence that cigarette smoking is addictive as well as evidence of non-myopic behavior. However, estimates from unrestricted models containing past and future cigarette prices and taxes as instruments for past consumption produced relatively high estimates of the discount factor, implying less than fully rational behavior. Becker *et al.* presented a variety of other estimates to address this issue, including those from models that exclude future variables from the set of instruments and others that impose more reasonable discount rates. The authors concluded that there was insufficient information in the data to accurately estimate the discount rate, and that their estimates were clearly inconsistent with myopic behavior. The authors' estimates of the short-run price elasticity of demand, ranging from –0.36 to –0.44, are generally consistent with the estimates from conventional demand models. However, they found that, due to the addictive nature of smoking, the demand for cigarettes was nearly twice as responsive in the long-run (long-run elasticity estimates ranging from –0.73 to –0.79).

Sung *et al.* (1994) used similar data for 11 Western United States states for the years 1967–90 in an interesting application of the Becker and Murphy model that simultaneously estimated cigarette demand and supply. Their estimates for demand were generally consistent with those of Becker *et al.* (1994) and hence with the hypothesis of rational addiction. In addition, they found that when cigarette taxes increased, because of the oligopolistic nature of the cigarette industry and the addictive nature of cigarette demand, cigarette prices rose by more than the amount of the tax increase. This is consistent with Becker *et al.*'s (1994) theoretical model of a monopolist producing cigarettes.

Several other applications of the Becker and Murphy model have employed aggregate time-series data for various countries or other jurisdictions. Keeler *et al.* (1993), using data from California, Pekurinen (1991), using data for Finland, and Bardsley and Olekalns (1998), with data for Australia, produced estimates consistent with the hypothesis of rational addiction. Duffy (1996), Cameron (1997), and Conniffe (1995), using annual time-series data for the United Kingdom, Greece, and Ireland, respectively, found little support for the rational-addiction model. However, the latter two studies were limited by the relatively small number of observations available for their analyses, while all three have problems resulting from the use of several highly correlated regressors.

Finally, Douglas (1998) used hazard models to examine the determinants of smoking initiation and cessation in the context of the Becker and Murphy (1988) rational-addiction model. In contrast to his finding that price does not significantly affect the hazard of smoking initiation, Douglas concluded that increases in price significantly increase the likelihood (hazard) of smoking cessation. He estimated a price elasticity for the duration of the smoking habit of 1.07 with respect to future price, consistent with the hypothesis of rational addiction; paradoxically, past and current prices were not found to have a statistically significant effect on cessation. Similarly, his parametric and non-parametric results imply that the hazard of smoking cessation has a positive duration dependence, a finding Douglas suggested is consistent with rational addiction in that the rational smoker will discount future health costs less as they become more imminent.

5.4 Recent developments in the economic modeling of addiction

While the rational-addiction model has been more widely used in empirical examinations of addiction than any of the other models, many object to several of the assumptions that provide the foundation for these studies. Perhaps the most criticized aspect of the model is the assumption of perfect foresight. As Winston (1980, p.302) explained, in the context of the Stigler and Becker (1977) model:

> [T]he addict looks strange because he sits down at period j = 0, surveys future income, production technologies, investment/addiction functions, and consumption preferences over his lifetime to period T, maximizes the discounted value of his expected utility, and decides to be an alcoholic. That's the way he will get the greatest satisfaction out of life. Alcoholics are alcoholics because they want to be alcoholics, *ex ante*, with full knowledge of its consequences.

Similarly, Akerlof (1991) noted that, in the rational-addiction models, individuals who become addicted do not regret their past decisions, given that they are assumed to have been fully aware of the consequences of their consumption of a potentially addictive good when making these decisions. A few recent theoretical papers have addressed both the concerns about the 'decision' to become addicted and the apparent lack of regret among addicts that arise from the rational-addiction model.

5.4.1 The initiation of addiction

As discussed by Jha *et al.* (see Chapter 7), young people generally have a poor understanding of the addictiveness of tobacco use. This, coupled with the fact that most smokers begin before the age of 20, suggests that the rational-addiction model is ill-suited to describing smoking initiation. A recent theoretical paper by Orphanides and Zervos (1995) addressed this and other perceived inconsistencies of the rational-addiction model that arise largely from the assumption of perfect foresight. In particular, the authors introduced uncertainty into the model by assuming that inexperienced users are not fully aware of the potential harm associated with consuming an addictive substance. In their model, an individual's knowledge comes from the observed effects of the addictive good on others as well as through his or her own experimentation with that good. More specifically, they assume that the harmful effects (including addiction) of consuming a potentially addictive good are not the same for all individuals, that each individual possesses a subjective understanding of his or her potential to become addicted, and that this subjective belief is updated via a Bayesian learning process as the individual consumes the addictive good. Thus, an individual who underestimates his or her potential for addiction and experiments with an addictive substance can end up becoming addicted. Rather than the 'happy addicts' implied by the rational-addiction model (Winston 1980), these addicts will regret becoming addicted. As Orphanides and Zervos describe it (1995, p.750), individuals 'simply *risk* the possibility of addiction because the good is perhaps not harmful to them individually, and they enjoy the immediate rewards of its consumption. Since individuals who become addicts regret having taken that risk, they are naturally unhappy *ex post*'.

As Orphanides and Zervos noted, the incorporation of subjective beliefs into the rational-addiction model helps explain youthful experimentation, the importance of peer influences, and other commonly observed facets of addiction. They go on to note that their model provides important implications for public policy, notably with respect to the control of advertising, the importance of information dissemination programs, and public support of 'rehabilitation programs' aimed at helping addicts break their addiction. However, they note that their model does not go far enough to address other observed behavior of addicts that is inconsistent with the rational-addiction model (specifically decisions to quit and reinitiate addictive consumption).

5.4.2 Adjustment costs

More recent efforts attempt to deal explicitly with cessation decisions in the context of models that focus on the role of adjustment costs (Jones 1999; Suranovic *et al.* 1999). Suranovic and his colleagues, for example, reconsidered the adjacent complementarity of the Becker and Murphy (1988) model, noting that one implication of adjacent complementarity is that efforts to reduce current consumption will lead to reductions in utility. These 'quitting costs' are an important feature of their model and help explain the seeming inconsistency between smokers' stated wishes to quit smoking and their continued cigarette consumption. For example, they help explain why smokers engage in various behavior modification treatments, such as the use of the nicotine patch, which help make quitting easier.

A second point of departure from the Becker and Murphy model concerns the timing of the consequences of smoking, which Suranovic *et al.* assume are concentrated at the end of a smoker's life. In addition, rather than assuming that individuals choose a lifetime consumption path that maximizes the present value of their lifetime utility, Suranovic *et al.* assume 'boundedly rational' behavior, implying that individuals choose current consumption only rather than their lifetime consumption path. As a result, their model suggests that aging is enough to induce cessation among some smokers. That is, as the health consequences of smoking become more immediate, raising the perceived benefits of cessation, smokers will be more likely to quit, an hypothesis that is confirmed by Douglas' (1998) finding of positive duration dependence (described above). As in the Becker and Murphy model, their model implies that quitting 'cold-turkey' is likely in the case of a strong addiction (one where quitting costs rise rapidly for small reductions in consumption). However, in contrast to Becker and Murphy, Suranovic *et al.* predicted gradual reductions in consumption progressing to quitting in the case of relatively weak addictions.

Jones and his colleagues have conducted empirical analyses implementing the notion of adjustment costs as an important determinant of smoking cessation (Jones 1994; Yen and Jones 1996; Contoyannis and Jones 1999). Yen and Jones (1996), for example, estimate a double-hurdle model for smokers that considers separately their decisions concerning how much to smoke and whether or not to quit, where both decisions are based, in part, on past consumption. In this model, the net benefits of quitting are a key determinant of whether or not a smoker will quit. Net benefits are determined by comparing the health and other benefits associated with quitting to the withdrawal costs associated with cessation. Their estimates provide some empirical support that greater adjustment costs and/or lower benefits from quitting significantly reduce the likelihood of cessation. Interestingly, and contrary to general perceptions, they find that the heaviest smokers have the greatest incentive to quit once the adjustment costs are accounted for. Contoyannis and Jones (1999) extend this analysis to examine the Suranovic *et al.* hypotheses concerning the impact of age and the perceived benefits of quitting on smoking cessation. Their analysis of UK data provides support for the hypothesis that the probability of cessation rises with age. In addition, they find that the probability of quitting is higher for both the lightest smokers and heaviest smokers than it is for more moderate smokers. They do not, however, find that increases in the perceived benefits of quitting—as measured by the perceived improvement in life expectancy resulting from cessation—significantly raise the probability of quitting.

Most recently, Goldbaum (in press) builds on the Becker and Murphy (1988) and Suranovic *et al.* (1999) approaches in a model that allows for fully rational behavior by a consumer whose lifetime is finite. The key difference between his model and the others is the introduction of a second stock variable that captures the delayed health consequences that result from addictive cigarette consumption. In Goldbaum's model, a young person may rationally decide to become addicted, trading off the immediate gratification associated with current cigarette consumption against the future consequences associated with addiction and the distant health consequences of smoking. The optimal consumption path that results from this model can include quitting at some future point in response to the accumulating stock of smoking-attributable health consequences. While this model does address some of the limitations of the earlier economic models of addiction, it appears to be based on a relatively naïve description of the initiation process.

5.4.3 Addiction and time-preference

A separate but related stream of recent research has focused on the role of time-preference in modeling addictive behavior. As noted above, the early work by Strotz (1956) considered the 'time-inconsistency' of preferences in helping to explain the regret associated with addiction. In his model, this time-inconsistency resulted from the use of a non-exponential discount function. Repeating from above, time-inconsistency in Strotz's model is reflected by an individual changing his consumption path at some point in time 'even though his original expectations of future desires and means of consumption are verified' (p. 165). Put differently, even with full information, perfect foresight, stable preferences, and rational behavior at initiation that results in a plan that would have the person smoking in all future periods, a smoker may eventually decide to quit.

Much empirical evidence, generally from disciplines other than economics, indicates that preferences are often time-inconsistent. Vuchinich and Simpson (1999), for example, show that a hyperbolic discount function (that results in time-inconsistencies), rather than the more commonly used exponential function (which is always time-consistent), better describes the nature of discounting among drinkers. In addition, they find that heavy social and problem drinkers have higher discount rates (a stronger preference for the present) than lighter drinkers; Bretteville-Jensen (1999) finds similar differences among current and former heroin and amphetamine users and non-users. However, the direction of causality accounting for the differences in rates of time-preference is unclear. Recent work by Becker and Mulligan (1997) on the endogeneity of time-preference, for example, suggests that addiction itself can lead to heavier discounting, while at the same time a greater preference for the present can make addiction more likely (Becker *et al.* 1991). As Grossman *et al.* (1998) describe, these interactions between time-preference and addiction, coupled with imperfect information, youthful initiation, and the importance of peer influences, provide strong justifications for government interventions to reduce youth tobacco use.

O'Donoghue and Rabin (1999a, b, c), building on earlier work by Phelps and Pollak (1968) and Laibson (1994), as well as the imperfectly rational addiction models described above, present an interesting discussion of time-inconsistency and self-control that has implications for the economic modeling of addiction. In a model incorporating the two key elements of most economic models of addiction—the dependence of current consumption decisions on past consumption and the presence of what they call 'negative internalities' or the negative impact of the addictive stock on current utility—they allow for time-inconsistent preferences (O'Donoghue and Rabin, 1999b). As they describe it (p. 2):

> These preferences give rise to a self-control problem because at any moment the person pursues immediate gratification more than she would have preferred if asked at any previous moment.

In addition, they allow for two extreme types of persons—the 'sophisticated' person, who understands her self-control problems and, as a result, knows how she will behave in the future, and the 'naïve' person, who is completely unaware of his self-control problems and does not fully understand how he will behave in the future—in addition to persons with time-consistent preferences. In their model, the naïve person may end up consuming more than they otherwise would if they had no self-control problem, while some sophisticated persons may end up consuming less because they understand their self-control problem and fear becoming addicted. Finally, as the authors note, the introduction of self-control problems into the economic models of addiction is of particular importance because this leads to a much different implication for welfare than that resulting from the rational addiction type models. Specifically, for both sophisticated and naïve persons, self-control problems lead to behavior that causes severe harm (something that would not happen in the rational-addiction models with time-consistent preferences).

Laux (1999) also examines the welfare implications of nicotine addiction using the estimates obtained in various empirical applications of the rational-addiction model. His approach emphasizes three basic arguments: that youths do not adequately understand the costs that youthful smoking decisions will impose on their adult selves, in large part because of their relatively myopic behavior; that adult smoking reflects myopic, or at least less than fully rational behavior, given the rates of time-preference implied from empirical applications of the rational-addiction model; and that the importance of peer effects exacerbate the welfare problems resulting from youth smoking. This leads Laux to treat the internal costs associated with youthful decisions to start smoking and subsequent addiction as a type of externality (the magnitude of which swamps the more conventional externalities from smoking). It should be noted that his approach depends heavily on the assumptions that societies should not treat youth as sovereign and that the impact of decisions made by minors on their smoking as adults can be quantified using the estimates from the rational-addiction model described above. Following this approach, Laux concludes that there are significant social costs arising from cigarette smoking and that government intervention to reduce these costs is warranted (see Chapter 6 for a welfare analysis of tobacco use that is similar in spirit to Laux's analysis).

5.5 Policy implications

While addiction was once considered a problem not conducive to standard economic analysis, this is clearly no longer the case. After sporadic past efforts to theoretically and empirically model addiction, the last decade has seen a growing number of economists devote substantial effort to more fully understanding the impact of addiction on the consumption of tobacco products, alcoholic beverages, illicit drugs, and other addictive commodities. While these models have generated much debate, both within and outside of economics, this debate has stimulated new research that has made and promises further important theoretical and empirical contributions. One thing, however, is clear from both the theoretical models and their empirical applications: the basic laws of economics do apply to addictive goods, including tobacco products.

By necessity, the economic models of addiction are highly stylized and include many simplifying assumptions. These assumptions have led many to object to these models (e.g. the assumptions of perfect foresight, full information, and rational behavior in the rational-addiction model). In some cases, however, these objections have led to new theoretical developments, with different models emphasizing particular aspects of addictive behavior. For example, the recent work by Suranovic and his colleagues (1999) emphasizing the role of adjustment costs seems better suited to examining decisions to continue smoking or to quit (as in the empirical application by Contoyannis and Jones 1999) than it does to examining smoking-initiation decisions. In contrast, the theoretical model employed by Orphanides and Zervos (1995) provides interesting insights into youthful decisions to initiate addictive behaviors, including smoking, and the subsequent regretting of these decisions, but does little to explain cessation efforts. Many of the most promising of these theoretical advances have yet to be tested empirically, in part because the necessary data to test them are not available.

Despite its limitations, the economic analysis of addiction has contributed to a better understanding of the impact of prices and control policies on addictive behaviors, including tobacco use. All of the theoretical models emphasize the role of price and the importance of past consumption as determinants of current smoking decisions. Empirical applications of these models clearly show that higher prices will lead to reductions in cigarette smoking and other tobacco use, while increases in past cigarette consumption (that may have resulted, for example, from lower past prices) will raise current smoking. Price, in the context of these models, includes many dimensions that reflect the costs associated with smoking, including those that result from restrictions on smoking in public and private places, limits on the availability of tobacco products, and new information that raises perceptions of the long-term health and other consequences of smoking. While this is true for non-addictive goods as well, the key implication of the addiction models is that the long-run impact of permanent price changes will be larger than would be expected based on estimates that ignore the role of addiction. Thus, significant permanent real increases in tobacco taxes, strong restrictions on smoking in public places and other control efforts can lead to significant reductions in smoking in the short-run, with even larger reductions in the long-run. In addition, these models generally provide theoretical support for the hypothesis that the dissemination of information on the consequences of tobacco use and/or limits on the provision of misleading information can lead to significant reductions in tobacco use. Moreover, many of the more recent theoretical developments in the economic modeling of addiction contain interesting insights concerning the welfare effects of addictive consumption that provide strong support for government intervention to reduce tobacco use, particularly among youth.

The empirical application of recent theoretical developments, and the continued refinement and expansion of the economic modeling of addiction, promises to further improve our understanding of the role of prices and control policies in affecting smoking initiation, cessation, cigarette consumption, and other aspects of tobacco use. This further research is likely to produce additional, policy-relevant findings on the determinants of cigarette smoking and other tobacco use.

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