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ABSTRACT

Policy makers continue to advocate and adopt cigarette taxes as a public health measure. Most previous individual-level empirical studies of cigarette demand are essentially static analyses. In this study, we use longitudinal data to examine the dynamics of young adults' decisions about smoking initiation and cessation. We develop a simple model to highlight the distinctions between smoking initiation, cessation, and participation and show that the price elasticity of smoking participation is a weighted average of corresponding initiation and cessation elasticities, a finding that applies more broadly to other addictive substances as well. The paper's remaining contributions are empirical. We use data from the 1992 wave of the National Education Longitudinal Study, when most of the cohort were high school seniors, and data from the 2000 wave, when they were about 26 years old. The results show that the distinction between initiation and cessation is empirically useful. We also contribute new estimates on the tax-responsiveness of young adult smoking, paying careful attention to the possibility of bias if hard-to-observe differences in anti-smoking sentiment are correlated with state cigarette taxes. We find no evidence that higher taxes prevent smoking initiation, but some evidence that higher taxes are associated with increased cessation.

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1. Introduction

Many policy makers continue to advocate and adopt cigarette taxes as a public health measure. For example, the European Commission (2004) and the U.S. Healthy People 2010 (USDHHS 2004) objectives call for regular increases in cigarette taxes to prevent smoking-related deaths and disease. Over the past six years (2000 - 2006), in addition to increases in the U.S. federal cigarette tax, 43 States and the District of Columbia enacted a total of 70 cigarette excise tax hikes (Orzechowski and Walker 2007). In 2007 a substantial hike in the U.S. federal cigarette tax was proposed but vetoed.

A large number of empirical studies in health economics estimate the impact of cigarette taxes or prices on aggregate cigarette consumption and individual cigarette demand. The standard approach to study individual cigarette demand uses a two part model, where the first part is a model of smoking participation, and the second part analyzes consumption conditional upon participation.[1] Because they use cross-sectional data (or in a few cases repeated cross-sections), these studies are essentially static analyses of the relationship between the level of taxes and smoking behavior at a point in time. In this study, we use longitudinal data to examine the dynamics of young adults' decisions about smoking initiation and cessation.

Our study of smoking dynamics makes several contributions to health economics research on substance use. In section 2 we develop a simple empirical model of smoking initiation and cessation. In section 3, we use the model to highlight the distinctions between smoking

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[1]Chaloupka and Warner (2000) and Grossman (2005) provide reviews of the empirical literature. Examples that use the two-part model to study adolescent and/or adult smoking include Lewit, Coate and Grossman (1981), Wasserman *et al.* (1991), Evans, Farrelly, and Montgomery (1999), Gruber and Zinman (2001), and Levy and Meara (2006).

initiation, cessation, and participation. Our first contribution is to stress that if smoking is addictive, the standard participation equation is mis-specified because it fails to condition on past smoking status. Our second contribution is to show that because current smoking participation reflects past decisions about initiation and cessation, the elasticity of smoking participation with respect to price is a weighted average of the price elasticities of initiation and cessation. These insights also contribute to economic research on the demand for other addictive substances. For example, one implication is that participation in the use of an addictive substance is less price elastic than the initiation or cessation of use because of the accounting relationship between stocks and flows.

The paper's remaining contributions are empirical. As discussed in section 4, we use data from the 1992 wave of the National Education Longitudinal Study (NELS), when most of the cohort were high school seniors, and data from the 2000 wave, when they were about 26 years old. Although cigarette prices increased by over 50 percent in real terms between 1992 and 2000, smoking prevalence among the NELS respondents also increased from 18 percent to 23 percent, about the same increase observed in other cohorts over these ages. But these numbers mask important dynamics: by the year 2000, about 13 percent of 1992 non-smokers initiated smoking; while about one-third of 1992 smokers had quit. Put differently, nearly half of smokers at around age 26 were *not* daily smokers as high school seniors.

In section 5 we estimate models that explore the determinants of young adults' decisions about smoking initiation and cessation. The results show that key explanatory variables have different impacts on initiation and cessation. We also contribute new estimates on the tax-responsiveness of young adult smoking, paying careful attention to the possibility of bias if hard-to-observe differences in anti-smoking sentiment are correlated with state cigarette taxes. Our first identification strategy is to include a direct measure of state anti-smoking sentiment as an additional explanatory control variable. Our second strategy exploits a new source of identifying variation by focusing on young adults who face difference cigarette taxes because they moved to a different state between 1992 and 2000. Using these strategies, we find no evidence that higher taxes prevent smoking initiation, but some evidence that higher taxes are associated with increased cessation. Section 6 concludes.

2. An Empirical Model of Smoking Initiation and Cessation

In this section we sketch a simple empirical model to guide the specification of the smoking initiation and cessation equations to be estimated. We use a myopic addiction model. The consumer's current period utility is given by $u(G_t, S_t, S_{t-1})$, where G is a non-addictive composite good and S is the addictive good – smoking. Our empirical work focuses on discrete smoking statuses and discrete choices: non-smokers ($S_{t-1} = 0$) choose to initiate smoking or not ($I = 1$ or 0) ; smokers ($S_{t-1} = 1$) choose to cease/ quit smoking or not ($Q = 1$ or 0) ; or, unconditional on past smoking status, people choose to participate in smoking or not ($S_t = 1$ or 0). The model can be easily extended to distinguish discrete levels of smoking, such as light versus heavy smoking. The model can also be extended to include additional past periods, so for example smoking at time t-2 can be allowed to influence the current utility from smoking. These extensions introduce additional historical smoking statuses, smoking-status-dependent utility functions, and smoking status transitions. Our empirical work mainly focuses on transitions between non-smoking and smoking, but we estimate some models that distinguish between different levels of past smoking.[2]

To begin to derive the equations to be estimated, we assume that a non-smoker decides to initiate smoking based on the utility gain from starting:

$$y^{I*} = u(G_t, S_t = 1, S_{t-1} = 0) - u(G_t, S_t = 0, S_{t-1} = 0) \qquad \textbf{(1)}$$

Similarly, a smoker decides to cease based on the utility gain from quitting:

$$y^{Q*} = u(G_t, S_t = 0, S_{t-1} = 1) - u(G_t, S_t = 1, S_{t-1} = 1) \qquad \textbf{(2)}$$

Finally, for the discussion below in section 3 it is useful to note that unconditional on past smoking status, smoking participation depends on the utility gain from smoking:

$$y^{S*} = u(G_t, S_t = 1, S_{t-1}) - u(G_t, S_t = 0, S_{t-1}) \qquad \textbf{(3)}$$

The utility gains y^{I*} and y^{Q*} are the unobserved continuous latent variables that underlie the observed discrete outcomes of smoking initiation and cessation. As shown in the Appendix for a specific utility function, the utility gains y^{I*} and y^{Q*} can be shown to be functions of current prices (P_t), other time-varying factors X_t, an environmental factor (F) such as prevailing anti-smoking sentiment that is assumed to be fixed over time, and a random term e:[3]

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[2]Because we only consider smoking status at time t-1, our models of initiation do not distinguish new starters from re-starters. Because we focus on transitions between non-smoking and smoking, we mainly abstract from differences in cigarette consumption conditional on smoking. The second part of the standard two-part model focuses on cigarette consumption conditional on smoking participation; see the references in footnote 1. A related strand of empirical research estimates double hurdle models of cigarette consumption (e.g., Jones 1989, Yen and Jones 1996, Labeaga 1999).

[3]In the Appendix, we also show that our approach is consistent with the shadow price approach suggested by Colman, Grossman, and Joyce (2002, 2003). Our approach could be extended to a rational addiction model by replacing current period utility u( ) with lifetime utility. The rational addict takes into account the implications of his current consumption of S for future choices and lifetime utility. As a result, y^{I*} and y^{Q*} would also depend upon expectations of future cigarette prices and other time-varying variables.

$$y^{I}* = \alpha_0 + \alpha_1 P_t + \alpha_2 F + \alpha_3 X_t + e^{I} \qquad \textbf{(4)}$$

$$y^{Q}* = \beta_0 + \beta_1 P_t + \beta_2 F + \beta_3 X_t + e^{Q} \qquad \textbf{(5)}$$

If the consumer decides to initiate or cease smoking based on whether $y^{I}* > 0$ and $y^{Q}* > 0$ respectively, this implies :

$$\Pr\{I_t = 1 | S_{t-1} = 0\} = G(\alpha_0 + \alpha_1 P_t + \alpha_2 F + \alpha_3 X_t) \qquad \textbf{(6)}$$

$$\Pr\{Q_t = 1 | S_{t-1} = 1\} = G(\beta_0 + \beta_1 P_t + \beta_2 F + \beta_3 X_t) \qquad \textbf{(7)}$$

Assuming G( ) is the standard normal cumulative distribution function implies the probit discrete time hazard models of smoking initiation and cessation we estimate below.

Because smoking initiation and cessation reflect changes in smoking status over time, it might seem surprising that equations (6) and (7) do not include P_{t-1} and X_{t-1} (or $\Delta P = P_{t-} - P_{t-1}$ and $\Delta X = X_{t-} - X_{t-1}$). Instead, the empirical model captures the role of past variables by conditioning on past smoking status (S_{t-1}). Current smoking decisions are influenced by past smoking status S_{t-1}, but except through S_{t-1} the combination of past prices and other demand influences that led to St-1 = 0 or 1 does not matter.[4] Our empirical model captures the role of past smoking status by allowing the parameter vectors α and β in equations (6) and (7) to differ. Put differently, our empirical model given by equations (6) and (7) is equivalent to a smoking participation model that includes on the right hand side: past smoking status; and the interactions of past smoking

[4]Becker, Grossman, and Murphy (1994) use an analogous result to identify their structural linear difference equation that shows current cigarette consumption as a function of past and future consumption. Becker, Grossman and Murphy (1994) and many previous rational addiction studies focus on continuous measures of the consumption of an addictive good, while we focus on discrete outcomes.

status with all of the other explanatory variables.[5]

3. More on the Distinctions between Smoking Initiation, Cessation, and Participation

The Role of Addiction

It is necessary to empirically distinguish smoking initiation, cessation, and participation because smoking is addictive. In contrast to the empirical model given by equations (6) and (7), the standard specification of a smoking participation equation does not condition on past smoking status and thus omits all past influences.[6] The standard specification is correct only if smoking is not addictive. If smoking is non-addictive S_{t-1} does not appear in the current period utility function. After appropriate sign changes the latent variables behind non-addictive smoking initiation, cessation, and participation decisions in equations (1) - (3) are identical: $y^{I*} = -y^{Q*} = y^{S*}$. That is, if smoking were non-addictive, there would be no meaningful distinction between initiation and the decision not to quit, because past smoking would be irrelevant to the current

[5]Our empirical model faces the familiar problem of distinguishing state dependence, where past smoking status is a determinant of current smoking, from unobservable heterogeneity, where past period non-smokers and smokers have different unobservable tastes. Even though past demand influences do not enter the structural model given by equations (6) and (7), the unobservable heterogeneity in tastes can be systematically related to past observed demand influences. For example, suppose the price P_{t-1} is higher in New York than in Kentucky. Because they chose to smoke despite facing a higher P_{t-1}, it is clear that the population of smokers in New York will on average have a stronger unobservable propensity to smoke than the population of smokers in Kentucky. The problem of distinguishing state dependence from heterogeneity arises if unobservables at time t-1 and t are correlated.

[6]An alternative to conditioning on past smoking status is to estimate a reduced-form smoking participation equation that includes the determinants of past smoking status as additional explanatory variables. DeCicca, Kenkel and Mathios (2005) estimate a smoking participation model that includes both current and past prices. As noted there (p. 300), this is only a first step towards the correct reduced-form specification because it does not include the entire relevant history of past prices and other demand influences.

decision to smoke.[7] This is consistent with common usage: the terms 'starting/ quitting' or 'initiation/ cessation' are not used to refer to changes in non-addictive or non-habitual behavior. For example, while we refer to someone starting or quitting smoking, we do not refer to someone starting or quitting milk consumption.

A testable implication of the hypothesis that smoking is not addictive is that the explanatory variables should have symmetric effects on smoking cessation and initiation. In terms of equations (6) and (7), the testable implication is that the parameter vectors α and β are identical (with appropriate sign changes). For example, if smoking is non-addictive an explanatory variable like the price of cigarettes is expected to have equal and opposite effects on initiation and cessation.[8] The standard specification of a smoking participation model implicitly imposes this restriction; we test it below.

Elasticities of Smoking Participation, Initiation, and Cessation

Linking smoking participation to initiation and cessation behavior also sheds new light on the interpretation of the standard smoking participation equation. Consider the individual-level relationship between the probability of smoking participation and the conditional probabilities of initiation and cessation:

$$\Pr\{S_t =1\}= \Pr\{I_t = 1 \mid S_{t-1} = 0\} \bullet (\Pr \{S_{t-1} =0\} + (1 - \Pr\{Q_t =1 \mid S_{t-1} =1) \bullet \Pr\{S_{t-1} = 1\} \qquad \mathbf{(8)}$$

The price-elasticity of smoking participation is a common focus of attention. Taking the

[7]Although Labeaga (1999) estimates a rational addiction model of smoking, he appears to implicitly assume that there is a single latent variable behind the smoking participation decision (see his equation 5, page 53).

[8]In a double-hurdle model of smoking and quitting, Yen and Jones (1996) suggest that variables unrelated to the fixed costs of quitting should have equal and opposite effects on the decision to quit and on cigarette consumption by continuing smokers. This is not inconsistent with our point about the determinants of non-smokers' decisions about initiation.

partial derivative of equation (8) with respect to price, the short-run impact of the current price of cigarettes on smoking participation is through its impact on current initiation and cessation decisions:[9]

$$\partial \Pr\{S_t = 1\} / \partial P_t = [\partial \Pr\{I_t = 1 | S_{t-1}=0\} / \partial P_t] \bullet \Pr\{S_{t-1} = 0\}$$
$$- [\partial \Pr\{Q_t = 1 | S_{t-1}=1\} / \partial P_t] \bullet \Pr\{S_{t-1} = 1\} \qquad \textbf{(9)}$$

To further explore the implications of this for the correct interpretation of the results, aggregate and replace the probabilities with corresponding fractions of the population (i, q, and s) and re-write equation (10) in elasticity form:

$$|\varepsilon^S_t| = |\varepsilon^I_t|(1 - s_{t-1})(i_t / s_t) + \varepsilon^Q_t (s_{t-1})(q_t / s_t) \qquad \textbf{(10)}$$

Equation (10) makes explicit some straight-forward relationships between the price-elasticities of smoking participation, initiation, and cessation that are often overlooked. First, the price-elasticity of smoking participation is a weighted average of the price-elasticities of initiation and cessation.

Second, because in the short run the weights do not sum to one, the stock of smoking participation will be much less price elastic than the flows of initiation and cessation. The weights correspond to the magnitudes of the annual flows of new smokers and former smokers, relative to the stock of smokers.[10] In very rough terms, in the U.S. about 1.5 million people start

[9]When taking the partial derivative we assume that the probabilities of past smoking participation $\Pr\{S_{t-1} = 0\}$ and $\Pr\{S_{t-1} = 1\}$do not depend on the current price. This assumption follows from a myopic addiction model. In a rational addiction model, the assumption holds for a change in price at time t that was not anticipated at time t-1.

[10]Using the empirical population fractions s_t, s_{t-1}, i_t and q_t, if N = adult population, the flow of new smokers = $N(1 - s_{t-1})(i_t)$, the flow of former smokers = $N q_t s_{t-1}$, and the stock of current smokers = $N s_t$. Because N cancels out, the ratios of the flows of new and former smokers to the stock of current smokers equal the weights on ε^I_t and ε^Q_t in equation (10).

smoking each year and about 1.5 million quit, compared to a stock of about 50 million smokers. So on an annual basis for all adults, the weights sum to 3/50 = 0.06. Some estimates suggest the price elasticity of adult smoking participation is around -0.2 (USDHHS 2000, pp. 327-337). If so, on an annual basis the price elasticity of initiation and cessation must average to be about 16.7 (= 1/0.06) times larger in absolute value, i.e. about -3.3. Or using the rough numerical estimates, if ε^S_t = -0.2, a 10 percent increase in price causes the number of adult smokers to fall by 1 million. The change of 1 million smokers requires large increases in the flows of starters and quitters. For example, this change could be achieved if a 10 percent price hike: causes initiation to fall by one-third from 1.5 million to 1 million; and causes cessation to increase by one-third from 1.5 million to 2 million.

In equation (10) smoking participation is less price elastic than initiation or cessation because of the accounting relationship between stocks and flows. As such, equation (10) does not contradict the behavioral prediction from the model of rational addiction that an addictive choice like smoking is more price elastic in the long run than in the short run. For example, in the short run smoking cessation might be relatively price inelastic, with the short run response mainly coming through reductions in intensity. However, if our model were extended to allow different levels of past smoking, because of addiction the utility gain from quitting would depend on the intensity of past smoking. In such a model, cutting down in the short run makes cessation more likely in the long run, which in turn means that smoking cessation is more price elastic in the long run than in the short run. This is consistent with the empirical evidence from Falba *et al.* (2003), who find that smokers who reduce the quantity they smoke are more likely to subsequently quit.

A third implication of equation (10) is that because smoking initiation and cessation rates vary over the life course, the correct interpretation of the elasticity of smoking participation (ε^S_t) also varies over the life course. Early in adolescence, quitting behavior is relatively unimportant. Even if the quit rate (q_t) is substantial, there is a small fraction of smokers (s_{t-1}) who can potentially quit. So for younger adolescents, ε^S_t mainly reflects the price elasticity of initiation. By early adulthood, initiation (i_t) becomes less common and the fraction of non-smokers at risk of initiating ($1- s_{t-1}$) is smaller, so the price elasticity of cessation gains in importance as a determinant of ε^S_t. As noted above, in the sample of young adults we use in our empirical study both initiation and cessation are significant. By middle age, ε^S_t is driven entirely by the price elasticity of cessation. As a matter of interpretation these patterns make it problematic to compare the price-elasticity of smoking participation estimates for samples of different ages – they reflect different behaviors.

Implications for the Correct Specification of a Model of Smoking Participation

In the empirical work below, we focus on estimating models of smoking initiation and cessation. However, the distinctions we emphasize have important implications for the correct specification of models of smoking participation. One approach is to estimate a structural smoking participation equation that includes prior smoking status as an endogenous explanatory variable.[11] Another approach is to estimate a reduced-form smoking participation equation that

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[11]The structural participation equation is analogous to the linear difference equation derived by Becker, Grossman, and Murphy (1991), where current cigarette consumption is a function of past and future cigarette consumption, the current price of cigarettes, and shift variables. Most studies of rational addiction focus on estimating this structural equation, although the reduced-form equation of current consumption as a function of current, past and future prices has also been estimated (e.g., Gruber and Kosegi 2000). Most studies also use a continuous measure of smoking. However, Kan and Tsai (2001) and Contoyannis and Jones

includes the determinants of prior smoking status as additional explanatory variables. Most previous studies estimate models of smoking participation that do not include a measure of prior smoking status, often because the data sets used do not contain that information. But the standard approach in previous studies can still be usefully compared with a correctly specified reduced-form approach. If prior smoking status is not known, smoking participation at time t can be re-expressed in terms of I and Q. Recursively substituting for S in equation (8) and substituting equations (1) and (2) into equation (3) yields an empirical model of smoking participation at time t:

$$S_t = G(\gamma_0 + \gamma_1 P_t + \gamma_2 F + \gamma_3 X_t + \gamma_4 P_{t-1} + \gamma_5 P_{t-2} + ...) \qquad \textbf{(11)}$$

The exact specification of equation (11) and the relationships between the γ parameters of the participation equation and the α and β parameters of the initiation and cessation models given by equations (6) and (7) are complicated and depend upon simplifying assumptions. In the Appendix we show that after a number of simplifying assumptions a linear probability model of smoking participation should be specified as:

$$S_t = \gamma_0 + \gamma_1 P_t + \gamma_2 P_{t-1} + \gamma_3 P_t P_{t-1} + \gamma_4 F + \gamma_5 F^2 + \gamma_6 F P_t + \gamma_7 F P_{t-1} \qquad \textbf{(12)}$$

The general point for empirical work is that current smoking participation depends on a series of past decisions, i.e. the probability of currently smoking is a joint probability. Therefore, the multiplicative terms in the joint probability mean that current smoking participation should be modeled as a function of the relevant history of prices and their interactions with each other and other determinants of smoking decisions. In practice, estimating an equation like (12) will

(2001) estimate structural models of a dichotomous measure of cessation and Gilleskie and Strumpf (2005) and Auld (2005) estimate structural models of a dichotomous measure of youth smoking initiation.

usually be infeasible because of lack of data or multicollinearity among the explanatory variables.

In contrast to equations (11) or (12), the standard approach estimates the probability of smoking participation at time t as a function of only current variables. The standard approach that omits past variables is correct if smoking is not addictive. But if smoking is addictive, the standard participation equation is mis-specified because it only includes the current price of cigarettes. This creates omitted variables bias to the extent current and past prices are correlated. Most of the variation in cigarette prices is driven by state excise tax policy. During times when tax policies are not frequently revised, cigarette prices will tend to be very serially correlated.[12] In this situation the current price of cigarettes tends to proxy for the history of prices. As a result, the estimated effect of the current price on smoking participation tends to reflect the effects of past prices on initiation and cessation decisions in earlier years. Put differently, the resulting price-elasticity estimate roughly corresponds to a long-run price-elasticity because it reflects long-standing differences in prices across states. An additional problem is that many studies are also unable to control for differences in anti-smoking sentiment across states that are correlated with long-standing differences in prices across states.[13]

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[12]Bertrand, Duflo, and Mullainathan (2004) and Helland and Tabarrock (2004) make a similar point in their demonstrations that serial correlation can cause serious problems in inference (deflated standard errors) in difference-in-difference estimates of policy effects.

[13]Warner (1982) and Hunter and Nelson (1992) provide evidence that states increased cigarette taxes in response to a shift in the public's demand for anti-smoking policies. DeCicca, *et al.* (2006) develop an empirical measure of state-level anti-smoking sentiment during the 1990s. They find that after controlling for differences in state anti-smoking sentiment, the price of cigarettes has a weak and statistically insignificant influence on smoking participation. In contrast, the CDC (1998) and Gruber (2000) continue to find significant price effects in model of youth smoking that include state dummies (state fixed effects) to control for unobservable state-level influences on youth smoking.

Because of the practical difficulties we do not attempt to estimate the model of smoking participation given by equation (12). Instead, for comparison with previous studies we adopt the standard (mis-) specification that omits the determinants of prior smoking status. Our main emphasis is on our models of smoking initiation and cessation.

4. Data

Overview of NELS

The National Education Longitudinal Study (NELS) began in 1988 as a nationally representative survey of U.S. eighth graders. Since this initial wave there have been four follow-up surveys, with the most recent coming in 2000 when most sample members were twenty-five or twenty-six years old. Of the five available NELS waves, four contain information on smoking behavior; only the third follow-up (1994) does not. To focus on the transition from youth to young adult smoking, we use the last two waves with smoking information — the second follow-up (1992) and the fourth follow-up (2000). While this is a relatively long interval, NELS retained approximately two-thirds of the respondents to the 1992 wave.[14] More precisely, of the 19,220 respondents to the 1992 wave, 12,144 are included in the 2000 wave. Table 1 presents descriptive statistics for the key variables used in the analysis.

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[14] NELS staff made special efforts to locate prior respondents for the 2000 wave. These measures included the use of marketing databases and, when possible and necessary, state motor vehicle registries. Additional efforts were made to locate those inherently more difficult to find (e.g., individuals in the military and those incarcerated at time of survey). In DeCicca, Kenkel and Mathios (2005), we use an inverse probability weighted (IPW) model to correct for attrition bias (Wooldridge 2002a, b). The IPW models and the unweighted models yield very similar results.

Smoking Patterns in the NELS Data

Our measure of smoking is based on responses to a question about the number of cigarettes smoked per day. Legitimate responses include: zero, less than one, one to five, six to ten, one-half to two packs (10-40 cigarettes) and more than two packs (41 or more cigarettes) per day. In the 2000 data: 75.3 percent report being non-smokers, 1.3 percent smoking less than one cigarette per day, 6.4 percent one to five, 7.0 percent six to ten, 9.3 percent eleven to forty, and 0.7 percent report smoking more than two packs per day. We collapse this information into dichotomous measures of whether each respondent smoked in 1992 and 2000. While smokers report less than their true consumption (Warner, 1978), a meta-analysis of studies that compared self-reported smoking with biochemical markers of smoking shows that people fairly accurately report *whether* they smoke (Patrick *et al.*, 1994). This suggests our dichotomous measure of smoking status is fairly accurate. We include the relatively small number of individuals who report smoking less than one cigarette per day with non-smokers, because this group likely includes those with very little attachment to daily smoking.

Using our measures of smoking we find that between 1992, when NELS respondents were about 17 years old, and 2000, the cumulative smoking initiation rate was 13 percent. This might seem to contradict conventional wisdom that smoking initiation mainly occurs during adolescence. Of course, over the previous eight years that preceded 1992, the cumulative initiation rate among NELS respondents was even higher at 18 percent. And evidence from other sources suggests that much of the initiation in the NELS cohort after 1992 was probably concentrated over the ages of 17 to 21. However, recent trends in other data also lead Lantz (2003, p. 169) to suggest that “the upsurge in smoking among young adults appears to be part of a broader phenomenon involving changes in substance use and risk taking behaviors among youth making the transition to young adulthood."

Between 1992 and 2000 the cumulative smoking cessation rate in the NELS cohort was about 34 percent, or slightly over 4 percent a year. Thus, while smoking cessation is not as common among young adults as it becomes later in the life course, it is still important in this sample of young adults.

Cigarette Taxes: Measurement and Identification of Causal Effects

The key explanatory variable of interest is the cigarette excise tax. Cigarette taxes were merged to the data on the basis of state of residence information in 2000.[15] There is not a strong consensus among researchers about whether to use cigarette taxes or prices in empirical models of smoking. Arguments in favor of the use of taxes include: prices may be subject to market-level endogeneity and so may be higher in areas with higher demand; and taxes are the directly-manipulable policy tool. We use taxes in our empirical models, and use the results to calculate the implied price elasticity. To calculate the price elasticity from the tax elasticity, we assume that taxes are fully passed through to prices.

Because we rely on cross-state differences in cigarette taxes for identification of causal effects, we use several strategies to control for the possibility that taxes are correlated with hard-to-observe state-level influences on smoking such as anti-smoking sentiment. The challenges

[15] Given the timing of fourth follow-up interviewing, which occurred between January and September 2000, only one state, New York, presents problems in assigning the appropriate tax rate. New York increased its cigarette tax from 56 to 111 cents, effective March 1, 2000. In previous work with NELS data, we assigned tax based on respondent date of interview, but this information is not available in the fourth follow-up. Because the majority of interviewing occurs after this increase, and because it was announced long before January 2000, we assign a tax of 111 cents to New York residents.

posed by relying on cross-state tax differences for identification are widely recognized (see for example DeCicca, Kenkel and Mathios 2002, Gruber and Zinman 2001, and Carpenter and Cook 2008). State cigarette taxes are not randomly set, but result from the political process which reflects public sentiment towards smoking. Warner (1982) and Hunter and Nelson (1992) provide evidence that states increased cigarette taxes in response to a shift in the public's demand for anti-smoking policies. If public anti-smoking sentiment is itself an important determinant of smoking, failing to control for differences in anti-smoking sentiment across states will bias estimates towards finding stronger tax-responsiveness. In addition, states with higher anti-smoking sentiment and higher taxes may have stronger non-tax tobacco control measures. If other tobacco control measures are important but hard-to-observe determinants of smoking, this leads to further bias in the estimated tax effect. Several studies that use data from repeated cross-sections include state fixed effects and rely on within-state variation in cigarette taxes for identification (for example, Gruber and Zinman 2001 and Carpenter and Cook 2008). We can not use that strategy, but the rationale behind our identification strategies is similar.

Our first strategy follows DeCicca *et al.* (2008) and uses a direct measure of state anti-smoking sentiment. The measure of state anti-smoking sentiment is based on a factor analysis of responses to questions about attitudes towards smoking in the Tobacco Use Supplements to the Consumer Population Survey (TUS-CPS). The factor analysis of the answers to the nine anti-smoking attitude questions suggests they reflect a common source. DeCicca *et al.* estimate the first factor for every individual TUS-CPS respondent, and then calculate the average of the estimated factor by state. In the empirical models below we use the measure of state anti-smoking sentiment based on the 1998-1999 TUS-CPS, which is matched to individual NELS respondents based on their state of residence in 2000.

DeCicca *et al.* (2008) provide an in-depth discussion of the usefulness of the measure of anti-smoking sentiment as a control variable. First, they present evidence that it is reasonable to interpret the result as a measure of state anti-smoking sentiment. For example, the lowest levels of anti-smoking sentiment measured this way are in tobacco-producing states. The highest measured anti-smoking sentiment is in Utah, presumably reflecting the influence of the Mormon religion. Second, DeCicca *et al.* explore the possibility that the measure of anti-smoking sentiment might itself be econometrically endogenous due to omitted variables or simultaneity. As discussed above sentiment might be correlated with other tobacco control measures. To the extent our models omit other important tobacco control measures, even after including the sentiment measure our results may still be biased towards over-estimating the tax-responsiveness of smoking. Smoking and sentiment might also be simultaneously determined at the state level, if high levels of smoking in a state cause lower anti-smoking sentiment as well as vice versa. However, DeCicca *et al.* find very similar results when they use an alternative measure of sentiment based only on survey responses of people living in never-smoking households. This measure of the strength of non-smokers' anti-smoking sentiment is less likely to pick up reverse causality from smoking to sentiment. DeCicca *et al.* also report simple analyses of state-level data that support a political economy model where anti-smoking sentiment in 1992 drives future tax increases. In this situation, simultaneity biases our results towards over-estimating the tax-responsiveness of smoking. Third, DeCicca *et al.* compare the usefulness of the sentiment measure with alternative proxies used in previous studies. The results suggest that the measure of anti-smoking sentiment is a more useful control variable than including an index of state regulations or indicators for residence in a tobacco-producing state. In data where it is possible to include state fixed effects, the results are similar to those obtained when the sentiment measure is included.[16]

As an alternative to including the measure of state anti-smoking sentiment, we use a second identification strategy. This strategy exploits a new source of identifying variation by focusing on young adults who face different cigarette taxes because they moved to a different state between 1992 and 2000. State movers face current taxes that are uncorrelated with the taxes and anti-smoking sentiment they faced during their adolescence. Holding other influences constant, this suggests that models estimated over the sample of state movers should yield less biased estimates of the causal impact of current taxes on smoking initiation and cessation. However, state movers might also face different peer influences. With peer influences, taxes have two potential impacts on an individual's smoking: a direct impact; and an indirect impact where changing peers' smoking influences the individual's smoking. Models estimated over the sample of state movers capture the direct impact of current taxes on smoking and the indirect impact of current taxes through their current peers' behavior. If movers and stayers face much different indirect impacts because of different peers, even if there is no bias from unobserved anti-smoking sentiment the estimated impact of taxes will be different between the two groups. But to the extent that individuals sort themselves into similar peer groups regardless of moving,

[16]In a recent study of youth smoking Carpenter and Cook (2008) mainly rely on including state fixed effects, but they explore our measure of anti-smoking sentiment as an alternative approach. Using a different individual-level data on youth smoking they "reproduce the main DeCicca et al. finding [that] the tax coefficient becomes smaller, with much of the estimated variance 'loading onto' the sentiment measure." (p. 18) In contrast to DeCicca et al., however, Carpenter and Cook continue to find evidence of significant tax-responsiveness after controlling for anti-smoking sentiment.

moving-induced differences in peer influences are likely to be small. Furthermore, even if peer influences differ, the magnitude and even the direction of the difference are difficult to predict.[17] However, it is important to keep in mind all the factors that are controlled for in the mover/ stayer analysis.

Given the mover/stayer identification strategy, a natural question is whether there are observable differences between these two groups. Table 1 contains several comparisons of movers and stayers. In particular, note that the levels of taxes in both 1992 and 2000 are virtually identical for the two groups. So on average, movers and stayers faced almost the exact same change in taxes between 1992 and 2000. This suggests that respondents' movement across states is largely orthogonal to taxes. To the extent that this is true, comparisons of movers and stayers should provide improved estimates of tax responsiveness, relative to the traditional cross-sectional model. While taxes are unrelated to mover/stayer status, there are other, non-trivial differences between stayers and movers. As seen in Table 1, movers are less likely to smoke, more likely to be white, and perhaps more academically inclined, as the average test score for this group is roughly one half of one standard deviation higher than their non-mover counterparts. On the surface, these differences suggest college attendance may be a prime reason for state moving.

[17] Clark and Loheac (2007) find that adolescent substance use is correlated with lagged peer group behavior, but they note that the peer influences they estimate are much smaller than in some previous studies. Based on their results, Clark and Loheac suggest that "such copycat [indirect] effects may make intervention more effective with respect to alcohol than to cigarettes or marijuana." (p. 781). Whatever its size, it is also unclear whether the indirect impact will be larger or smaller for movers compared to stayers. Clark and Loheac do not find systematic differences in the role of peer influences between adolescents who recently moved and others. Gaviria and Raphael (2001) suggest that movers may be more influenced by peers, at least with respect to illicit drugs.

Although there are observable differences between movers and stayers, there seems little reason to suspect that tax-responsiveness varies across these groups in ways that invalidate the mover vs. stayer identification strategy. To the extent moving is related to college attendance, movers may be more future-oriented than stayers. In a simple two-period rational addiction version of the model presented in the Appendix, more future-oriented consumers are predicted to be more price-responsive (derivation available upon request).[18] Intuitively, future-oriented consumers are more price-responsive because they react more to the fact that a permanent price increase not only increases the current price but also increases the price of next period consumption, which is a complement to current consumption. If because of their greater future orientation movers are more price-responsive than stayers, by focusing on movers our identification strategy remains somewhat biased towards finding a significant negative tax response.

Analysis Sample

As noted above, the fourth follow-up of NELS includes 12,144 individuals. Restricting to those with complete smoking and relevant state-of-residence information in both 1992 and 2000 reduces sample size slightly to 10,706, or about 88 percent of fourth wave respondents. All specifications include controls for gender, race, year of birth, region and the respondent's composite score on from standardized tests in reading and mathematics. Missing data on the

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[18]On the other hand, in the general rational addiction model Becker, Grossman, and Murphy (1991, note 3) show that under what they argue is a plausible condition, more future-oriented consumers will be less price-responsive. The condition involves second and cross-partial derivatives of the utility function. In words, it requires that "The increase in S [the addictive stock] has a larger effect on its marginal utility than does the increase in c [current consumption]." We thank Michael Grossman for pointing out the possible interaction between future orientation and tax-responsiveness.

covariates race (35 cases), year of birth (251 cases) and test score (136 cases) reduces the available sample for complete case analysis to 10,336.[19] We follow our earlier work and use conditional mean imputation to fill in missing values for these covariates. Hence, our overall analysis sample consists of the above-mentioned 10,706 individuals with smoking and state information in 1992 and 2000. Differences between the results we present and those generated by complete case analysis are trivial.

4. The Dynamics of Yong Adult Smoking

Probit Models of Young Adult Smoking Behaviors

In this section, we estimate probit models of smoking initiation and cessation between 1992 and 2000. For the smoking initiation models, the at-risk sample consists of the 8,759 respondents who were non-smokers in 1992. For the smoking cessation models, the at-risk sample consists of the 1,947 respondents who were smokers in 1992. In addition, to test the restrictions implicit in the standard specification in previous research, we also estimate probit models of smoking participation in 2000. In the models of smoking participation, 1992 non-smokers and smokers are pooled together yielding a sample of 10,706. The results are presented in Table 2.

The results in Table 2 suggest that the distinction between smoking initiation and cessation is empirically important and useful. As discussed above in section 3, if smoking is non-addictive it would be appropriate to ignore past smoking status and estimate the standard specification of a smoking participation model. In that case, the latent variables underlying

[19]Note that some observations are missing information on more than one covariate. So although there are 422 cases of missing information, there are only 370 observations missing one or more covariates.

participation, initiation and cessation are identical and it would be appropriate to pool together 1992 non-smokers and 1992 smokers . That is, it would be appropriate to constrain the estimated parameters in a model of smoking in 2000 to be the same for 1992 non-smokers and 1992 smokers. The standard specification of the participation model presented in Table 2 imposes this constraint. A likelihood ratio test rejects the constraint, implying that the standard specification is incorrect.[20]

In addition to differences in the estimated impact of taxes, which will be discussed in more detail below, the results in Table 2 reveal a number of substantive differences between the determinants of smoking initiation and the determinants of smoking cessation. For example, while about 13 percent of 1992 non-smokers initiated smoking, males were about 4 percentage points more likely to initiate smoking than were females. In contrast, while about 34 percent of 1992 smokers quit, there was only a slight (1.5 percentage point) and statistically insignificant difference in cessation between males and females. Race/ethnicity, age, and academic ability as measured by standardized tests in reading and mathematics all have quantitatively different impacts on smoking initiation versus cessation.

As in previous studies, the role of cigarette taxes in smoking initiation and cessation attracts special attention. In addition to the benchmark models, Table 2 contains the results from our first identification strategy where we use a direct measure of state anti-smoking sentiment to

---

[20]Let L_0 and L_1 be the log-likelihood values associate with the unconstrained and constrained models, respectively. The log-likelihood for the unconstrained model equals the sum of the log-likelihoods for the initiation and cessation models. So for the models that include anti-smoking sentiment $L_0 = -3300.5472 + (-1212.0467) = -4512.5939$. The log-likelihood for the constrained model is the log-likelihood for the corresponding participation model: $L_1 = -5{,}469.458$. The likelihood ratio test statistic $-2\ (L_1 - L_0) = 1{,}913.7282$ is distributed χ^2 with 14 degrees of freedom, and is statistically significant at above the 0.001 level.

control for differences across states that may be correlated with taxes. As shown in Table 2, in the benchmark models taxes are negatively and statistically significantly associated with smoking participation, and positively and statistically significantly associated with smoking cessation. The implied price elasticity of smoking participation is -0.49, fairly similar to a commonly cited consensus estimate of around -0.7 for the price elasticity of youth smoking participation (Treasury Department 1998, GAO 1998, CBO 1998). However, the previous cross-sectional studies behind the consensus have been unable to adequately control for differences across states in anti-smoking sentiment. The tax coefficients in Table 2 are very sensitive to whether the measure of state anti-smoking sentiment is included. After controlling for anti-smoking sentiment, the results in Table 2 provide no evidence that higher taxes reduce smoking participation or smoking initiation. There is some evidence that higher taxes increase smoking cessation: the implied price elasticity of smoking cessation is 0.47, but this is based on a statistically insignificant parameter estimate.

The estimates show a strong negative association between the measure of anti-smoking sentiment itself and the smoking behaviors of young adults. A one-unit increase in anti-smoking sentiment (which is approximately a one-standard-deviation increase) is associated with: a decrease in smoking participation of 14 percentage points; a decrease in smoking initiation of 3.4 percentage points; and an increase in smoking cessation of 16 percentage points. However, the measure of anti-smoking sentiment is included as a control variable to obtain an unbiased estimate of the causal impact of taxes on youth smoking. Because the measure may be econometrically endogenous, we have not necessarily identified the causal effect of anti-smoking sentiment on smoking behavior.

The Appendix reports additional empirical results that explore the nature of the state-level differences captured by the measure of anti-smoking sentiment. We merged state-level measures of school spending and social capital with our NELS data. At the individual-level schooling is strongly associated with smoking (Kenkel, Lillard and Mathios 2006), and state school spending might tend to capture general state-level attitudes toward public policy. Reasoning along somewhat similar lines, Brown *et al* (2006) explore the influence of a community's social capital on smoking. Appendix Table A1 presents the results from probit models of smoking behaviors that include these new measures as additional explanatory variables. The estimated coefficients on the new measures are always statistically insignificant and do not provide any evidence that school spending or social capital are strongly related to youth smoking participation, initiation, or cessation. Moreover, the estimated coefficients on the measure of anti-smoking sentiment are robust to the inclusion of each of the new measures. Appendix Table A2 presents the simple correlations between these state-level variables. The measure of anti-smoking sentiment is most strongly correlated with the cigarette tax and is virtually uncorrelated with school spending. The measure of anti-smoking sentiment has a non-trivial correlation (0.33) with the social capital index, suggesting that these two variables share common variation. However, the results of the probit models in Appendix Table A1 show that only the independent variation in the anti-smoking sentiment measure is associated with the youth smoking behaviors. The Appendix results thus tend to support the interpretation that the measure of anti-smoking sentiment indeed captures state-level attitudes specific to smoking.

Smoking Initiation and Cessation by Mover/ Stayer Status

Table 3 presents results from our second identification strategy, where we estimate separate models for respondents who stayed in their 1992 state of residence versus those respondents who moved to a different state between 1992 and 2000. Recall, the identification strategy is based on the argument that state movers face current taxes that are uncorrelated with the taxes and anti-smoking sentiment they faced in adolescence. Thus, models estimated over the sample of state movers should yield less biased estimates of the causal impact of current taxes on smoking behavior. The results for the tax variable are presented in Table 3; the complete results are available upon request.

For initiation we find that stayers appear to be more tax-responsive than movers. We interpret this pattern as evidence of bias in the models estimated over the sample of stayers. The bias in the sample of stayers stems from the fact that for stayers the 2000 tax tends to be highly correlated with the anti-smoking sentiment respondents faced during their adolescence and young adulthood.[21] Our preferred model for the sample of movers provides no evidence that higher taxes prevent smoking initiation; in fact, the point estimate actually implies that higher taxes increase smoking initiation.

[21]An alternative interpretation is that the difference in the estimated tax-responsiveness of movers versus stayers is due to the role of peer influences. Our estimates of tax-responsiveness capture both the direct impact of taxes on the individual's smoking and the indirect impact through peer influences (if the taxes change peers' smoking and this in turn influences the individual's smoking). As discussed above in section 4, if movers and stayers face much different indirect impacts, even if there is no bias from unobserved anti-smoking sentiment the estimated tax-responsiveness will be different for movers and stayers. For the reasons discussed in the text and footnote 17 above, we are skeptical that the pattern of results in Table 3 is due to the role of peer influences.

In contrast, we find some evidence that higher taxes encourage smoking cessation. Again, in our preferred specification that uses state movers, the impact of taxes is in the expected positive direction and implies a relatively large price-elasticity of cessation of 1.49, although the coefficient lacks statistical significance perhaps due to a rather small sample size (N=321).

Smoking Cessation by Light/ Heavy Smoking Status

Finally, Table 4 presents estimates from exploratory models of smoking cessation that distinguish between two different levels of 1992 smoking. Table 4 again presents only the results for the tax variable; the complete results are available upon request. The first model is estimated using the sub-sample of 1,267 "light" smokers, defined as those individuals who smoked between one and ten cigarettes per day in 1992. The second model is estimated for the sub-sample of 680 "heavy" smokers who reported smoking more than ten cigarettes per day in 1992. Each model is estimated with and without our state anti-smoking sentiment measure. (We do not use our second identification strategy that distinguishes movers from stayers due to small cells when defined over both light/ heavy smoking and mover/stayer status.) Not surprisingly, 1992 light smokers were much more likely to quit than were 1992 heavy smokers (39 percent versus 24 percent). The estimates also suggest that an increase in cigarette taxes has a larger marginal effect on the probability of smoking cessation among light smokers than among heavy smokers.[22]

[22]In the preferred specification that controls for anti-smoking sentiment, the larger marginal effect translates into a smaller price elasticity of cessation: $\varepsilon^Q = 0.62$ for light smokers versus $\varepsilon^Q = 0.71$ for heavy smokers. This is due to the substantially higher rate of cessation among light smokers. While the marginal effect of taxes on light smokers' cessation is larger in absolute terms, it is smaller relative to their average rate of cessation. The marginal effects in Table 4 are calculated at the averages of the other explanatory variables for each sub-sample (light smokers and heavy smokers). Consequently, the marginal effects are evaluated at different points of the probability function. The marginal effects calculated at the same point of the probability function (at the averages of the explanatory variables for the full sample) are very similar to those reported in Table 4.

However, in our preferred specification that controls for state anti-smoking sentiment, the results lack statistical significance. In larger samples or in older samples that include more quitters, the results in Table 4 provide preliminary evidence that it may be important for cessation models to make distinctions between levels of past smoking.

5. Conclusions

In this paper, we extend the standard approach to estimating individual cigarette demand by decomposing smoking participation into smoking initiation and cessation. The estimated models for a sample of young adults show that the distinction between smoking initiation and cessation is empirically useful. Our results have particular policy relevance to the conventional wisdom that youth smoking is more tax- or price-responsive than adult smoking.[23] Our two different identification strategies show the same pattern: we find no evidence that taxes discourage smoking initiation but some evidence that taxes encourage smoking cessation. Looking at our results as a whole, we suggest that conventional wisdom may have it exactly backwards: adult smoking behavior may be more, not less, tax- or price-responsive than adolescent smoking.

As a broad generalization, what is special about adolescent smoking is smoking initiation. More precisely, as we show above the price elasticity of smoking initiation tends to drive the price elasticity of youth smoking participation; the price elasticity of smoking cessation plays a

[23]For example, the 2000 Surgeon General's Report concludes that: "The price of tobacco products has an important influence on the demand for tobacco products, *particularly among young people*." (USDHHS 2000, p. 359, emphasis added). Similarly, a World Health Organization Report concludes that: "Price increases on tobacco products are one of the most effective means of reducing cigarette smoking. Studies show that a price increase of 10% results in a 2.5% – 5% smoking reduction in the short run and possibly up to 10% in the long run, if prices are increased to keep pace with inflation. *Young people may reduce their smoking at two to three times the rate of older people."* Gilbert and Cornuz (2003, emphasis added).

more important role in the price elasticity of adult smoking participation. Our results contribute to a series of studies that use longitudinal data and find evidence that higher prices increase cessation but have little or no impact on smoking initiation in the U.S. (Douglas 1998, Douglas and Hariharan 1994, DeCicca, Kenkel and Mathios 2002), Britain (Forster and Jones 2001), and Spain (Nicolas 2002).

APPENDIX

Specification of the Latent Utility Gains

Text equations (1) and (2) define the utility gains y^{I*} and y^{Q*} that are the unobserved continuous latent variables that underlie the observed discrete outcomes of smoking initiation and cessation. Assuming a simple functional form for utility implies the empirical model given by equations (4) and (5). Suppose utility from the non-addictive good G and the addictive good S is given by:

$$u = aG + bS_t + c\, S_t\, S_{t-1} + dG\, S_{t-1} \qquad \textbf{(A1)}$$

The linear utility function in (A1) is similar to the quadratic utility function assumed in the empirical rational addiction model of Becker, Grossman, and Murphy (1994). (Extending the function to include the quadratic terms for smoking is not interesting given that in our model S_t is dichotomous. However, below we sketch how the model can be extended to distinguish discrete levels of past smoking.) In (A1), the parameter $c > 0$ captures adjacent inter-temporal complementarity where the marginal utility from S_t depends upon prior smoking : $\partial u/\partial S_t = b + c\, S_{t-1}$. The marginal utility of G may also depend upon prior smoking, so $\partial u/\partial G = a + d\, S_{t-1}$, but there are not strong *a priori* reasons to sign the parameter d.

Let W = income and P_t = current price of cigarettes, so the budget constraint is $W = G + P_t\, S$, which implies $G = W - P_t S$. Substituting this in yields:

$$\begin{aligned} y^{I*} &= u(G_t, S_t{=}1, S_{t-1} = 0) - u(G_t, S_t{=}0, S_{t-1} = 0) \\ &= aW - a\,P_t + b - aW \\ &= -a\,P_t + b \qquad \textbf{(A2)} \end{aligned}$$

That is, when deciding to start a non-smoker compares the loss in utility from foregone consumption of G, given by $-aP_t$, to the gain in utility from smoking, given by b.

Similarly,

$$\begin{aligned} y^{Q*} &= u(G_t, S_t{=}0, S_{t-1} = 1) - u(G_t, S_t{=}1, S_{t-1} = 1) \\ &= aW - [aW - aP_t + b + c + dW - d\,P_t] \\ &= (a + d)\,P_t - (b + c) - dW \qquad \textbf{(A3)} \end{aligned}$$

When deciding to quit, the smoker compares the possible gain in utility from increasing consumption of G, given by $(a + d)\,P_t$, to the loss in utility from giving up smoking, given by -(b+c). The sign of the term dW is ambiguous and depends on whether prior smoking increases or decreases utility from current period goods consumption. Note that the smoker's loss in utility from giving up smoking is greater than the non-smoker's gain from starting, because of addiction (the c term). The c term can also be thought of as an adjustment cost to quitting (Suranovic 1999, Jones 1999). Even this simple functional form for the utility function implies that $y^{I*} \neq - y^{Q*}$. For example, the marginal effect of price on starting is given by -a, while the marginal effect of price on quitting is given by (a+d). Note that if smoking were not addictive, c = d = 0, so (A3) would reduce to (A2). This illustrates for the specific utility function the point made more generally in section 3, that for non-addictive smoking $y^{I*} = y^{Q*}$

The expressions for y^{I*} and y^{Q*} imply the empirical initiation and cessation equations presented in text equations (4) and (5), where differences in tastes for smoking (b, c, and dW) are captured by the anti-smoking sentiment the individual faces (F), individual socioeconomic characteristics (X), and the random error term.

The model can be extended to make additional distinctions between smoking histories by considering multiple smoking-status-dependent utility functions and smoking status transitions. To illustrate, consider a model of smoking cessation that distinguishes between light smoking (LS) and heavy smoking (HS). For a past period light smoker ($LS_{t-1} = 1$), let utility from the non-addictive good and light smoking be given by:

$$u' = a\,G + b'\,LS_t + c'\,LS_t\,LS_{t-1} + d'\,G\,LS_{t-1} = a\,G + b'\,LS_t + c'\,LS_t + d'\,G \qquad \textbf{(A4)}$$

For a past period heavy smoker ($HS_{t-1} = 1$), let utility from the non-addictive good and heavy smoking be given by:

$$u'' = a\,G + b''\,HS_t + c''\,HS_t\,HS_{t-1} + d''\,G\,HS_{t-1} = a\,G + b''\,HS_t + c''\,HS_t + d''\,G \qquad \textbf{(A5)}$$

The decision to quit light smoking depends on the utility gain from quitting light smoking compared to continuing light smoking and will involve the parameters a, b', c' and d'. Similarly, the decision to quit heavy smoking will involve the parameters a, b", c", and d". This extension allows the strength of addiction or adjacent complementarity to vary with the level of past smoking. The natural assumption is that c" > c', so past heavy smoking has a stronger impact on the marginal utility of current heavy smoking than is true for past light smoking's impact on the marginal utility of current light smoking.

The extension also involves additional smoking status transitions, such as the transition from light smoking to heavy smoking and vice versa. Because the purpose of this Appendix is to illustrate how the approach can be extended, we do not specify the complete set of smoking-status dependent utility functions and smoking status transitions.

The Reservation Price Approach

Colman, Grossman and Joyce [CGJ] (2002, 2003) argue that a woman's smoking participation decision is made with reference to a reservation price. CGJ (2002) use a quadratic utility function that does not involve addiction. From this they derive their equation (2), which states that a woman's smoking participation before pregnancy depends on whether her reservation price exceeds the monetary price of a pack of cigarettes T_b:

$$(\alpha_C/\mu) - (\beta_b/\mu) > T_b$$

$$\Leftrightarrow \qquad - \mu T_b + \alpha_C - \beta_b > 0 \qquad \textbf{(A6)}$$

To compare the CGJ condition to our approach, recall that text equation (3) states that someone decides to participate in smoking by examining whether $y^{S*} > 0$. Substituting in the linear utility function yields a condition describing the smoking participation decision that can easily be compared to the CGJ approach:

$$\begin{aligned} y^{S*} &= u(G_t, S_t = 1, S_{t-1}) - u(G_t, S_t = 0, S_{t-1}) \\ &= aW - a P_t + b + c \ S_{t-1} + d (W - P_t) S_{t-1} - aW \qquad \textbf{(A7)} \\ &= -(a + d S_{t-1}) P_t + b + c \ S_{t-1} + d W S_{t-1} > 0 \end{aligned}$$

We can now compare the CGJ approach and our approach by comparing (A6) and (A7) term by term. In CGJ μ is the marginal utility of wealth. In our model it corresponds to the first term in the last line of (A7): $\mu =$ a for past-period non-smokers and $\mu = a + d$ for past-period smokers. So the first term in both (A6) and (A7) is the marginal utility of wealth multiplied by the price of cigarettes (T_b or P_t).

In CGJ the marginal utility of smoking is given by α_C. The marginal utility of smoking in our model is given by the next terms in the last line of (A7): $\alpha_C = b$ for past-period non-smokers and $\alpha_C = b + c$ for past-period smokers. In CGJ, β_b is a coefficient to capture differences in the utility from smoking based on pregnancy status, which is not a feature of our model.

The CGJ condition does not contain terms involving past smoking, because they have assumed that smoking is not addictive so past smoking does not affect the current marginal utility of wealth or smoking.

Therefore, after making appropriate adjustments for differences in modeling assumptions, our latent variable approach and the CGJ reservation price approach yield comparable conditions describing how smoking decisions are made.

Specification of the Participation Equation

Text equation (8) above shows that the probability of smoking participation at time t depends upon the probabilities of initiation (I) and cessation (Q). To further simplify the analysis, assume there are two periods: young adulthood (time t) and youth (time t-1):

$$\Pr\{S_t = 1\} = (\Pr\{I_t = 1 | S_{t-1} = 0\})(1 - S_{t-1}) + (1 - \Pr\{Q_t = 1 | S_{t-1} = 1\}) S_{t-1} \qquad \textbf{(A6)}$$

If for simplicity's sake we assume that no one starts smoking before adolescence, $S_{t-1} = I_{t-1,.}$ and equation (A1) can be re-written as:

$$
\begin{aligned}
S_t \quad = \quad & \Pr\{I_t = 1 \mid S_{t-1} = 0\} + \Pr\{I_{t-1} = 1 \mid S_{t-2} = 0\} \\
& - \Pr\{I_t = 1 \mid S_{t-1} = 0\} \Pr\{I_{t-1} = 1 \mid S_{t-2} = 0\} \\
& - \Pr\{Q_t = 1 \mid S_{t-1} = 1\} \Pr\{I_{t-1} = 1 \mid S_{t-2} = 0\} \qquad \textbf{(A7)}
\end{aligned}
$$

Text equations (6) and (7) show the probabilities of smoking initiation and cessation as functions of current prices (P_t), other variables (X_t), an environmental factor (F) such as prevailing anti-smoking sentiment that is assumed to be fixed over time, and random terms e. To further simplify the analysis, we allow the influence of the X variables to be captured in the constant term, and we use the linear probability model where the function G ( ) in text equations (6) and (7) is the identity function. Under these assumptions (A7) simplifies to:

$$
\begin{aligned}
= \quad & [\alpha_0 + \alpha_1 P_t + \alpha_2 F] + [\alpha_0 + \alpha_1 P_{t-1} + \alpha_2 F] \\
& - [\alpha_0 + \alpha_1 P_t + \alpha_2 F] [\alpha_0 + \alpha_1 P_{t-1} + \alpha_2 F] \\
& - [\beta_0 + \beta_1 P_t + \beta_2 F] [\alpha_0 + \alpha_1 P_{t-1} + \alpha_2 F]
\end{aligned}
$$

$$
\begin{aligned}
= \quad & [2\alpha_0 - \alpha_0^2 - \beta_0 \alpha_0] + [\alpha_1 - \alpha_0 \alpha_1 - \beta_1 \alpha_0] P_t + [\alpha_1 - \alpha_0 \alpha_1 - \beta_0 \alpha_1] P_{t-1} \\
& + [-\alpha_1^2 - \beta_1 \alpha_1] P_t P_{t-1} + [2\alpha_2 - 2\alpha_0 \alpha_2 - 2\beta_0 \alpha_2] F + [-\alpha_2^2 - \beta_2 \alpha_2] F^2 \\
& + [-\alpha_1 \alpha_2 - \beta_1 \alpha_2] F P_t + [-\alpha_2 \alpha_1 - \beta_2 \alpha_1] F P_{t-1}
\end{aligned}
$$

$$
= \quad \gamma_0 + \gamma_1 P_t + \gamma_2 P_{t-1} + \gamma_3 P_t P_{t-1} + \gamma_4 F + \gamma_5 F^2 + \gamma_6 F P_t + \gamma_7 F P_{t-1} \qquad \textbf{(A8)}
$$

Equation (A8) is a specific form of text equation (12), a reduced form smoking participation equation. Equation (A8) has seven estimable parameters (γ_0 - γ_7) which are functions of the six parameters of the equations for smoking initiation (α_0, α_1, α_2) and cessation (β_0, β_1, β_2). Thus in this special case it is possible to recover the separate effects of current price on initiation and cessation from this specification of the smoking participation equation.

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Table 1. Sample means and standard deviations, by state moving status.

	Full sample	Stayers	Movers
Daily smoker	0.226	0.237	0.184
	-0.418	-0.425	-0.387
State cigarette tax in 1992	27.247	27.231	27.306
	-11.64	-11.72	-11.32
State cigarette tax in 2000	47.543	47.785	46.647
	-31.59	-31.48	-31.97
Male	0.469	0.464	0.489
	-0.499	-0.499	-0.5
Black	0.091	0.094	0.077
	-0.287	-0.292	-0.266
Hispanic	0.126	0.143	0.063
	-0.331	-0.349	(0.243)
Other race	0.083	0.078	0.101
	(0.275)	-0.268	-0.301
Born in 1972	0.046	0.052	0.025
	-0.207	-0.219	-0.155
Born in 1973	0.286	0.294	0.255
	-0.447	-0.45	-0.433
Born in 1975	0.011	0.009	0.017
	-0.102	-0.093	-0.13
Test score	51.715	50.542	56.06
	-10.108	-9.797	-10.059
Northeast	0.176	0.178	0.166
	-0.381	-0.383	-0.372
Midwest	0.254	0.27	0.192
	-0.435	-0.444	-0.394
South	0.353	0.345	0.385
	-0.478	-0.477	-0.487
N	10706	8430	2276

Notes: Omitted categories are female, white, born in 1974, western region. Stayers are individuals who lived in same state in 1992 and 2000; movers are those who changed states between these years. Summary statistics in the second column include only non-switchers and those in the third column include only switchers. Samples correspond to those used to generate model estimates

Table 2. Probit models of smoking participation, initiation, and cessation

	Participation		Initiation		Cessation	
Cigarette tax	-0.00107	0.00029	-0.00031	0.00016	0.00244	0.00124
	[-0.00031]	[0.00084]	[-0.00006]	[0.00003]	[0.00088]	[0.00045]
	-1.79	-0.51	-0.52	-0.21	-1.99	-0.97
Anti-smoking sentiment	----	-0.48353	----	-0.16824	----	0.43223
		[-0.14139]		[-0.03453]		[0.15703]
		-3.54		-0.96		-1.54
Male	0.13148	0.13241	0.20195	0.2025	-0.04098	-0.04105
	[0.03856]	[0.03883]	[0.04180]	[0.04191]	[-0.01488]	[-0.01491]
	-4.32	-4.4	-7.54	-7.57	-0.68	-0.68
Black	-0.53569	-0.53176	-0.13886	-0.1385	0.1669	0.16052
	[-0.15676]	[-0.15549]	[-0.02832]	[-0.02842]	[0.06066]	[0.05832]
	-10.42	-10.51	-2.73	-2.73	-0.97	-0.93
Hispanic	-0.39265	-0.37533	-0.13796	-0.13218	0.27464	0.26094
	[-0.11490]	[-0.10975]	[-0.02832]	[-0.02713]	[0.09980]	[0.09480]
	-7.76	-7.44	-3.2	-3.05	-2.1	-1.99
Other race	-0.24865	-0.24477	-0.11813	-0.11685	-0.10898	-0.10964
	[-0.07276]	[-0.07157]	[-0.02425]	[-0.02398]	[-0.03960]	[-0.03983]
	-5.53	-5.34	-1.94	-1.92	-0.71	-0.71
Birth year 1972	0.13318	0.13995	-0.01247	-0.00955	-0.13316	-0.13611
	[0.03897]	[0.04092]	[-0.00256]	[-0.00196]	[-0.04839]	[-0.04945]
	-2.13	-2.29	-0.17	-0.13	-1.28	-1.33
Birth year 1973	0.1075	0.11256	0.09291	0.09503	-0.03969	-0.04042
	[0.03145]	[0.03291]	[0.01907]	[0.01950]	[-0.01442]	[-0.01469]
	-2.93	-3.03	-2.26	-2.27	-0.62	-0.63

Birth year 1975	-0.00938	-0.0008	0.09012	0.09373	-0.3556	-0.35538
	[-0.00274]	[-0.00023]	[0.01850]	[0.01923]	[-0.12922]	[-0.12911]
	-0.08	-0.01	-0.7	-0.73	-0.96	-0.95
Test score	-0.02206	-0.02179	-0.01058	-0.01051	0.01909	0.01877
	[-0.00645]	[-0.00637]	[-0.00217]	[-0.00216]	[0.00694]	[0.00668]
	-9.64	-9.51	-3.84	-3.81	-6.64	-6.59
Northeast	0.23523	0.13892	0.19569	0.16131	-0.24746	-0.1659
	[0.07280]	[0.04203]	[0.04316]	[0.03513]	[-0.08649]	[-0.05878]
	-5.18	-2.94	-4.41	-2.8	-2.38	-1.52
Midwest	0.23937	0.12468	0.23957	0.19926	-0.18407	-0.0827
	[0.07317]	[0.03733]	[0.05272]	[0.04334]	[-0.06573]	[-0.02982]
	-5.13	-2.32	-4.82	-2.93	-1.57	-0.62
South	0.08347	0.00044	0.07769	0.04946	-0.08863	-0.01067
	[0.02466]	[0.00013]	[0.01616]	[0.01023]	[-0.0320]	[-0.0039]
	-1.51	-0.01	-1.37	-0.86	-0.75	-0.08
log-likelihood	-5476.3017	-5469.458	-3301.0437	-3300.5472	-1213.3107	-1212.0467
Implied price elasticity	-0.49	0.13	-0.17	0.08	0.93	0.47
N	10706	10706	8759	8759	1947	1947

Notes: Marginal effects are in brackets [ ], absolute values of t-ratios are in parenthesis ( ). Price elasticities are calculated by multiplying tax elasticities by the ratio of average price to average tax. In 2000, this ratio was 7.445. Standard errors adjusted for non-independence of observations within states.

Table 3 Smoking initiation and cessation models, by state mover/stayer status.

	Initiation models			Cessation models		
	Full sample	Stayers	Movers	Full sample	Stayers	Movers
Cigarette tax	-0.000306	-0.001255	0.002931	0.002435	0.002108	0.004186
	[-0.000063]	[-0.000265]	[0.000534]	[0.000885]	[0.000759]	[0.00158]
	-0.52	-2.02	-2.03	-1.99	-1.51	-1.56
Dependent mean	0.129	0.134	0.112	0.336	0.328	0.377
Implied elasticity	-0.17	-0.7	1.69	0.93	0.82	1.49
N	8759	6,804	1,955	1,947	1,626	321

Notes: Marginal effects are in brackets and absolute values of t-ratios are in parenthesis ( ). Initiation models are probit regressions of 2000 smoking status for those who were not daily smokers in 1992, when most individuals were about seventeen years old. Cessation models are also probit regressions, but of 2000 *non*-smoking status for those who reported being daily smokers in 1992. All models included the following additional explanatory variables: male, black, hispanic, other race, birth year 1972, birth year 1973, birth year 1975, test score, northeast, midwest, and south. Price elasticities are calculated by multiplying tax elasticities by the ratio of average price to average tax. In 2000, this ratio was 7.445. Standard errors adjusted for non-independence of observations within states.

Table 4 Smoking Cessation models, by level of 1992 smoking

	Light Smokers in 1992		Heavy Smokers in 1992	
Cigarette tax	0.00314	0.00177	0.00167	0.00155
	[0.00120]	[0.00068]	[0.00051]	[0.00048]
	-2.89	-1.29	-0.61	-0.52
Includes measure of anti-smoking sentiment?	No	Yes	No	Yes
Dependent mean	0.388	0.388	0.24	0.24
Implied elasticity	1.09	0.62	0.75	0.71
N	1267	1267	680	680

Notes: Marginal effects are in brackets and absolute values of t-ratios are in parenthesis ( ). All models included the following additional explanatory variables: male, black, hispanic, other race, birth year 1972, birth year 1973, birth year 1975, test score, northeast, midwest, and south. Price elasticities are calculated by multiplying tax elasticities by the ratio of average price to average tax. In 2000, this ratio was 7.445. Standard errors adjusted for non-independence of observations within states.

Appendix Table A1. Estimates from Table 2 models including other state-level covariates.

	-1	-2	-3	-4	-5
A. Participation Models					
Cigarette tax	0	-0.002	0	-0.001	0
	-0.51	-2.17	-0.34	-1.78	-0.91
Anti-smoking sentiment	-0.4835	----	-0.4808	----	-0.546
	-3.54		-3.23		-3.53
School spending	----	0.0219	0.001	----	----
		-1.27	-0.06		
Social capital index	----	----	----	-0.0469	0.0191
				-1.34	-0.53
N	10706	10,706	10706	10586	10586
B. Initiation Models					
Cigarette tax	0	0	0	0	0
	-0.21	-1.22	-0.52	-0.47	-0.13
Anti-smoking sentiment	-0.1682	----	-0.1056	----	-0.1332
	-0.96		-0.57		-0.62
School spending	----	0.0269	0.0026	----	----
		-1.36	-0.26		
Social capital index	----	----	----	-0.0439	-0.028
				-1.11	-0.58
N	8759	8759	8759	8656	8656
C. Cessation Models					
Cigarette tax	0.0012	0.0022	0.0014	0.0023	0
	-0.97	-1.39	-1.07	-1.88	-0.75

Anti-smoking sentiment	0.4322 -1.54	----	0.5283 -1.72	----	0.4806 -1.67
School spending	----	0.0108 -0.3	0.0348 -0.92	----	----
Social capital index	----	----	----	0.0597 -0.67	0.004 -0.93
N	1947	1947	1947	1930	1930

Notes: Column 1 estimates are taken from the even-numbered columns of Table 2. "School spending" represents state-level per pupil spending on elementary and secondary schools in 2000 and is measured in 1000s of dollars (Source: *Estimates of School Statistics*, via the Statistical Abstract of the United States). "Social Capital Index" represents Robert Putnam's Comprehensive Social Capital Index (Source: www.bowlingalone.com/StateMeasures.xls). Sample sizes are slightly smaller in models that include the Social Capital Index since it is not available for all states.

Appendix Table A2. Simple correlations between state-level variables.

	Cigarette Tax	Anti-Smoking Sentiment	School Spending	Social Capital Index
Cigarette Tax	1	0.64	0.55	0.28
Anti-Smoking Sentiment	0.64	1	-0.02	0.33
School Spending	0.55	-0.02	1	0.18
Social Capital Index	0.28	0.33	0.18	1

Notes: "School spending" represents state-level per pupil spending on elementary and secondary schools in 2000 and is measured in 1000s of dollars (Source: *Estimates of School Statistics*, via the Statistical Abstract of the United States). "Social Capital Index" represents Robert Putnam's Comprehensive Social Capital Index (Source: www.bowlingalone.com/StateMeasures.xls).