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A Microeconometric Analysis of Smoking in the UK Health and Lifestyle Survey

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DISCUSSION PAPER 139

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Abstract

This paper provides an overview of microeconometric evidence on various aspects of smoking using data from the UK Health and Lifestyle Survey (HALS1). In doing so it illustrates how the choice of an appropriate statistical model is influenced by the survey design and the definition and measurement of variables.

The HALS is a rich source of information on cigarette smoking which provides data on all aspects of the "life-cycle" of a smoker. Results are reported for parametric survival analysis of the age of starting and the number of years of smoking; univariate and bivariate probit models for attempts and success in quitting smoking; and generalised Tobit models, including the Box-Cox double hurdle model, for the number of cigarettes smoked.

Survival analysis shows that parental smoking increases the probability of becoming a smoker and reduces the age of starting. Those with more education and in higher socio-economic groups are less likely to start and, if they do, tend to start later. The bivariate probit models suggest that addiction, proxied by previous peak consumption, does not affect the desire to quit but does lead to a significant reduction in the chance of succeeding. There is clear socio-economic gradient in success in quitting, but not in the desire to quit. Those with more education are more likely to have quit. Those with other smokers in the household are less likely to have quit. Results for the duration analysis suggest that the determinants of the number of years smoked are broadly similar to those for quitting.

The results for the Box-Cox double hurdle model are consistent with a "fixed cost" model of addiction. Addiction reduces the probability of quitting and raises the number of cigarettes smoked. However the effects of other variables work in opposing directions for participation and consumption. The implication is that, after controlling for addiction, the more someone smokes the more likely they are to try to quit, as the potential benefits of quitting are greater.

1. Introduction

This paper provides an overview of microeconometric evidence on various aspects of smoking using data from the UK Health and Lifestyle Survey (HALS1). In doing so it shows how the appropriate statistical techniques are influenced by the design of the survey and the definition and measurement of variables.

The Health and Lifestyle Survey (HALS) is a national representative sample of British adults. The original survey (HALS1) was carried out between Autumn 1984 and Summer 1985 yielding a usable sample of 9003 individuals [Cox et.al. (1987)]. The original cross-section survey has recently been augmented by a longitudinal follow-up of the original respondents [Cox et.al. (1993)]. The HALS is a rich source of information on cigarette smoking which provides data on all aspects of the "life-cycle" of a smoker. This is summarised in the following stylised decision tree, which provides a framework for all of the models presented in this paper [Fig.1].

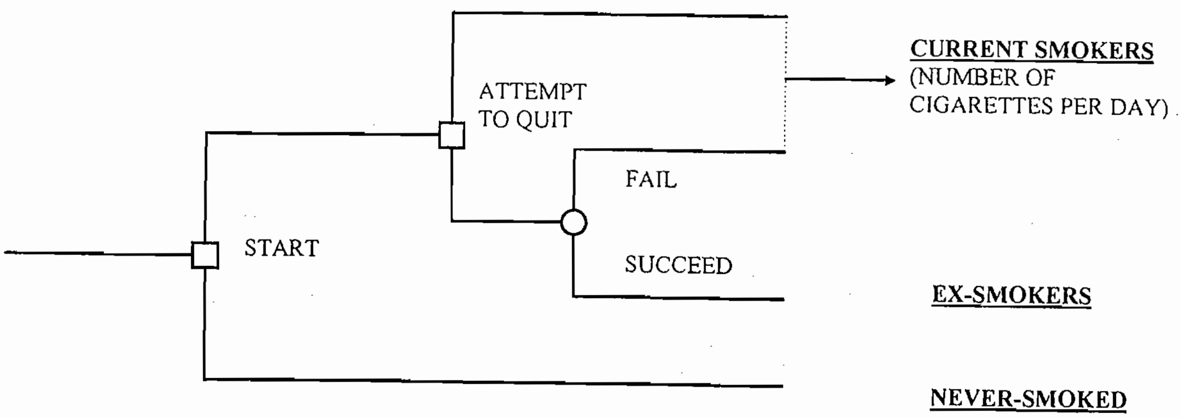


Fig.1: The decision tree.

The stages in the life-cycle of a smoker can be illustrated by moving through the tree in chronological order (i.e. from left to right); each of these stages corresponds to specific data that are available in the HALS. First, retrospective information is available on the qualitative choice whether or not to start smoking which could, for example, be estimated by a probit model. This discrete choice is augmented by data on the age of starting smoking; which can be interpreted as a "failure time" and estimated by survival analysis. In this paper a split-population logistic log-linear survival model is used to provide evidence on the determinants of starting and on the delay before starting [Table 2].

Following the upper branch of the tree gives the (self-selected) sample of those individuals who have smoked at some time in their life. Some of these individuals had quit by the time of the survey and a probit model is estimated for success in quitting [Table 3]. The observed success in quitting can be combined with self-reported data on whether an individual has made a serious attempt to quit. The desire to quit and success in quitting are modelled jointly by a sequential bivariate probit model [Table 4].

The results presented in Tables 3 and 4 are similar to those reported in Jones (1994). One issue raised in that paper, and in a subsequent comment by Shmueli (1995), is whether the estimation is mis-specified due to problems of measurement error and simultaneity bias. This is explored in more detail here with new results based on the methodology proposed by Godfrey and Hutton (1993) [Table 5].

Survival analysis is relevant for the sub-sample of individuals who have smoked at some time in their lives. As well as data on the decision to quit it is possible to construct a variable for the number of years an individual has smoked. Table 6 presents estimates for a Weibull log-linear survival model. These new results suggest that the influences on the duration of smoking are similar to those on the likelihood of quitting. In particular addiction (proxied by previous peak consumption) affects the number of years of smoking as well as the probability of quitting.

The final branch in the tree leads to the typical level of cigarette consumption by current smokers, the traditional focus of consumer demand analysis. The final section of the paper reports results from Yen and Jones (1994) who develop a "fixed cost" model of addiction which is estimated with the Box-Cox double hurdle model [Tables 7-9]. These results complement other studies that have shown the value of variants of the double-hurdle approach for microeconomic analysis of cigarette smoking [see e.g. Atkinson et al. (1984), Mullahy (1985), Jones (1989, 1992), Fry and Pashardes (1994), Garcia and Labeaga (1991)].

2. The Health and Lifestyle Survey

The Health and Lifestyle Survey (HALS) is a national representative sample of adults in Great Britain. The survey was conducted by the Office of the Regius Professor of Physic and the Department of Psychiatry at the Cambridge University School of Clinical Medicine, and the sample selection and fieldwork were carried out by Social and Community Planning Research. The data were collected between Autumn 1984 and Summer 1985 at two home visits; a one hour interview, followed by a nurse visit to collect physiological measurements and tests of cognitive function. The nurse also gave out questionnaires to assess personality and psychiatric status.

The available sample is 9003 individuals, aged 18 and over, living in private households. The HALS is a cross section survey and analysis of the data is therefore retrospective rather than prospective. By implication, the sample should be representative of the 1984/85 population, but not of the original birth cohorts. The issue of attrition due to differential mortality rates may be important, particularly if the data were to be used to model the impact of smoking on health.

The available sample represents a response rate of 73.5%. When information from the nurse visit and questionnaire is included the response rate falls to 53.7%. The survey was compared to the 1981 Census of population to gauge its representativeness. There is a slight excess of women, particularly elderly women, and some under-representation of those with low incomes and less education among respondents who completed all three stages of the survey. Overall the authors conclude that 'the study appear to offer a good and representative sample of the population' [Cox et al. (1987)]. HALS1 is a household survey and will be prone to some sample selection bias as those with chronic health problems and disabilities are 'more likely to be in hospital, or otherwise unavailable for interview' [Cox et al. (1987)].

Principal Variables

Microeconomic studies of cigarette consumption that use household expenditure data typically estimate a single participation equation for whether or not individuals or households are "smokers" or "non-smokers". In contrast the HALS provides information that separates non-smokers into those who have never smoked and those who class themselves as ex-smokers. This allows the analysis to be extended to distinguish between starting and quitting. It should be stressed that HALS1 is a single cross-section and that the participation variables measure prevalence rather than incidence of smoking and therefore reflects the number of individuals who have started or quit up to the time of the survey. For example, the results for quitting should be interpreted in terms of the stock of individuals who have quit rather than the flow of new quits over a specific period.

The measure of cigarette consumption is the number of cigarettes smoked per day (CIGDAY). This volume based dependent variable is typical of health interview surveys and, unlike an expenditure variable, does not control for differences in the price or quality of cigarettes smoked. However, as a measure of "typical" consumption, it is less likely to suffer from the problems of infrequency of expenditure and recall and response bias that are likely to arise in expenditure surveys.

Existing evidence suggests that attitudes towards smoking are principally concerned with the financial, health and social consequences of the habit [see e.g. Marsh and Matheson (1983)]. In particular, it suggests that the decision to quit smoking is based on the perceived benefits of abstinence rather than the perceived harm of continuing smoking. It is helpful to view the participation decision as a choice made under uncertainty; where the uncertainty stems from the effects of continued smoking and of abstinence on health, the benefits of quitting in terms of self-esteem and social pressure, and individuals' doubts about their ability to quit.

Addiction

Analysis of habit formation and addiction is well-established in the economics literature. It encompasses the class of models in which an individual's past behaviour influences their current preferences [see for example Pollak (1976a), Spinnewyn (1981), Boyer (1983), Becker and Murphy (1988)]. A variant on economic models of addiction is the idea of an asymmetric response in the demand for addictive goods. The psychology literature, as exemplified by Ashton and Stepney (1982), makes it clear that the development of nicotine addiction has two general characteristics, tolerance and withdrawal effects. To the economist two stylised features of withdrawal effects stand out. Firstly, the effects are asymmetric and only occur when consumption falls below its previous level; that is when smokers try to cut down or quit. Secondly, once a certain threshold is passed, the role of consumption is not simply to provide satisfaction but also to ward off the unpleasant consequences of withdrawal. In this respect withdrawal can be interpreted as increasing the 'efficiency' of consumption. Yen and Jones (1994) develop a model that treats withdrawal effects as 'fixed costs', which must be overcome to quit smoking. This model is described in more detail in section 7.

The HALS is a rich source of data to examine addiction effects as it contains a number of variables that describe an individual's 'smoking history'. These include information on whether the individual's parents smoked, the age when the individual started smoking, and a measure of peak consumption. The latter is used to proxy the 'addictive stock', it measures *'the most you have smoked regularly per day'* in a numbers of cigarettes, and is available for both current and ex-smokers (ADDICTION). A similar measure is used by Chaloupka (1991) in his application of the Becker-Murphy rational addiction model.

Health

In economic analysis, health is usually viewed as a fundamental choice variable and the demands for medical care, smoking, and so on are derived demands. In practice, future health is inherently uncertain, and individuals do not choose the realisations, but only the conditioning variables, in the random process that determines their health. Measures of an individual's current health, as recorded in a household survey, are interpreted here as conditioning variables which influence future health. As such, including measures of current health may help to mitigate the problems caused by unobservable heterogeneity. The HALS provides three types of health indicator:

(a) *Self-assessed health.* This is based on a standard excellent/good/fair/poor scale. This is transformed to give a binary variable that equals 1 if the individual's self-rating is fair or poor (ILLHEALTH).

(b) *Self-reported health.* This includes reports of specific symptoms and experience of specific illnesses. For example, DISABILITY is a binary variable that indicates whether the individual has a disability or long-standing illness.

(c) *Measured health.* A special feature of the HALS is that it includes physiological measures collected at the nurse visit. Three measures are used; forced expiratory volume in one second (FEV1), lowest pulse rate (PULSE), and body mass index (BMI). These indicate the individual's current respiratory and cardio-vascular health and their general physique.

Blaxter (1987) and Mays et al. (1992) have explored the comparability of these different measures of health. They find that, apart from disability and long-standing illness, most measures show a strong positive correlation.

Social interaction

Social influences on consumer behaviour fall into a variety of categories. For one thing there are the laws, customs, conventions and norms of behaviour which form an individual's social and cultural background. Social interaction also plays a role in the process of learning about the availability and qualities of previously unfamiliar products. In the case of addictive goods, novices often learn the 'technology' of effective consumption from experienced users. Consumption itself may be a means of communication [see e.g. Douglas and Isherwood (1980)].

The economic literature on social interaction and consumer behaviour is rather sparse. the standard approach is to introduce social interaction as a form of *externality*. See for example Becker (1974), Pollak (1976b), Alessie and Kapteyn (1991). Also see Lewit et al. (1981), who use peer effects in an empirical study of smoking. The externality approach is adopted here and it is assumed that other people's smoking has a direct influence on an individual's decision to quit. An appropriate HALS variable is OTHER-SMOKERS, a binary variable that indicates the presence of other smokers in the individual's household. This variable is not ideal as it does not allow for social influences outside the household, and there is a potential simultaneity problem as members of the same household should all influence each other.

The full list of variables used in this paper is summarised in Table 1. The table gives the sample means for the usable sample of 6,491 respondents (excluding those with missing values at any stage of the survey), the sub-sample of 3,801 respondents who had smoked at some time in their lives prior to the survey, and the 2,147 current smokers.

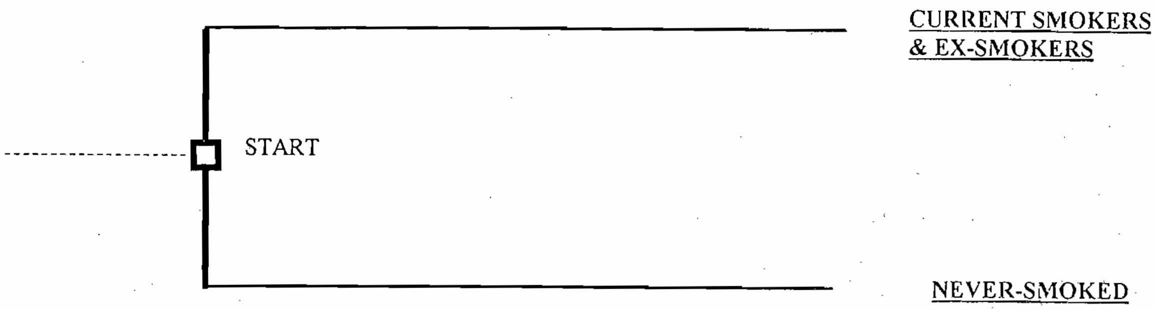
TABLE 1

Variable Definitions and Sample Means

		Full sample (n=6491)	Ever smoked (n=3801)	Current smoker (n=2147)
D	1 if a smoker (0 otherwise)	0.333	0.569	-
CIGDAY	Number of cigarettes per day	5.479	9.357	16.565
ADDICTION	most smoked regularly per day	-	22.606	24.154
OTHER-SMOKERS	1 if other smokers in household	-	0.542	0.678
ADVICE	1 if received any advice to quit	-	0.388	0.480
AGESTART	age started smoking	-	16.900	16.657
ILLHEALTH	1 if self-rated health is poor/fair	0.279	0.316	0.362
FEV1	forced expiratory volume in 1 sec.	2.697	2.652	2.662
PULSE	lowest pulse rate	70.634	71.440	73.099
DISABILITY	1 if disabled or long standing illness	0.302	0.319	0.279
BMI	Quetelet's body mass index(wt/nt^2)	24.506	24.473	23.839
PROFESSIONAL	Registrar General's social class 1	0.055	0.047	0.028
MANAGERIAL	" 2	0.234	0.209	0.176
OTHER NON-MANUAL	" 3	0.134	0.118	0.113
SEMI-SKILLED	" 5	0.161	0.174	0.196
UNSKILLED	" 6	0.050	0.061	0.073
ARMY	" 11	0.006	0.008	0.007
WIDOW	1 if widow/widower	0.076	0.070	0.055
DIVORCED	1 if divorced	0.039	0.045	0.059
SEPARATED	1 if separated	0.021	0.026	0.032
SINGLE	1 if single	0.167	0.133	0.173
AGE	age in years	44.930	46.128	42.271
LONDON	1 if resident in Greater London	0.104	0.102	0.125
DEGREE	1 if individual has a degree	0.050	0.042	0.029
LSCHOOL18	1 if left school at 18 or over	0.107	0.081	0.066
CSE2-5	1 if cse grades 2-5 or none	0.532	-	-
MALE	1 if male	0.458	0.522	0.480
PARSM1	1 if only mother smoked	0.066	-	-
PARSM2	1 if only father smoked	0.470	-	-
PARSM3	1 if both parents smoked	0.330	-	-

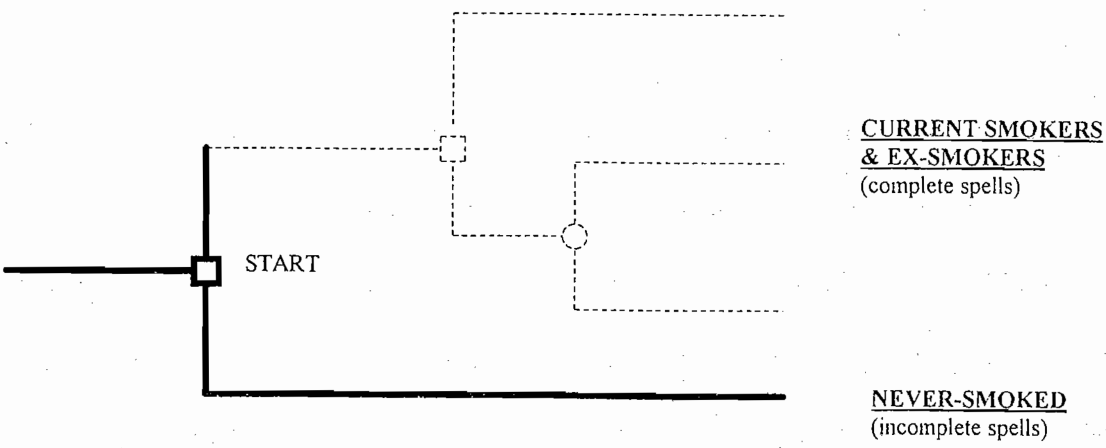
3. Starting Smoking

When it comes to constructing an empirical model of smoking, it is important to make a distinction between starting and quitting [Jones (1994)]. With the HALS it would be possible to analyse the retrospective data on whether respondents have ever smoked, defined by the HALS as having smoked at least one cigarette per day for as long as six months, and estimate a qualitative choice model, such as a probit, for starting smoking [Fig.2]. However this analysis can be augmented by using the self-reported data on the age of starting smoking [Fig.3].



Q.55(a) "Have you ever smoked at least one cigarette a day as long as six months"

Fig.2: Probit analysis of starting



Q.58(a) "How old were you when you started to smoke cigarettes"

Fig.3: Duration analysis of age started

The age of starting can be interpreted as a "failure time" or duration and modelled using parametric survival analysis. Assume that survival time T is a random variable and that the observed survival time is t (age started smoking). The model is characterised by three functions; the survival function, $S(t) = P[T \geq t]$; the density function, $f(t)$; and the hazard function, $h(t)=f(t)/S(t)$.

For the smokers in the sample the age of starting is observed and the data can be interpreted as a complete spell. However the sample also contains individuals who have not started. In the standard survival model these observations are interpreted as incomplete spells, and it is assumed that all of these individuals will eventually "fail" and start smoking. Estimation of the model has to allow for the right censoring of these incomplete spells. The sample likelihood for the model is,

$$L = \Pi[f(t_i)]^{\delta i}[S(t_i)]^{\delta i}$$

where $\delta_i = 1$ for complete spells and $\delta_i = 0$ for incomplete spells.

In their analysis of U.S. data on the age of starting smoking, Douglas and Hariharan (1994) argue that the standard survival analysis may not be appropriate and that a split-population model should be used. This specification allows for the fact that many people are confirmed non-smokers and will never adopt the habit. It augments the standard model by adding a probability (P_i) that an individual will never fail. This probability is modelled here using a probit specification.

In order to estimate the parametric survival model an underlying distribution has to be assumed for T. The choice of distribution determines the implied shape of the hazard function. For example the exponential distribution has a survival function $\exp(\lambda t)$ and a constant hazard λ. The Weibull distribution has a survival function $\exp(-(\lambda t)^p)$ and hazard $\lambda p(\lambda t)^{p-1}$; where the hazard is monotonically increasing for $p>1$ and monotonically decreasing for $p<1$. The logistic distribution has a survival function $1/(1+(\lambda t)^p)$ with a non-monotonic hazard $\lambda p(\lambda t)^{p-1}/(1+(\lambda t)^p)$. Explanatory variables, or covariates, are introduced into the model by assuming $\lambda = \exp(-x'\beta)$. Nonparametric analysis of the HALS data suggests that the logistic model is appropriate for the age of starting. Also, this is the model used by Douglas and Hariharan (1994). Table 2 reports estimates for the split-population logistic model.

TABLE 2

Split-population logistic log-linear survival model for age started smoking (n=6491)

Variable	Coefficient	Std. Error	t-ratio
Constant	2.7872	0.2394E-01	116.437
PARSM1	-0.42580e-01	0.2432e-01	-1.751
PARSM2	-0.38061e-01	0.1602e-01	-2.375
PARSM3	-0.38061E-01	0.1602E-01	-2.375
PROFESSIONAL	0.17288E-01	0.2555E-01	0.677
MANAGERIAL	0.14988E-02	0.1389E-01	0.108
OTHER NON-MANUAL	0.10861E-01	0.1601E-01	0.678
SEMI-SKILLED	-0.23587E-01	0.1382E-01	-1.707
UNSKILLED	-0.31927E-01	0.1979E-01	-1.613
AGE	0.31864E-02	0.3226E-03	9.878
MALE	-0.13685	0.1015E-01	-13.485
LSCHOOL18	0.75757E-01	0.2128E-01	3.561
DEGREE	-0.43356E-01	0.1152E-01	-3.764
QUAL2	0.27451E-01	0.2818E-01	0.974
Constant	0.57253	0.7699E-01	7.437
PARSMI	-0.60693	0.8044E-01	-7.545
PARSM2	-0.39307	0.5051E-01	-7.782
PARSM3	-0.59240	0.5433E-01	-10.903
PROFESSIONAL	0.16795	0.7795E-01	2.154
MANAGERIAL	0.18087	0.4584E-01	3.946
OTHER NON-MANUAL	0.16608	0.5322E-01	3.120
SEMI-SKILLED	-0.27621E-01	0.5036E-01	-0.548
UNSKILLED	-0.16298	0.8160E-01	-1.997
AGE	-0.42807E-02	0.1117E-02	-3.834
MALE	-0.43331	0.3428E-01	-12.639
LSCHOOL18	0.16283	0.6250E-01	2.605
DEGREE	-0.19478	0.3877E-01	-5.024
CSE2-5	0.84468E-02	0.8423E-01	0.100
σ	0.15166	0.1201E-02	126.296

log-likelihood - 4659.445
Average predicted failure probability = 0.599

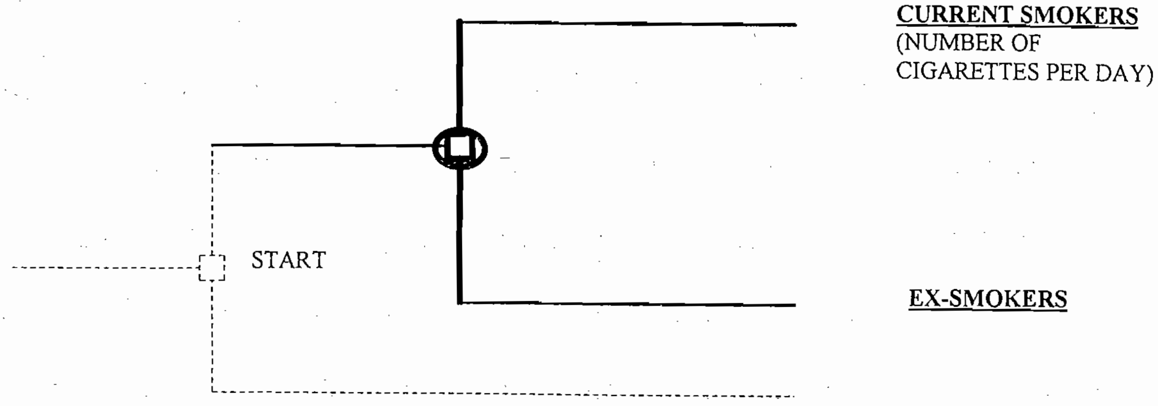
The split-population model combines the "discrete choice" whether to start together with the delay in starting smoking. In Table 2 the first set of coefficients relate to survival time and can be interpreted in terms of qualitative effects on the age of starting. The second set of coefficients relate to the probability of never starting.

Table 2 shows that parental smoking (PARSM1-3) increases the probability of someone starting smoking and means that they are likely to start earlier. The positive coefficient on AGE suggests that people have started smoking earlier in recent years. Three measures of educational attainment are included and all of these suggest that those with higher levels of education are less likely to start, and if they do, they start later. The variables for socio-economic group show a clear gradient for the participation equation, with those in semi- and unskilled occupations being more likely to start. The results show the same qualitative pattern for age of starting but the coefficients are not statistically significant.

The average predicted failure probability suggests that 60 per cent of the sample will eventually start smoking, and hence that 40 per cent will remain confirmed non-smokers. 40 per cent is virtually equivalent to the observed proportion of individuals who have never smoked in the HALS sample (41 per cent) and illustrates the relevance of the split-sample model in this context.

4. Quitting

The univariate probit model



Q.55(a) "Do you regularly smoke at least one cigarette a day"

Fig.4: Probit analysis of quitting

For the sub-sample of individuals who have started smoking, a binary variable can be constructed for whether they had quit at the time of the HALS1 survey [Fig.4]. This can be modelled by a univariate probit equation. The observed dependent variable is y, which equals 1 for a current smoker and 0 for an ex-smoker. This can be interpreted in terms of a continuous latent variable y*, which reflects the individual's propensity to remain a smoker. So that,

$$y = 1 \quad \text{if} \qquad y^* = x'\beta + u > 0 \, , \, u \sim N(0,1)$$

$$= 0 \;\; \text{otherwise}$$

The sample likelihood function for the probit model is,

$$L = \prod [1 - P(y=1)]^{(1-yi)} \, P(y=1)^{yi}$$

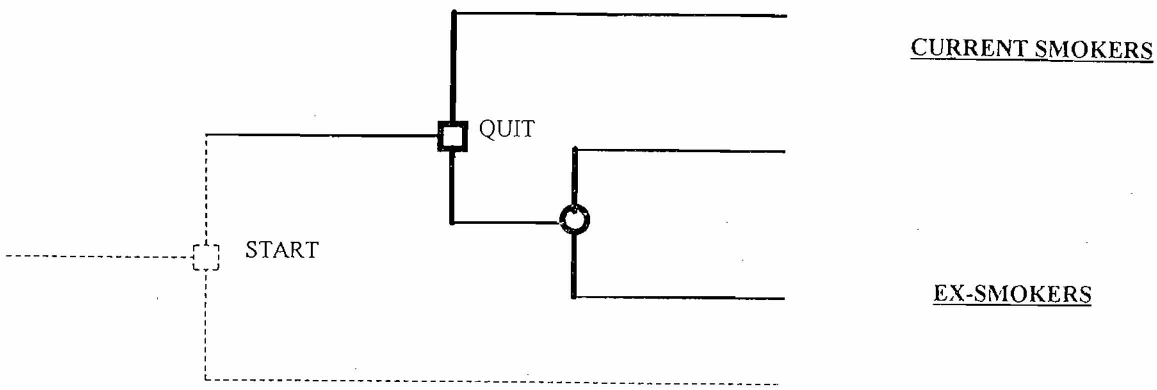
or,

$$L = \prod[1 - \Phi(x'\beta)]^{(1-y_i)}\Phi(x'\beta)^{y_i}$$

where $\Phi(.)$ is the standard normal CDF.

Sequential bivariate probit model

In addition to information on success in quitting, the HALS identifies those current smokers who have made a 'serious attempt' to quit. These two variables are summarised in Fig.5, and can be modelled jointly as a sequential or sample-selection bivariate probit model [van de Ven and van Praag (1981)]. This model assumes that those who are successful in quitting come from the self-selected sample of those who have made a serious attempt to quit.



Q.56(c) "Have you ever seriously tried to give up smoking altogether"

Q.55(a) "Do you regularly smoke at least one cigarette a day"

Fig.5: Sequential bivariate probit model

Let y_1 be a binary variable for whether the individual has made a serious attempt to quit and y_2 be a binary variable for their success in quitting (notice the change in definition from the variable y used in the univariate probit). Then y_2 is only observed if $y_1 = 1$. The sample likelihood for this model is,

$$L = \Pi\{1 - P(y_1=1)\}^{(1-y1)}$$

$$\{P(y=1)[1-P(y_2=1|y_1=1]\}^{y1(1-y2)}\{Py_1=1)P(y_2=1|y_1=1)\}^{y1y2}$$

which can be estimated as a bivariate probit model with sample selection.

Table 3 gives maximum likelihood estimates of the probit model for current smokers versus ex-smokers. Summary statistics are the restricted and unrestricted log-likelihoods along with a chi-squared statistic for the null hypothesis that all the slope coefficients equal zero. Measures of goodness of fit are the count R^2, which gives the proportion of correct predictions, and McFadden's R^2, calculated as one minus the ratio of unrestricted to the restricted likelihoods. Table 4 gives maximum likelihood estimates for the sequential bivariate probit model of whether an individual has made a serious attempt to quit and their success in quitting . The first equation applies to the full sample of 3801 observations, the second applies to the 3066 who have attempted to quit. Rho is the estimated correlation coefficient for the disturbances. Allowing for the change in sign, the parameter estimates in Tables 3 and 4 are very similar in magnitude; suggesting that the sample separation does not enhance the estimates of whether or not someone has succeeded in quitting.

TABLE 3

Binominal Probit Model for current smokers/quitters (n=3801)

Log-Likelihood	-2062.57
Restricted (Slopes=0) Log-L	-2598.279
Chi-Squared (21)	1071.418
Count R^2	0.726
McFadden R^2	0.206

Variable	**Coefficient**	**Std.Error**	**t-ratio**
ADDICTION	.10298E-01	0.1603E-02	6.423
OTHER-SMOKERS	0.74040	0.4676E-01	15.834
AGESTART	0.10498E-01	0.4433E-02	2.368
ILLHEALTH	0.26922	0.5226E-01	5.152
BMI	-0.57980E-01	0.5940E-02	-9.761
PULSE	0.17568E-01	0.2049E-02	8.573
DISABILITY	-0.20273	0.5143E-01	-3.942
FEV1	-0.24702	0.3873E-01	-6.377
PROFESSIONAL	-0.54686	0.1159	-4.719
MANAGERIAL	-0.20522	0.6260E-01	-3.278
OTHER NON-MANUAL	-0.16517	0.7483E-01	-2.207
SEMI-SKILLED	0.69045E-01	0.6637E-01	1.040
UNSKILLED	0.13026	0.1015	1.283
ARMY	-0.11348	0.2479	-0.458
WIDOW	-0.20054	0.9511E-01	-2.109
DIVORCED	0.34105	0.1151	2.964
SEPARATED	0.59273E-01	0.1479	0.401
SINGLE	0.28374E-01	0.7571E-01	0.375
AGE	-0.28563E-01	0.2287E-02	-12.488
MALE	0.87637E-01	0.5899E-01	1.486
LSCHOOL18	-0.15330	0.8711E-01	-1.760
Constant	1.5513	0.2703	5.738

TABLE 4

Sequential bivariate probit model for attempt/succeed in quitting (n=3801)

Variable	Coefficient	Std. error	t-ratio
ADDICTION	-0.11627E-01	0.4396E-02	-2.645
OTHER-SMOKERS	-0.78330	0.9460E-01	-8.280
AGESTART	-0.12789E-01	0.6600E-02	-1.938
ILLHEALTH	-0.28433	0.9449E-01	-3.009
BMI	0.62666E-01	0.1548E-01	4.047
PULSE	-0.18091E-01	0.2230E-02	-8.113
DISABILITY	0.18080	0.8557E-01	2.113
FEV1	0.22684	0.6963E-01	3.258
PROFESSIONAL	0.57528	0.1556	3.698
MANAGERIAL	0.21816	0.7386E-01	2.954
OTHER NON-MANUAL	0.15598	0.8385E-01	1.860
SEMI-SKILLED	-0.85709E-01	0.1045	-0.820
UNSKILLED	-0.17318	0.1801	-0.961
ARMY	0.57542E-01	0.3054	0.188
WIDOW	0.20119	0.1106	1.819
DIVORCED	-0.31553	0.1273	-2.478
SEPARATED	-0.48616E-01	0.1637	-0.297
SINGLE	0.40468E-01	0.2318	0.175
AGE	0.30479E-01	0.4556E-02	6.691
MALE	-0.86255E-01	0.6256E-01	-1.379
LSCHOOL18	0.16866	0.1037	1.627
Constant	-1.4916	0.3648	-4.089
OTHER-SMOKERS	-0.32142	0.5168E-01	-6.219
ILLHEALTH	-0.47313E-01	0.5353E-01	-0.884
BMI	0.15279E-01	0.6205E-02	2.463
PULSE	-0.11052E-01	0.2170E-02	-5.094
DISABILITY	0.20480	0.5671E-01	3.612
FEV1	0.21915	0.4217E-01	5.197
PROFESSIONAL	0.21281	0.1424	1.494
MANAGERIAL	0.83009E-01	0.6858E-01	1.210
OTHER NON-MANUAL	0.13318	0.8189E-01	1.626
SEMI-SKILLED	0.78834E-01	0.6899E-01	1.143
UNSKILLED	0.13156	0.1028	1.279
ARMY	0.22564	0.2902	0.777
WIDOW	0.63317E-01	0.1085	0.584
DIVORCED	-0.20582	0.1095	-1.879
SEPARATED	-0.73181E-01	0.1468	-0.498
SINGLE	-0.29620	0.7294E-01	-4.061
AGE	0.11778E-01	0.2325E-02	5.066
MALE	-0.43950E-01	0.5947E-01	-0.739
LSCHOOL18	0.40104E-01	0.9694E-01	0.414
Constant	0.33811	0.2757	1.226
RHO	0.56776	1.428	0.397
Log-Likelihood - 3418.509			

The significant negative coefficient for ADDICTION indicates that those with higher peak consumption are less likely to have quit. If past consumption is taken as an indicator of the individual's degree of dependence, this implies that addiction does play a role in quitting. However, the results suggest that the effect does not carry over to whether or not an individual has tried to quit. Heavy smokers are no less likely to try to quit but are less likely to succeed. The evidence that past consumption affects the ability, but not the desire, to quit does seem to imply that people are 'tied-in' to a habit they would prefer to abandon.

The presence of other smokers in the household (OTHER-SMOKERS) is a strong predictor of an individual having quit. This supports the evidence from the GHS in Jones (1989), and suggests that social interaction is an important determinant of smokers' behaviour. Tables 3 and 4 show that those who are single, divorced or separated are less likely to have quit than those who are married. Those whose self-assessed health is poor or fair, rather than excellent or good, are less likely to have quit. Similarly those with poorer respiratory performance and higher pulse rate are less likely to have quit. Those with a disability or long-standing illness and those with higher body-mass indexes are more likely to have quit. Taken at face value, these results suggest that being in good general health (measured by self-assessed health or clinical measures of respiratory and cardio-vascular performance) creates an incentive to quit, while being in poor health creates a disincentive. Having a disability or long-standing illness has the opposite effect, which is consistent with those suffering chronic conditions being expected to quit as part of their treatment.

In Table 3 the variables for socio-economic group show a consistent gradient, with those in higher groups significantly more likely to have quit. In contrast, Table 4 does not suggest the same differences in serious attempts to quit. There is evidence that the desire to quit may be common across social classes, but those in lower socio-economic groups appear to be less successful at actually quitting that those in groups 1 and 2. LSCHOOL18 appears with a positive coefficient, suggesting that the more educated are more likely to have quit, but this effect is poorly determined.

5. Errors in variables and simulateneity bias

Shmueli (1995) highlights the problems raised by the use of measures of current health, and by the omission of past health, in retrospective analysis of cross section data on the prevalence of smoking. These problems arise because an individual's health at the time when they quit is unobservable.

While recognising the potential for errors in variables and simultaneously biases identified by Shmueli, this section argues that tests for exogeneity used in Jones (1994) are appropriate to detect these problems and are more informative than he suggests. Further evidence to support the findings reported in Jones (1994) is presented. This is based on Godfrey and Hutton's (1993) two-step procedure for discriminating between errors in variables/simultaneity and misspecification. It is argued that the results of these tests do shed light on the relationship between current smoking and past health, although this evidence is conditional on an (untestable) auxiliary assumption about the relationship between current and past health.

Shmueli is right to stress that the Health and Lifestyle Survey (HALS1) is a single cross-section and that the participation variable used in Jones (1994) and in Tables 3 and 4 measures the prevalence rather than the incidence of smoking, and therefore reflects the number of individuals who have quit up to the time of the survey. The results of that study should be interpreted in terms of the stock of individuals who have quit rather than the flow of new quits over a specific period. What is actually being modelled is "continued abstinence" which, to some extent, can be viewed as a current decision and can be expected to depend on current health. Shmueli also interprets the data in this way and refers to the decision to "continue quitting", but he argues that the health effect of interest is on the original decision to quit. He suggests that the central empirical question is whether an individual's health at the time of quitting has a "preventive" or a "curative" effect.

The Health and Lifestyle Survey provides evidence on reasons for quitting and current and future health come at the top of the list; 34 per cent of men and 26 per cent of women give current ill-health as a reason for quitting, and 30 per cent of men and 23 per cent of women cite fear of future ill-health. Evidence from the HALS also suggests that quite a high proportion of the sample are recent quitters; 22 per cent of ex-smokers in the HALS report that it is 2 years or less since they quit and 41 per cent report that it is 5 years or less. Finally it was stressed above that the decision being modelled is "continued abstinence" from smoking and it is clear that current health may play a role in this decision.

The testing strategy proposed by Godfrey and Hutton (1993) is used to discriminate between errors in variables/simultaneity and misspecification in the context of linear models. This entails a two-step procedure. The first step is to construct a Sargan-Hansen-Newey type "J-test", in order to assess the specification of the model and the validity of the instruments. A significant J-test implies that the specification of the model and the choice of instruments requires further scrutiny. If the J-test is not significant, the second step is to use a Hausman type "H-test". As recommended by Godfrey and Hutton (1993), both the J and H statistics are computed using the variable addition approach. The J-test is given by nR^2 from the regression of the IV residuals on the set of instruments (where R^2 is the uncentred R-squared). The H-test is computed by adding the reduced form residuals for each of the potentially endogenous variables to the original equation and testing for their significance.

To implement this two-step approach I adopt a linear probability specification for the binary dependent variable is adopted. The use of the linear probability model, estimated by the generalised method of moments (GMM) to allow for endogenous regressors, provides a robust and tractable alternative to nonlinear models [see e.g. Mullahy and Portney (1990)]. The structural and reduced form equations are all assumed to be linear and are estimated by both OLS, with heteroscedasticity corrected standard errors, and by GMM. The dependent variable is binary, and equals 1 if the individual is current smoker or 0 otherwise. The regressors are the same as those used in Jones (1994). For the GMM estimation the additional instruments are dummy variables for whether or not one or both of the respondent's parents were smokers (PARSM1, PARSM2, PARSM3), along with regional dummies and the individual's height in metres (HEIGHTM).

Shmueli concentrates on measurement errors and simultaneity bias with respect to current health, but the health variables may not be the only source of misspecification. Jones (1994) discusses the reasons why variables measuring addiction, other smokers in the household, health advice, and health may all be prone to problems of unobservable heterogeneity and simultaneity. Table 5 present three versions of the Godfrey and Hutton procedure. Column (1) presents estimates in which all of the variables are instrumented, in column (2) all measures of current health are instrumented and in column (3) only self-assessed health is instrumented. In all three cases the J-test is insignificant, and does not provide evidence against the specification and the validity of the instruments. Moving to the second stage the H-tests do not reject the exogeneity of any of the variables, reinforcing the finding in Jones (1994) and in Tables 3 and 4. This suggests that the estimates of the link between "continued abstinence" from smoking and current health can be viewed with confidence and do not appear to be biased by measurement error or simultaneity.

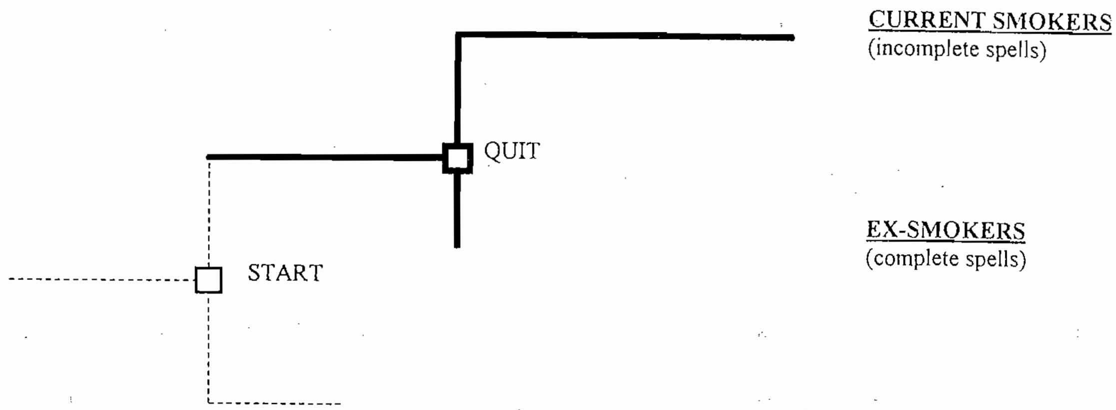
TABLE 5

J and H Tests

Specification:	**(1)**	**(2)**	**(3)**
J-Test (χ^2):	3.039	5.311	12.049
(5% critical value)	(9.49)	(15.5)	(21.00)
H-Tests (t-ratios, p-values in parentheses)			
ADDICTION	1.179		
	(0.238)		
OTHER-SMOKER	-0.580		
	(0.562)		
ILLHEALTH	0.017	0.217	1.087
	(0.915)	(0.829)	(0.277)
FEV1	-0.136	-0.261	
	(0.892)	(0.794)	
PULSE	-0.435	-1.213	
	(0.663)	(0.225)	
DISABILITY	-0.956	-1.286	
	(0.339)	(0.199)	
BMI	-0.984	-0.827	
	(0.325)	(0.408)	

6. The Duration of Smoking

Evidence on the dynamics of smoking can be obtained by analysing the duration of smoking; the number of years someone smokes before quitting. The HALS contains the information required to define an individual's duration of smoking. For current smokers this is given by their current age less the age they started smoking. For ex-smokers it is given by current age less the number of years since they quit (EXFAGAN) less the age they started smoking. Together this gives the number of years of smoking (SMOKE-YEARS) which is modelled here using parametric survival analysis [Fig.6].



Q.1(b) "Age last birthday"

Q.58(a) "How old were you when you started to smoke cigarettes"

Q.65(f) "How long ago did you completely stop smoking"

Fig.6: Duration of smoking

Those individuals who were current smokers at the time of the cross-section survey can be interpreted as "incomplete spells" and estimation of non-parametric and parametric hazard functions must allow for the right-censoring of these observations. The nature of the data available in the HALS means that the duration of smoking has to be viewed as a single spell and the model is not able to deal with multiple spells of smoking and with repeated attempts to quit.

The first step in the empirical analysis is to compute a non-parametric hazard for SMOKE-YEARS, this is estimated in Limdep using the method of Cutler and Ederer. The results suggest that the hazard is monotonic with positive duration dependence and hence a Weibull specification is adopted for the parametric modelling of the survival time (t). This implies a survival function $S(t) = \exp(-(\lambda t)^p)$, and hazard rate $h(t) = f(t)/S(t) = \lambda p(\lambda t)^{p-1}$. The log-likelihood function for the model, with censoring for incomplete spells, is

$$LnL = \Sigma_{\delta=1} \ln\{1/\sigma\ f(\mu_i/\sigma)\} + \Sigma_{\delta=0} \ln\{S(\mu_i/\sigma)\}$$

where $\mu_i = \ln(t_i) - \beta' x_i$, and δ is the censoring indicator which equals 1 for ex-smokers and 0 for current smokers. The maximum likelihood estimates for the Weibull model are in Table 6.

The estimate of p is significantly greater than 1 and indicates positive duration dependence; the longer someone smokes the more likely they are to quit. For the Weibull model the coefficients on the covariates are proportional to the effect of the variables on $E(t|x)$ and their signs can be interpreted as the qualitative effects on the duration of smoking. With the exception of SEPARATED and SINGLE, the qualitative effects on the duration of smoking follow the same pattern as the results presented in Tables 3 and 4 for participation rates. In other words variables that increase the likelihood of someone being an ex-smoker are also associated with a shorter duration of smoking.

An increase in ADDICTION, measured by previous peak consumption, is associated with a longer duration of smoking, as is the presence of other smokers in the household (OTHER-SMOKERS). Those with more years of formal education (LSCHOOL18) have a shorter duration of smoking. The results also show a clear gradient by occupational social class, with those in higher socio-economic groups smoking for fewer years. Most of the health variables suggest an inverse relationship between current health and the duration of smoking, however those with a disability or long-standing illness (DISABILITY) smoke for fewer years.

TABLE 6

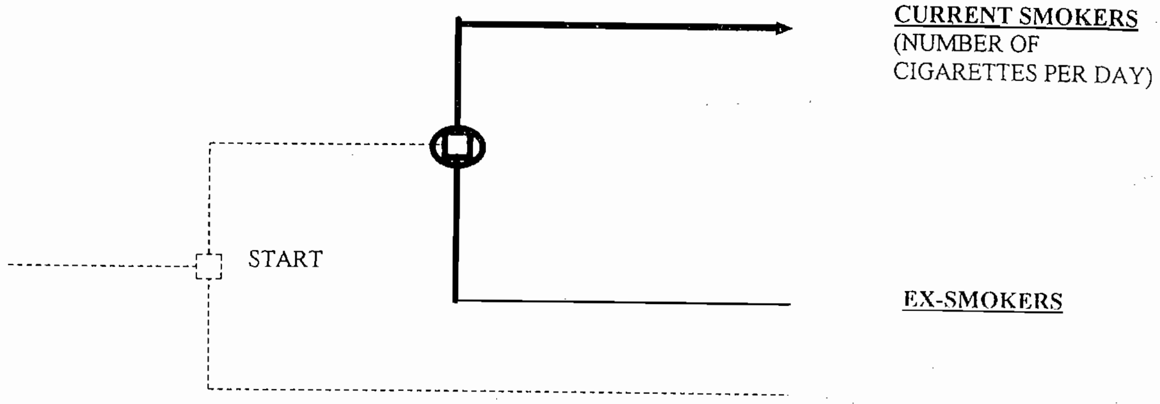
Weibull log-linear survival model for years of smoking (n=3801)

Variable	coefficient	std.error	t-ratio
ADDICTION	0.96972E-02	0.1160E-02	8.361
OTHER SMOKERS	0.47882	0.3609E-01	13.269
ILL HEALTH	0.12543	0.3891E-01	3.224
BMI	-0.27394E-01	0.4045E-02	-6.773
PULSE	0.97713E-02	0.1470E-02	6.646
DISABILITY	-0.89058E-01	0.3541E-01	-2.515
FEV1	-0.35230	0.2007E-01	-17.552
PROFESSIONAL	-0.33044	0.6965E-01	-4.744
MANAGERIAL	-0.92210E-01	0.4302E-01	-2.143
OTHER NON-MANUAL	-0.10536	0.5100E-01	-2.066
SEMI-SKILLED	0.62705E-01	0.4988E-01	1.257
UNSKILLED	0.95417E-01	0.7814E-01	1.221
ARMY	-0.13964	0.1665	-0.839
WIDOW	-0.19654	0.6388E-01	-3.077
DIVORCED	0.18434	0.1060	1.739
SEPARATED	-0.26460E-01	0.1232	-0.215
SINGLE	-0.18414	0.5476E-01	-3.362
MALE	0.26724	0.3686E-01	7.249
LSCHOOL18	-0.23228	0.5451E-01	-4.261
Constant	4.1375	0.1555	26.613
σ	0.62166	0.1239E-01	50.194

log - likelihood: - 3161.146

7. The level of cigarette consumption

In this section the decision to quit smoking is modelled jointly with the typical level of consumption by current smokers [Fig.7].



Q.55(a) "Do you regularly smoke at least one cigarette a day"

Q.56(a) "How many cigarettes do you generally smoke in a day"

Fig.7: Double hurdle model of cigarette consumption

Yen and Jones (1994) develop a model in which the decision to quit smoking depends on the expected net benefit of quitting; in terms of health, wealth and social prestige. This implies that a smoker will quit if the perceived benefits exceed the fixed costs associated with nicotine dependence. Let A be a latent variable, reflecting the fixed costs of quitting, which depends on a set of regressors (x_0) and a disturbance term (ε_0),

$$A = x_0\alpha_0 + \varepsilon_0$$

Let B be a latent variable, reflecting the benefits of quitting, which for tractability is equated with the individual's desired level of consumption y*. This depends on another set of regressors

(x_2) and a disturbance term (ε_2),

$$B = y^*_2 = x_2\alpha_2 + \varepsilon_2$$

So the condition for someone **not** attempting to quit and remaining a smoker is,

$$y^*_1 = A - B > 0$$

where,

$$y^*_1 = x_0\alpha_0 + \varepsilon_0 - x_2\alpha_2 - \varepsilon_2$$

or,

$$y^*_1 = x_1\alpha_1 + \varepsilon_1$$

This fixed cost specification has two important features:

(i) Independent variables that have no (or small) influence on the fixed costs of quitting are likely to have opposing effects on the decisions to quit and how much to smoke. This reflects the intuition that, **conditional** on overcoming the fixed costs of quitting, it is the heavier smokers who have the greater incentive to quit.

(ii) There will be a negative correlation between the unobservable disturbance terms in the quit and consumption equations. This implies that it would not be appropriate to assume independence between the two error terms and that the consumption equation will be prone to selection bias.

In the empirical model it is assumed that the desired level of consumption is related to the observed level of consumption (y), as measured in the HALS, by a Box-Cox transformation [see Jones and Yen (1994)],

$$y^*_2 = (y^\lambda - 1)/\lambda \qquad \lambda > 0$$
$$= \ln(y) \qquad \lambda = 0$$

The resulting Box-Cox double hurdle model provides a flexible parametric model which nests many of the limited dependent variable models that have been used in the previous literature on smoking. The likelihood-ratio tests for these nested models are presented in Table 7. All restricted models are rejected, each with a p-value of less than 0.0001. The estimated error correlation σ_{12} is significant at the 0.01 level, rejecting independence of errors. As suggested by the fixed costs model, there is evidence of strong negative correlation between the error terms.

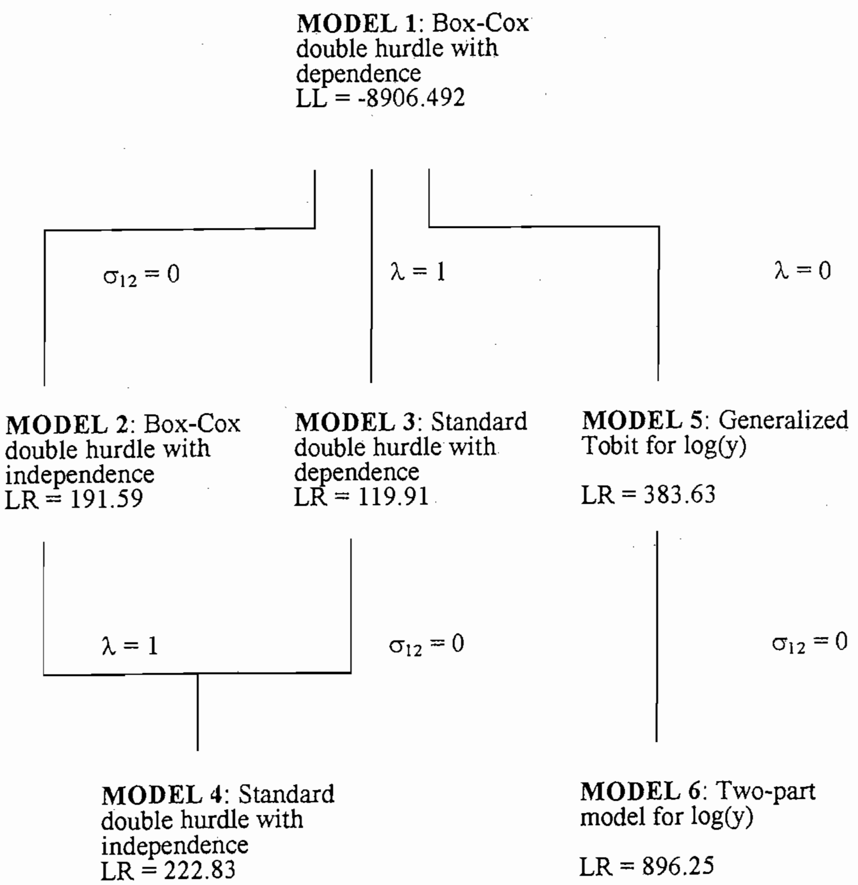
The estimate of the Box-Cox parameter (λ) equals 0.562 which is significantly different from both zero and one at the 0.01 level. Thus, both the standard double hurdle model and generalized Tobit model are rejected. The value of 0.562 is "close" to a square root transformation (although the estimate is significantly different from 0.5). The square root is the variance stabilising transformation for Poisson data [McCullagh and Nelder (1989, p.196)]. This suggests that it may be more appropriate to interpret the typical number of cigarettes as count data rather than as a continuous dependent variable. For example the model could be estimated by the Negbin hurdle model used by Pohlmeier and Ulrich (1994). The problem with this approach is that these kind of models do not allow for dependence between the participation and consumption equations, and hence for the selection bias implied by the fixed cost model of addiction. Interestingly, Wasserman et.al. (1991) estimate a two-part model using the logarithm of cigarette consumption and they interpret the model as a "pseudo-Poisson" specification.

However their model does not allow for selection bias and therefore contradicts the fixed cost model of addiction.

In the full Box-Cox double hurdle model the predicted impact of the individual regressors on the probability of quitting and on the observed level of cigarette consumption are complicated by the dependence between the two hurdles and by the nonlinear transformation between y_2* and y. As a result the magnitude of the estimated coefficients are difficult to interpret. To give a more intuitive interpretation the marginal effects of the continuous explanatory variables on participation and consumption are explored by calculating elasticities. Table 8 gives the elasticities of participation, the conditional level of consumption, and the unconditional level of consumption evaluated at sample means [see Jones and Yen (1994) for details of the computation of these elasticities, standard errors are computed by the delta method, and see Yen and Jones (1994) for further results].

TABLE 7

The Box-Cox double hurdle and LR tests for nested models.



LL - value of log-likelihood function

LR - likelihood ratio statistic

TABLE 8

Estimated Elasticities

Variable	Probability	Cond.level	Uncond.level
ADDICTION	0.298***	0.435***	0.733***
	(0.027)	(0.033)	(0.020)
AGESTART	0.144***	-0.200***	-0.057**
	(0.049)	(0.060)	(0.028)
FEV1	-0.295***	0.345***	0.050
	(0.057)	(0.072)	(0.038)
PULSE	0.657***	-0.633***	0.023
	(0.096)	(0.123)	(0.073)
BMI	-0.782***	0.901***	0.118**
	(0.095)	(0.125)	(0.072)
AGE	-0.697***	0.796***	0.100
	(0.061)	(0.085)	0.062)

Note: Asymptotic standard errors in parentheses. Asterisks indicate levels of significance: *** = 0.01, ** = 0.05 and * =0.10.

The influence of addiction, measured by previous peak consumption, has a positive effect on both the probability of smoking and the level of consumption. The variable ADDICTION is strongly significant in both equations, the LR statistic for excluding the variable from the model is $\chi^2(2) = 1181.53$. A Smith and Blundell (1986) type test does not reject the exogeneity of ADDICTION, this is calculated by including the residuals from a reduced form equation for ADDICTION in both hurdles which gives an LR statistic of 3.047 (p-value=0.2179). This can only be an imperfect test as our cross section dataset does not include a full set of appropriate lagged values to instrument past consumption. Previous UK studies based on microdata have not analysed the influence of lagged consumption, but the positive effect on the level of consumption is consistent with the evidence from panel data in Chaloupka (1991) and Labeaga (1993). The evidence in Table 8 indicates that, on average, a 10 per cent increase in previous peak consumption will increase the probability of remaining a smoker by around 3 per cent and increase the level of current cigarette consumption by around 4 per cent. This suggests that smoking habits persist and that addiction does constrain individuals' ability to quit.

In the full model, all of the other regressors show different qualitative effects on participation and on consumption. This is something that is consistent with the fixed cost model of addiction, which suggests that the parameters for variables that appear in both equations will tend to have opposite signs. The implication is that, after controlling for the fixed costs associated with addiction, the more someone smokes the more likely they are to try to quit as the potential benefits of quitting are greater. Hence the model predicts that variables which increase the level of smoking will decrease the likelihood of remaining a smoker.

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