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By Jan C. van Ours

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Tilburg University

Dynamics in the use of drugs

Jan C. van Ours *

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Abstract

This paper uses information about prime age individuals living in Amsterdam to study the dynamics in the use of drugs, in particular alcohol, tobacco, cannabis, cocaine, and ecstasy. The analysis concerns starting rates, transitions from non-use to use, as well as quit rates, transitions from use to non-use. Particular attention is given to the effect of the age of onset on quit behavior. The empirical analysis shows that for most of the drugs investigated the age of onset has a positive effect on the quit rate. The earlier individuals start using a particular drug the less likely they are to stop using that drug.

Keywords: alcohol; tobacco; cannabis; cocaine; ecstasy; drug use; age of onset

JEL-codes: C41, D12, I19

*Department of Economics, Tilburg University, CentER, and CEPR; email: vanours@uvt.nl. Address: Department of Economics, Tilburg University, P.O. Box 90153, NL–5000 LE Tilburg, The Netherlands. The author thanks CEDRO (Center for Drug Research), and the SCO-Kohnstamm Institute of the University of Amsterdam for making their data available. The author also thanks seminar participants in Canberra and Melbourne (Departments of Economics) for comments on a preliminary version of this paper.

1 Introduction

This paper is on the dynamics in the use of drugs, i.e. alcohol, tobacco, cannabis, cocaine and ecstasy. The use of drugs is considered to be harmful in particular for health reasons. While some alcohol use may be beneficial to health, all smoking is damaging health. Although legal in almost every country heavy alcohol use is discouraged and tobacco use is discouraged altogether. Cannabis is classified in some countries as a "soft drug" because its use is not considered to be very risky.[1] Although in some countries the use of cannabis is not prohibited and cannabis is easy to obtain, in most countries cannabis is an illicit drug. Cocaine and ecstasy are considered to be "hard drugs" because their use involves health risks.

The dynamics in use are drug-specific but there are also common elements. Most people that start using drugs do so at a relatively young age. If they have not yet used a drug at a particular age, which is drug-specific, they are very unlikely to do so at a later age. The duration of use is also important. Some individuals may use a particular drug only for a short period because they are experimenting and decide early that quitting drug use is a sensible thing to do. Other drugs users are very unlikely to stop using. The size of the stock of drug users depends on the inflow into drug use and the duration of use. Policies to reduce the stock of drug users can be aimed at reducing the inflow or increasing the outflow. The two processes may not be independent. Therefore, an important issue from a policy point of view is the possible correlation between the two, especially whether there is a positive

[1] Macleod et al. (2004) for example conclude on the basis of an overview on 48 longitudinal population studies that the only fairly consistent association is the one between cannabis use and lower educational attainment. Less consistent associations were found between cannabis use and both psychological health problems and problematic behavior.

effect of the age of onset on the quit rate. If such a positive effect exists it may be more efficient to focus on policies that aim at postponing the age of onset than use policies that aim at stimulating quits at a later age.

Previous studies on the dynamics of drug use are mostly on the dynamics of cigarette smoking, often focussing on the effects of cigarette prices.[2] Douglas and Hariharan (1994) analyze US data using a hazard rate model to examine the impact of cigarette prices on smoking initiation. They find no effect. Douglas (1998) examines the smoking initiation hazard using the same data and a slightly different model, again finding no price effects for initiation. [3] DeCicca et al. (2002) supports these findings. Lopez Nicolas analyzing Spanish data finds weak price effect on smoking initiation but larger effects on smoking quits. Forster and Jones (2001, 2003) analyze British data and find no price effect on the decision to start smoking while they do find price effects on the quit decision. Finally, Kidd and Hopkins (2004) analyze Australian data to find that price affects the decision to start smoking, but not the decision to quit smoking. All in all, the evidence of the price effects on the dynamics of tobacco use is limited and mixed.[4]

Studies on the dynamics in the use of other drugs are rare. Starting rates for cannabis, and cocaine are analyzed in Van Ours (2003) to examine whether in the Netherlands cannabis is a stepping-stone for cocaine.[5] The dynamics in Australian cannabis use are studied in Van Ours and Williams (2005). Cannabis prices are

[2]See Chaloupka and Warner (2000) for an overview of the economics of smoking.

[3]He does find a price effect on smoking cessation.

[4]In addition to sale taxes on tobacco products, tobacco smoking can be discourages through regulatory intervention concerning tobacco advertising and encouragement of smoke-free environments as well as anti-smoking education.

[5]Lack of information about cannabis prices and cocaine prices made it impossible to study price effects. Starting rates for alcohol and tobacco in the Netherlands are investigated in Van Ours (2004), again ignoring price effects.

found to affect the starting rates for cannabis but not the quit rates. Van Ours and Williams (2005) is one of the few studies that examines the effect of the age of onset on the quit rate finding that there is a positive correlation between the two.[6] Such a positive relationship is also found for smoking in Khuder et al. (1999). On the basis of an analysis of US data this study concludes that men who started smoking before 16 years of age have a much lower probability to quit smoking than those that started at a later age.

In conclusion, previous studies on the dynamics in drug use have focused on starting rates and quit rates of smoking. However, even the studies that investigate both starting rates and quit rates do not investigate whether or not these processes are correlated. And, studies on quit rates do not investigate the effect of the age of onset. The current paper uses information about prime age individuals living in Amsterdam to study the dynamics in drug use. The distinguishing features are the following. First, in the analysis the correlation between starting rates and quit rates is taken into account. Second, the study deals with several types of drugs and does not just focus on tobacco or cannabis. Third, the effect of the age of onset on the quit rate is taken into account.

The main result of the paper is that age is an important determinant of the dynamics in drug use. If individuals do not start using a particular drug at a young age they are not very likely to do so at a higher age. And, individuals that start using a particular drug at a young age are less likely to quit drug use than individuals that start later on in life.

The set-up of the paper is as follows. Section 2 discusses drug use in Amsterdam

[6]Van Ours (2005) shows that cannabis use has a negative effect on the wage of individuals. The negative effect is smaller the higher the age of onset of cannabis use.

and presents details of the data used in the analysis. Section 3 presents the set-up of the statistical analysis. Section 4 discusses the estimation results and section 5 concludes.

2 Drug use in Amsterdam

2.1 Stylized facts

The Netherlands has a drugs policy that distinguishes hard drugs from soft drugs. The distinction relates to the health risks involved in drug use. Hard drugs are those substances which can seriously harm the health of the user and include heroin and cocaine. Soft drugs, i.e. cannabis derivatives marijuana and hashish cause far fewer health problems. The possession of a small quantity of soft drugs for personal use is no offence. However, the possession of hard drugs is a crime. Ecstasy was put on the list of hard drugs in 1988.

An international comparison of annual prevalence of cannabis, cocaine and ecstasy is given in Table 1. Countries are ranked from high to low according to annual prevalence of cannabis use. As shown, there are substantial differences between countries. While in Australia about 15% of the population aged 15 to 64 years used cannabis in the past year this was only 6% in Germany (for a slightly different age category). In terms of annual prevalence cannabis use in the Netherlands is substantially below that of a country like the US which has a stringent cannabis policy. Thus it would be tempting to conclude that cannabis policy has counterproductive effects. However, it is difficult to simply compare countries on the basis of aggregate statistics. Nevertheless, from a close comparison of cannabis use in Amsterdam and San Francisco Reinarman et al. (2004) conclude that the policy regime does not

seem to have an effect on cannabis use. Also for cocaine and ecstasy there are substantial differences between countries. Cocaine use is especially high in Spain and the US, while ecstasy use is relatively high in Australia and the UK.

Information about lifetime use and annual year prevalence of a number of selected drugs among inhabitants of 12 years and older in Amsterdam is presented in Table 1. The lifetime use of alcohol and tobacco has not changed much in the period 1987 to 2001; about 85-90% used alcohol, and about 70% tobacco. With respect to the other drugs there is a clear increase in lifetime use in the course of the 1990s; cannabis use increased from about 23% in 1987 to about 38% in 2001, cocaine from 5.7% to 10%, and ecstasy from a little over 1% in the beginning of the 1990s to almost 9% early twenty-first century. Also for amphetamines there was an increase while for heroin there were fluctuations in lifetime use with a decrease between 1997 and 2001.

Table 2 also shows that except for tobacco annual prevalence increased for all drugs with the increase in the use of ecstasy being by far the largest. In the course of the 1990s ecstasy reached a level of use comparable to that of cocaine. In 2001 2.8% of the Amsterdam population of 12 years and older used cocaine in the past year, while 3.6% used ecstasy. To the extent that the difference between lifetime prevalence and annual prevalence is an indication of persistence of use Table 2 shows that persistence of use is high for alcohol and tobacco, and much lower for cannabis, cocaine and other illicit drugs. The mean age of first use ranges from 17.4 years for alcohol and tobacco to 25.9 years for ecstasy.

2.2 The data

The data used in the analysis concern prime age inhabitants of Amsterdam who were asked about their drug use in 1994, 1997 or 2001. The dataset used in the analysis contains information about 2095 prime age females and 1830 prime age males (see the appendix for details). Figures 1 to 5 give information about age-specific dynamics in drug use. Presented are the age-specific starting rates, i.e. the probabilities to start using at a particular age conditional on not having started before that age.[7] Furthermore, the cumulative age specific starting probabilities are shown, based on the age-specific starting rates. Then there are quit rates, i.e. the probabilities to stop using at a particular duration of use conditional on not having stopped up to that duration.[8]

Figure 1a shows that alcohol starting rates are high between ages 15 to 20. There are clear spikes at age 16, 18, 20 and 25. These spikes may have to do with the memory of individuals that groups events at particular ages. In the Netherlands age 16 is the age at which individuals are allowed to drive a small motorcycle and at age 18 individuals are allowed to drive a car. The spikes at age 20 and 25 may have to do with individuals rounding numbers. Among the males that have not started using at age 15 50% starts using at age 16. For females the starting probability at age 15

[7] In the calculations of the age, specific starting rates individuals that have not started using at the time of the survey are considered to have a right censured duration until drugs use. Also, individuals that indicate to have started using a drug below age 10 are assumed to have started at age 10. That is the reason that the starting rate has a small spike at age 10. Alternatively the individuals that indicate to have started using a particular drug below age 10 could have been removed from the sample. Since this does not involve many individuals that graphs and estimation results would not have changed.

[8] If an individual was using a particular drug at the time of the survey his duration of use is considered to be right-censored. Finally, there are cumulative quit probabilities based on the calculated duration-specific quit rates.

is 40%. A similar spike occurs at age 18. Figure 1b shows that at age 20 almost 90% of the individuals have experienced alcohol use. After that there is hardly an increase in the cumulative number of users. The spike at age 25 for example is about 10%, but this concerns only a small number of individuals. Figures 1c and 1d show that the quit rates for alcohol use are very small. Once individuals have started using alcohol they stick to it.

Figure 2 shows similar numbers for tobacco use. For reasons of comparison the scales used are the same as those of Figure 1. The starting rates for tobacco in Figure 2a also shows spikes at age 16, 18 and 20, though much smaller than for alcohol. For tobacco for example the starting rate at age 16 is about 20%. Figure 2a shows that the maximum probability to use tobacco of 78% is reached at an age of about 25. This implies that about 22% of the individuals in Amsterdam will never use tobacco. The quit rates for tobacco shown in Figure 2c is not very high. About 2.5% of the starters already stop using tobacco after 1 year. After that the quit rate varies between 0.5% and 2%. The cumulative probability to remain a user levels off at about 75%. So three-quarters of the individuals that started using tobacco remain doing so in the rest of their life.

As shown in Figure 3a for cannabis use there are similar spikes in the starting rates at age 16, 18 and 20 as for alcohol and tobacco, although at a much lower level of about 10%. The cumulative probability to be a cannabis user levels off at 50% for females and 60% for males. The quit rates for cannabis use are very high in the first year, about 23% for females and about 15% for males. Also after 1 year of use the quit rate is high, between 5 and 10%. As Figure 3d shows eventually about 20% of the females and about 40% of the males keep on using cannabis.

Figure 4 shows that not many individuals start consuming cocaine, while of those that do many quit in the first year of use.[9] The age of onset is higher for cocaine than for cannabis. The cumulative starting probability for cocaine levels off after age 40 indicating that after age 40 not many individuals are inclined to start using cocaine if they have not done so before that age. Also for cocaine the quit rates are high in the first year of use, about 33% for males and 45% for females. Because a lot of individuals start using cocaine later on in life and the maximum age in the sample is 50, the potential duration of use is limited. Therefore, Figures 4c and 4d graph quit rates and cumulative quit probabilities up to a duration of 15 years.

Finally, Figure 5 shows the dynamics of use for ecstasy. The patterns shown for ecstacy are very similar to the patterns shown for cocaine. People start using ecstasy later on in life, not many individuals do this, and if they do a substantial part does it only for a short period. Because ecstasy use is a recent phenomena the quit rates and cumulative quit probabilities are presented up to a duration of 7 years.

Summarizing the dynamics of drug use, there is a clear difference between on the one hand alcohol and tobacco and on the other hand cannabis, cocaine and ecstasy. Alcohol use and tobacco use are characterized by high starting rates at a low age and by low quit rates. Cannabis, cocaine and ecstasy use are characterized by low starting rates at a higher age and by high quit rates especially right after individuals started using. Apparently, among the users of cannabis, cocaine and ecstasy there are many experimenters, i.e. individuals that use a drug for a very short time but then decide very quickly to stop using. Because almost everyone starts using alcohol

[9]Note that for reasons of comparison the scales of the figures for cannabis, cocaine, and ecstasy are the same.

and the quit rates among alcohol users are so small the dynamics of alcohol use are not included in the empirical analysis.

3 Statistical analysis

Orphanides and Zervos (1995) present an theoretical model that is helpful in interpreting dynamics in drug use. Their theoretical model has some similarities with job search theory. In their theory, drugs are not equally addictive to all individuals. Since individuals do not have information about their addictive nature the only way to find out about it is to experiment with drug use. In deciding to do so, individuals balance the instant pleasure derived from drug use experimenting with the probabilistic disutility that they may get addicted to the drug. So, in the theory of Orphanides and Zervos experimenting with drug use is important. Experimentation also explains why annual prevalence is often substantially below life time prevalence. In the same way as job seekers are confronted with a flow of job offers, youngsters are confronted with offers to use drugs irrespective of whether they are actively seeking for these offers. And, in the same way as job seekers may decide to accept or reject job offers youngsters may decide to accept or reject an offer to use drugs. The decision to quit is also in line with this theory. If individuals find out that they are of the addictive kind with respect to a particular drug they will (try to) stop using that drug. If they find out quickly there will be a high quit rate right after the initiation.

To investigate the determinants of the starting rates and quit rates of tobacco, cannabis, cocaine and ecstasy mixed proportional hazard models with flexible base-

line hazards are used.[10] Differences between individuals in the rate by which they start using a particular drug are characterized by the observed characteristics, the elapsed duration of time they are exposed to potential use and unobserved characteristics. Age 10 is taken to be the time at which this potential exposure to drugs starts.

The starting rate for a particular drug, at time (age) t conditional on observed characteristics x and unobserved characteristics v is specified as:[11]

$$\theta_j^s(t \mid x, v_j) = \lambda_j^s(t) \exp(x'\beta_j + v_j) \text{ for } j = a, b, c, d \tag{1}$$

where $\lambda^s(t)$ represents individual age dependence, v represents individual specific unobserved heterogeneity, the subscript a represents tobacco, the subscript b cannabis, the subscript c cocaine, the subscript d ecstasy, and the superscript s refers to starting.

We model flexible age dependence by using a step function:

$$\lambda_j^s(t) = \exp(\Sigma_k \lambda_{jk}^s I_k(t)) \tag{2}$$

where k (= 1,..,N) is a subscript for age-intervals and $I_{jk}(t)$ are time-varying dummy variables that are one in subsequent age-intervals. The exact specification of the age-intervals depends on the particular drug. Since tobacco already has an average low age of onset there is a more detailed classification at lower ages than for cocaine and ecstasy which have high average ages of onset. For each of the drugs the last interval refers to age over 30. Because a constant term is also estimated, λ_{j1}^s is normalized to 0.

[10] These models are often used to analyze labor market dynamics, in particular unemployment durations; see Van den Berg (2001) for an overview.

[11] Omitting a subscript for individual.

The conditional density functions of the completed durations of non-use can be written as

$$f_j^s(t_j \mid x, v_j) = \theta_j^s(t_j \mid x, v_j) \exp(-\int_0^{t_j} \theta_j^s(s \mid x, v_j) ds) \tag{3}$$

The quit rates are also modelled using mixed proportional hazard specifications. The quit rate for a particular drug, at duration of use τ conditional on observed characteristics z and unobserved characteristics u is specified similarly as:[12]

$$\theta_j^q(\tau \mid z, v_j) = \lambda_j^e(\tau) \exp(z'\gamma_j + u_j) \tag{4}$$

where $\lambda^e(t)$ represents individual duration dependence and u represents individual specific unobserved heterogeneity, and the superscript q refers to quit.

Duration dependence is again modelled by using a step function:

$$\lambda_j^q(t) = \exp(\Sigma_m \lambda_{jm}^q I_m(t)) \tag{5}$$

where m (= 1,..,M) is a subscript for duration of use-intervals and $I_{jm}(t)$ are time-varying dummy variables that are one in subsequent duration intervals.

The conditional density functions of the completed durations of drug use can be written as

$$f_j^q(\tau_j \mid z, v_j) = \theta_j^q(\tau_j \mid z, u_j) \exp(-\int_0^{\tau_j} \theta_j^q(s \mid z, u_j) ds) \tag{6}$$

The most interesting parameters of interest in the quit rates are the parameters that relates to the age of onset. They indicate to what extent the quit rate is influenced by the age of onset. However, if the parameters of the quit rate are

[12]Note that except for the age of onset the personal characteristics that are assumed to affect the starting rates are the same as those that are assumed to affect the quit rates. There is no reason to assume that a personal characteristic influences one rate but not the other. Note also the assumption that quits are definite. Once individuals have indicated to have quit use they don't return to use again.

estimated separately from the parameters of the starting rate the influence of the age of onset may not reflect a causal effect. It may be that there are unobserved personal characteristics that affect both the starting rate and the quit rate. If some individuals have an inclination towards drugs use they may start to use drugs rather early in life and they will stick to that use. Then, there is a positive correlation between age of onset and quit rate even if there is no causal relationship from age of onset to quit rate. To be able to make a distinction between causality and correlation through unobserved characteristics this correlation has to taken into account.[13]

The possible correlation between the unobserved components is taken into account by specifying for each drug the joint density function of the durations of non use and the durations of use conditional on z and x as

$$f_j^{sq}(t_j, \tau_j \mid x, z) = \int_{u_j} \int_{v_j} f_j^q(t_j \mid x, v_j) f_j^s(\tau_j \mid z, u_j) dG_j(v_j, u_j) \tag{7}$$

where the $G_j(v_j, u_j)$ are assumed to be a discrete distributions with 3 points of support (v_{1j}, u_{1j}), (v_{2j}, u_{2j}), (v_{3j}), where $u_{2j} = v_{3j} = -\infty$ to allow for the possibility of zero starting rates and zero quit rates. The specification of the distribution of unobserved heterogeneity implies that conditional on the observed personal characteristics (including age and duration of use) there are three groups of individuals. The first group has a positive starting rate and a positive quit rate. The second group has a positive starting rate and a zero quit rate. Individuals in this group that start using never stop. The third group has a zero starting rate, and therefore the quit rate is non-existent.[14]

The associated probabilities are denoted as $\Pr(v_j = v_{1j}, u_j = u_{1j}) = p_{j1}$, $\Pr(v_j =$

[13] See Belzil (2001) who uses a similar type of model to relate unemployment durations to subsequent employment durations.

[14] Note the imposing some groups to have a zero starting rate or a zero quit rate is similar to using a split-population model. In a split-population model the distribution of unobserved heterogeneity

$v_{2j}, u_j = -\infty) = p_{j2}$, $\Pr(v_j = -\infty) = p_{j3}$. The p_{jn} $(n = 1, .., 3)$ are assumed to have multinomial logit specifications $p_{jn} = \frac{\exp(\alpha_{jn})}{\Sigma_{jn} \exp(\alpha_n)}$, and to normalize $a_{j3} = 0$.

The explanatory variables are dummy variables for survey dates and personal characteristics. The dummy variables for survey dates pick-up cohort effects. The interpretation of the effect of personal characteristics on starting rates and quit rates needs some clarification. To understand the dynamics of drug use information about the past is necessary, i.e. characteristics that are valid at the time when the individual was potentially confronted first with the choice of whether or not to use a particular drug, and then conditional on using that drug whether or not to stop using. Ideally, the information is time-varying over the relevant period of life of individuals indicating how relevant circumstances change. Information that could be important concerns family situation, experiences at school, changing supply conditions, prices of drugs, et cetera. Unfortunately, this type of information is generally rarely available, and is also lacking in the current analysis. Variables that indicate personal characteristics, i.e. marital status and presence of children, at the time of the survey are not very useful because they could be influenced by drug use and be endogenous rather than exogenous with respect to potential drug use. The educational level attained may be an exception. Although the highest educational level may be attained long after the use of a particular drug started one might assume that this level represents ability rather than educational investment. In the interpretation of the parameter estimates of the starting rates and quit rates it is assumed that educational level indeed represents ability. A high educational level that is attained eventually can be used to explain choice with respect to the use

is assume to depend on personal characteristics. In a MPH-model this distribution is assumed to be independent of personal characteristics.

of drugs earlier on in life.[15] Apart from educational level there is also information about parental cannabis use. This variable indicates whether or not cannabis use is 'family tradition'. Individuals may be more likely to start using a particular drug if the parents have experienced cannabis use.

4 Results

The parameters of the models are estimated using the method of maximum likelihood and are shown in Table 3.[16] The discussion of the parameter estimates will be done separately for each drug.

4.1 Parameter estimates

4.1.1 Tobacco

The parameter estimates for tobacco use are to a large extent similar for males and females. Education has a negative effect on the starting rate and a positive effect on the quit rate. Low educated individuals are more likely to use tobacco and stick to that. Parental cannabis use has a significant effect on the starting rate for

[15] This assumes educational level to be exogenous with respect to drug use and ignores the possibility that drug use has an effect on the educational level attained. See Macleod et al. (2004) for evidence that goes against this assumption.

[16] As in the making of Figure 1 to 5 individuals that do not use a particular drug at the time of the survey have a right-censored duration of non-use for that drug. In the same way individuals that use a particular drug at the time of the survey have a right-censored duration of use for that drug. Not presented in Table 3 are the parameter estimates for the survey date (2 dummy variables in both starting rates and quit rates), for the age dummy variables in the starting rate, and for the duration dependence variables in the quit rates. There is some influence of calendar time. For females the cannabis starting rates in 1997 and 2001 were higher than in 1994, for both males and females the ecstasy starting rates increase over time. The latter has to do with ecstasy penetrating the market in the course of the 1990s. The effect of age on the starting rates and the effect of duration dependence on the quit rate mimic the patterns illustrated in Figures 1 to 5. The parameter estimates for survey date, age and duration are available on request.

tobacco. The age of onset also has a significant effect on the quit rate. The sooner an individual start smoking the more difficult it is to quit smoking. Conditional on the observed characteristics there are three groups of individuals. About 70% of the individuals has a positive starting rate and a positive quit rate. About 10% of the individuals has a positive, but much smaller starting rate and a zero quit rate. The remaining 20% has a zero starting rate for tobacco use. There is a positive correlation between the unobserved component in the starting rate and quit rate; those that are more likely to start soon are also more likely to stop soon. A possible interpretation of the two groups with different starting rates and quit rate is that the first group consists of experimenters. Individuals in this group want to experiment with tobacco (and perhaps with other drugs) but they are not likely to stick to that.

4.1.2 Cannabis

For males with secondary education the starting rate for cannabis use is higher than for other males. Other than that educational level does not effect cannabis starting rates and quit rates. For females there is a positive effect of educational level on the cannabis starting rate and no effect on the quit rate. Parental cannabis use encourages the starting rate and decreases the quit rate. Individuals of which one or both parents have used cannabis are more likely to start using cannabis themselves and stick to that. For both males and females the age of onset of cannabis use has a positive effect on the cannabis quit rate. As with smoking, the sooner an individual starts using cannabis the more difficult it is to quit this use. Conditional on the effect of the observed characteristics two groups of individuals can be distinguished that differ in the dynamics of cannabis use. For males there is a group of 54% that has a positive starting rate and a positive quit rate. The other group of 46% consist

of individuals that has a positive but much smaller cannabis starting rate and a zero cannabis quit rate. For females, conditional on the effect of the observed characteristics also two groups can be distinguished in terms of their cannabis starting rate but they are different from the two groups for males. For females, the first group has a positive starting rate, the second group has a zero starting rate. This implies by definition that starting rate and quit rate are uncorrelated through unobserved characteristics since the group of cannabis users is homogeneous in terms of their quit rate.

4.1.3 Cocaine

The educational level of individuals has no effect on the starting rates for cocaine. Only higher educated males are more likely to quit after having started cocaine use. For the other educational categories there is no effect on cocaine quit rates. Parental cannabis use only has a significant effect on the cocaine starting rate for males. The age of onset of cocaine use has a positive effect on the quit rate.[17] For both males and females conditional on the effect of the observed characteristics two groups can be distinguished in terms of their cocaine starting rate; the first group of 20% of the males and 14% of the females has a positive starting rate, the second group has a zero starting rate. This is similar to the dynamics in cannabis use for females and implies that cocaine starting rates and cocaine quit rates are uncorrelated through unobserved characteristics.

[17] Although for females the coefficient is significant at a 10% level only.

4.1.4 Ecstasy

The educational level of individuals has a positive effect on the starting rate for ecstasy. Parental cannabis use also has a strong positive effect on this starting rate. For the ecstasy quit rate none of the coefficients differ significantly from zero, which may have to do with the fact that there are not many observations on individuals using ecstasy. As for unobserved heterogeneity there are two groups similar as for cocaine, which implies that starting rates and quit rates are not correlated. The size of the group with a positive starting rate is 55% for males and 39% for females, but as indicated through the mass point the starting rates are very small.

4.2 Sensitivity analysis

The estimation results sofar have been attained under some assumptions the effects of each of which are subject to a sensitivity analysis. As a first sensitivity analysis the distribution of unobserved heterogeneity was investigated in more detail to find out whether more than two or three mass points could be distinguished. This turned out to be not the case. Second, because the educational level of individuals may not be exogenous with respect to drug use all models were estimated after omitting the dummy variables for educational level. The main results are not sensitive for the inclusion or omission of the educational variables. Third, it was investigated how sensitive the effect of the age of onset on the quit rate is for the correlation of the unobserved components in the starting rates and quit rates. The parameter estimates are shown in Table 4. When estimating starting rates and quit rates separately possible correlation between the unobserved components in both rates is ignored. As shown, in this case the effects of the age of onset on the quit rates for

tobacco and in the case of males also for cannabis go down. For the male tobacco quit rate the coefficient no longer differs significantly from zero.[18] If the fact that some individuals with a high starting rate also have a high quit rate is ignored one underestimates the effect of the age of onset on the quit rate.

Furthermore, it was investigated to what extent the effect of the age of onset on the quit rate is nonlinear. This was done by using dummy variables for different categories of the age of onset. The parameter estimates are shown in Table 4 as well. As indicated there are clear thresholds in the effect of the age of onset on the quit rate. For males the age of onset of tobacco use is irrelevant up to the age of 25. Males that start smoking after age 25, which is by itself a rare event, are not very likely to continue for a long time. For females the age threshold in the case of smoking is 19. Females that start smoking after age 18 are will quit smoking sooner than females that start earlier on in life. Females that start after age 21 have an even higher quit rate and females that start after age 25 have a very high quit rate. For cannabis use there is a threshold of age 14 for males and age 16 for females. And both for males and females the effect on the cannabis quit rates increases with the age of onset. For cocaine the threshold for males is at age 25 while for females it is age 21. For ecstasy no threshold effects are found.

The general picture that emerges from the parameter estimates is the following. Higher educated individuals have a lower starting rate for tobacco, a higher quit rate for tobacco and a higher starting rate for cannabis. Parental cannabis use has a positive effect on the starting rates for all drugs investigated here, while it has a

[18]Note that for female cannabis use and for cocaine and ecstasy use there is no correlation between the unobserved components anyway. Nevertheless, the estimates are presented in Table 4 for reason of comparison.

negative effect on the cannabis quit rates. The age of onset has a positive effect on the quit rates for tobacco, cannabis, and cocaine. The parameter estimates show that those that are not very likely to start using a particular drug, if they start using that drug they will keep on doing so for the rest of their life. There is also a clear causal effect from the age of onset to the quit rate. If individuals start using later on in their life they are more likely to stop using.

Because of the nonlinearity of the models used it is difficult to get an idea about the magnitude of the effects of personal characteristics. To illustrate the magnitude of parental cannabis use and the effect of the age of onset on the quit rate some simulations are performed. The results are presented in Table 5, the upper part concerns starting rates, the lower part quit rates. The simulations concern individuals with secondary education for the survey year 2001.[19] The upper part of Table 5 shows the cumulative starting probabilities for individuals without and with parental cannabis use. For tobacco parental cannabis use stimulates an early start. Males without parental cannabis use have a cumulative starting probability at age 15 of 33%, which is 40% with parental cannabis use. For females these numbers at age 15 are 32% and 45%. Also for the other drugs the effect of parental cannabis use on the starting rates can be quite large. At age 15 for example without parental cannabis use there is a probability of 5% for a male reference person and of 3% for a female reference person to have started using cannabis. With parental cannabis use these numbers are 17% and 14%.

The lower part of Table 5 shows simulation results for cumulative quit probability of the various drugs 1 year and 5 years after the start.[20] As shown the effect of

[19]The survey year is not relevant for most of the drugs except for ecstasy because of the big increase in ecstasy use in the 1990s.

[20]The assumption for the tobacco users and male cannabis users is that the relevant composition

parental cannabis use is not that big. Much more important is the age of onset, especially for tobacco and cannabis use. If a male reference person with no parental cannabis use starts using cannabis at age 16, after 5 years the probability to have stopped using is 18%. If that same individual starts at age 30 the probability to have stopped after 5 years is 52%.

5 Conclusions

This paper uses information about prime age individuals living in Amsterdam to study the dynamics in the patterns of drugs use. The analysis concerns starting rates as well as quit rates. The analysis of the starting rates shows that if individuals have crossed a certain drug-specific 'threshold age' and have not started to use then they are not very likely to do so at a later age. For alcohol and tobacco the 'threshold age' is about 20, for cannabis this is 25, and for cocaine and ecstasy it is about 30. Furthermore, the empirical analysis shows that for most of the drugs investigated the age of onset is negatively correlated with the quit rate. The earlier individuals start using a particular drug the less likely they are to stop using that drug. Policies that aim at reducing the use of drugs should take the dynamics in drug use into account. Reducing the stock of drug users can come from decreasing the inflow into drug use or increasing the outflow from drug use, i.e. reducing the duration of use. The age of onset is a crucial variable. Policies that aim at reducing the starting rate will lead to higher ages of onset. This will both reduce the probability that individuals will start using drugs as well as increase the quit rates from the use of drugs.

of unobserved heterogeneity is the one that is achieved on average at age 30.

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Appendix A. The data

The data used in the analysis concern inhabitants of Amsterdam. CEDRO, the Center for Drug Research of the University of Amsterdam collected the data on drug use in 1994, 1997 and 2001 (see Abraham et al. (2003) for a detailed description). The survey population is defined as all persons in the Municipal Population Registry of Amsterdam. There are some differences between the surveys, but the information used in this paper is collected consistent through time. In 1994 two interview methods were used, a written and a computer assisted version (using laptop computers where the interviewer directly typed in the answers). The sample was randomly subdivided into two equal sized samples. It turns out that the interview method did not affect the answers to the questions. The 1997 survey was fully computer assisted. The 2001 survey was based on a mixture of methods. Respondents could choose between a paper questionnaire, a computer assisted face-to-face interview, an interview per telephone, via their own computer on the Internet or on a compute disk (floppy disk by mail). The non-response in 1994 was 49.2%, in 1997 48.1%, and in 2001 60.9%.

The focus of the paper is on prime age individuals, i.e. individuals aged 26 to 50 years. Because some studies find individuals from ethnic minority groups to underreport drug consumption individuals not born in the Netherlands or without a Dutch nationality are omitted. After removing observations with incomplete information about the personal characteristics the net sample contains 2095 prime age females and 1830 prime age males.

The information concerning the age of onset is based on the question addressed to individuals that indicated previous use of particular drug (for example cannabis): "At what age did you start using cannabis?". For individuals that did not start using a particular drug the current age is used to calculate the (right-censored) duration of non-use.

The information concerning the duration of use is based on the question addressed to individuals that indicated previous use of a particular drug but not current use: "At what age did you use cannabis for the last time?" The duration of use is calculated as the difference between the quit age and the starting age. For individuals that currently use the current age is used to calculate the (right-censored) duration of use. The explanatory variables in the analysis are the following.

- *Secondary education*: Dummy variable with a value of 1 if the individual attended secondary general or vocational education, and a value of 0 otherwise. Secondary education refers to intermediate vocational or secondary general education.

- *Higher education*: Dummy variable with a value of 1 if the individual attended higher vocational or academic education, and a value of 0 otherwise. Since there are two dummy variables for education the overall reference group consists of individuals with lower education.

- *Year 1997 (Year 2001)*: Dummy variable with a value of 1 if the individual participated in the survey of 1997 (2001) and a value of 0 otherwise.

- *Cannabis use parents*: Dummy variable with a value of 1 if one or both parents have ever used cannabis and a value 0 otherwise.

Table A1 gives information about the main characteristics of the dataset. In terms of personal characteristics there are few differences between males and females. About a quarter of the individuals has secondary education and about half of them has higher education. Of the males in the sample 8% has one or more parents that previously used cannabis; for the females this is 9%. Lifetime use of drugs is higher among the individuals in the sample than presented in Table 2 because of the age structure of the sample. Since the sample concerns ages 26 to 50 young individuals of which many individuals did not yet started to use drugs are ignored. And, individuals older than 50 years, which often did not experience drug use at all are also outside the sample. As shown lifetime use of alcohol is above 90%, lifetime use of tobacco is about 75%. The use of cannabis, cocaine, and ecstasy is lower among females than among males. The mean age of onset is similar to the ages presented in Table 2. The main exception is the mean age of onset for ecstasy use. In the sample it is higher than presented in Table 2. This is due to Table 2 presented numbers for 2001 while Table A1 presents averages for the three surveys of 1994, 1997, and 2001. Between 1994 and 2001 the use of ecstasy has increased a lot, and with the increase of use the average age of onset was lowered as well.

Table A1 Means of variables

		Males	Females
	Age	36.9	36.9
	Secondary education	0.28	0.25
	Higher education	0.48	0.48
	Cannabis parents	0.08	0.09
	Year 1997	0.30	0.32
	Year 2001	0.32	0.33
	N	1830	2095
Users (%)	Alcohol	95.8	92.9
	Tobacco	76.4	76.7
	Cannabis	56.2	47.2
	Cocaine	17.5	12.6
	Ecstasy	10.8	7.5
Age of onset [a])	Alcohol	15.7	16.5
	Tobacco	16.6	16.2
	Cannabis	19.4	19.5
	Cocaine	24.7	24.1
	Ecstasy	28.7	27.3

[a)] Averaged age over user

Table 1 Annual prevalence of drug use; international comparison

	Age	Year	Cannabis	Cocaine	Ecstasy
Australia	15-64	2001	15.0	1.5	3.4
United States	12+	2002	11.0	2.5	1.3
United Kingdom	16-59	2003	10.6	2.1	2.0
France	15-64	2002	9.8	0.3	0.3
Spain	15-64	2001	9.7	2.6	1.8
Italy	15-44	2001	6.2	1.1	0.2
Netherlands	15-64	2001	6.1	1.1	1.5
Germany	18-59	2000	6.0	0.8	0.7

Source: United Nations (2004)

Table 2 Lifetime use and annual prevalence of drug use in Amsterdam, mean age of first use; selected drugs[a)]

	1987	1990	1994	1997	2001	Mean age of onset
Lifetime use						
Alcohol	87.5	86.0	86.4	88.7	87.2	17.4
Tobacco	71.3	67.7	66.7	71.8	68.8	17.4
Cannabis	23.2	25.2	29.8	36.7	38.1	19.9
Cocaine	5.7	5.7	7.0	9.4	10.0	24.9
Ecstasy	-	1.3	3.3	7.0	8.7	25.9
Amphetamines	4.5	4.2	4.7	6.0	6.6	22.7
Heroin	-	1.1	1.4	1.8	1.3	23.7
Annual prevalence						
Alcohol	78.7	78.0	77.8	80.2	80.6	
Tobacco	49.6	46.8	45.7	46.7	42.3	
Cannabis	9.5	10.2	11.2	13.2	13.1	
Cocaine	1.6	1.3	1.9	2.6	2.8	
Ecstasy	-	0.7	1.6	3.2	3.6	
Amphetamines	0.6	0.5	0.5	0.9	1.1	
Heroin	0.3	0.1	0.2	0.4	0.7	

[a)] Population of 12 years and older; mean age of first use in 2001 (for heroin in 1997)

Source: Abraham et al. (2003)

Table 3 Starting rates and quit rates; parameter estimates[a)]

	Tobacco		Cannabis	
	Males	Females	Males	Females
a. Starting rates				
Secondary education	-0.05 (0.4)	-0.48 (3.8)*	0.40 (2.4)*	0.94 (8.0)*
Higher education	-0.53 (4.5)*	-0.73 (6.4)*	0.04 (0.2)	1.19 (11.4)*
Cannabis parents	0.31 (2.1)*	0.54 (2.3)*	1.30 (8.2)*	1.68 (14.7)*
Mass point (1)	-1.54 (12.1)*	-1.79 (14.3)*	-4.11 (21.0)*	-5.92 (34.5)*
Mass point (2)	-3.45 (7.7)*	-4.00 (7.7)*	-8.43 (29.7)*	-
Mass point (3)	$-\infty$	$-\infty$	-	$-\infty$
b. Quit rates				
Secondary education	0.29 (2.0)*	0.19 (1.4)	-0.00 (0.0)	0.04 (0.3)
Higher education	0.31 (2.4)*	0.37 (3.1)*	0.14 (1.2)	0.13 (1.2)
Cannabis parents	-0.38 (1.7)	-0.08 (0.5)	-0.32 (2.5)*	-0.34 (3.5)*
Age of onset (/10)	0.77 (3.3)*	0.97 (6.8)*	0.86 (10.5)*	0.42 (5.8)*
Mass point (1)	-4.60 (11.4)*	-4.91 (16.8)*	-3.85 (16.4)*	-2.49 (12.0)*
Mass point (2)	$-\infty$	$-\infty$	$-\infty$	$-\infty$
Heterogeneity				
α_1	1.19 (9.1)*	1.28 (7.3)*	0.15 (2.8)*	2.13 (7.1)*
α_2	-0.62 (1.7)	-0.56 (1.4)	-	-
Implied probabilities (%)				
p_1	68	70	54	89
p_2	11	11	46	0
p_3	21	19	0	11
-Loglikelihood	6205.2	7165.9	6260.1	6418.4

	Cocaine		Ecstasy	
	Males	Females	Males	Females
a. Starting rates				
Secondary education	0.11 (0.4)	-0.06 (0.2)	0.41 (1.8)	1.30 (4.2)*
Higher education	-0.42 (1.6)	-0.17 (0.7)	0.19 (0.9)	1.06 (3.6)*
Cannabis parents	0.70 (2.9)*	0.19 (1.0)	2.25 (10.3)*	1.82 (6.6)*
Mass point (1)	-3.66 (9.5)*	-3.20 (13.2)*	-7.26 (23.0)*	-7.96 (18.9)*
Mass point (2)	-	-	-	-
Mass point (3)	$-\infty$	$-\infty$	$-\infty$	$-\infty$
b. Quit rates				
Secondary education	0.18 (1.0)	-0.08 (0.4)	-0.10 (0.4)	-0.11 (0.4)
Higher education	0.39 (2.1)*	0.12 (0.7)	0.18 (0.8)	0.08 (0.3)
Cannabis parents	-0.07 (0.5)	-0.14 (1.0)	-0.10 (0.4)	-0.15 (0.7)
Age of onset (/10)	0.35 (3.3)*	0.21 (1.8)	0.09 (0.7)	0.10 (0.6)
Mass point (1)	-2.16 (6.5)*	-1.72 (4.7)*	-1.43 (2.9)*	-1.09 (2.1)*
Mass point (2)	-	-	-	-
Heterogeneity				
α_1	-1.31 (11.7)*	-1.84 (24.5)*	0.21 (0.6)	-0.47 (1.2)
α_2	-	-	-	-
Implied probabilities (%)				
p_1	20	14	55	39
p_2	0	0	0	0
p_3	80	86	45	61
-Loglikelihood	2492.6	2145.9	1469.0	1217.1

[a)] Sample age 26 to 50 years; 1830 males and 2095 females; all starting rate estimates include dummy variables for survey years (2) and age dependence (18 for tobacco, 16 for cannabis, and 9 for cocaine and ecstasy); all quit rate estimates include dummy variables for survey years (2) and duration dependence (3 for tobacco, cannabis, and cocaine, 1 for ecstasy); absolute t-values in parentheses; a * indicates significance at a 95%-level.

Table 4 Sensitivity quit rates; parameter estimates age of onset[a)]

	Tobacco		Cannabis	
	Males	Females	Males	Females
(a.) Independent rates				
Age of onset(/10)	0.18 (1.1)	0.31 (2.2)*	0.54 (6.5)*	0.42 (5.8)*
-Loglikelihood	6232.2	7206.8	6280.4	6418.4
LR-test independence	54.0*	81.8*	40.6*	0.0
(b.) Flexible specification				
Age 15-16	-0.08 (0.6)	0.16 (1.4)	0.51 (2.6)*	0.22 (1.3)
Age 17-18	0.21 (1.4)	0.09 (0.7)	0.73 (3.8)*	0.52 (3.2)*
Age 19-21	0.23 (1.0)	0.60 (3.3)*	0.80 (4.1)*	0.57 (3.5)*
Age 22-25	0.39 (0.9)	1.35 (3.7)*	1.08 (5.2)*	0.83 (4.7)*
Age 25+	2.41 (10.9)*	2.53 (12.5)*	1.84 (8.1)*	0.73 (3.6)*
-Loglikelihood	6201.0	7157.1	6258.7	6413.2
-Logl. linear specification [b)]	6205.2	7165.9	6260.1	6418.4

	Cocaine		Ecstasy	
	Males	Females	Males	Females
(a.) Independent rates				
Age of onset(/10)	0.35 (3.3)*	0.21 (1.8)	0.09 (0.7)	0.10 (0.6)
-Loglikelihood	2492.6	2145.9	1469.0	1217.1
LR-test independence	0.0	0.0	0.0	0.0
(b.) Flexible specification				
Age 22-25	0.05 (0.4)	0.36 (2.4)*	0.34 (1.1)	0.24 (0.9)
Age 25+	0.33 (2.3)*	0.17 (1.1)	0.54 (1.8)	0.08 (0.3)
-Loglikelihood	2494.1	2145.1	1467.7	1216.9
-Logl. linear specification [b)]	2492.6	2145.9	1469.0	1217.1

[a)] The set-up of the analysis is similar to Table 3; absolute t-values in parentheses; a * indicates significance at a 95%-level.

[b)] See Table 3.

Table 5 Results simulations (%)[a)]

a. Cumulative starting probabilities - no parental cannabis use

	Males				Females			
Age	Tobacco	Cannabis	Cocaine	Ecstasy	Tobacco	Cannabis	Cocaine	Ecstasy
15	33	5	2	1	32	3	2	0
20	67	39	5	1	67	27	4	1
25	71	51	10	3	70	41	8	2
30	71	54	16	7	70	46	11	6

b. Cumulative starting probabilities - parental cannabis use

	Males				Females			
Age	Tobacco	Cannabis	Cocaine	Ecstasy	Tobacco	Cannabis	Cocaine	Ecstasy
15	40	17	5	5	45	14	2	3
20	70	54	9	10	70	76	5	6
25	72	55	15	24	72	86	8	12
30	72	55	20	40	72	88	12	23

c. Cumulative quit probabilities - no parental cannabis use (1 year - 5 years)

	Males				Females			
Age	Tobacco	Cannabis	Cocaine	Ecstasy	Tobacco	Cannabis	Cocaine	Ecstasy
13	4-8	6-15			4-8	12-27		
16	4-8	10-24			5-10	15-33		
20	5-10	13-31	18-34	12-28	8-15	20-43	23-43	25-53
25	6-12	17-39	19-36	17-37	16-29	25-52	32-56	31-61
30	39-61	33-65	24-44	20-44	42-67	23-49	27-49	27-56

d. Cumulative quit probabilities - parental cannabis use (1 year - 5 years)

	Males				Females			
Age	Tobacco	Cannabis	Cocaine	Ecstasy	Tobacco	Cannabis	Cocaine	Ecstasy
13	3-6	4-11			4-7	9-21		
16	3-5	7-18			4-9	11-25		
20	4-7	10-23	16-31	11-27	7-13	16-34	21-40	18-40
25	4-8	13-30	17-33	16-35	14-26	20-42	29-52	23-47
30	28-46	25-52	22-40	19-41	38-61	18-39	25-46	20-43

[a)] Other characteristics: Survey 2001, secondary education

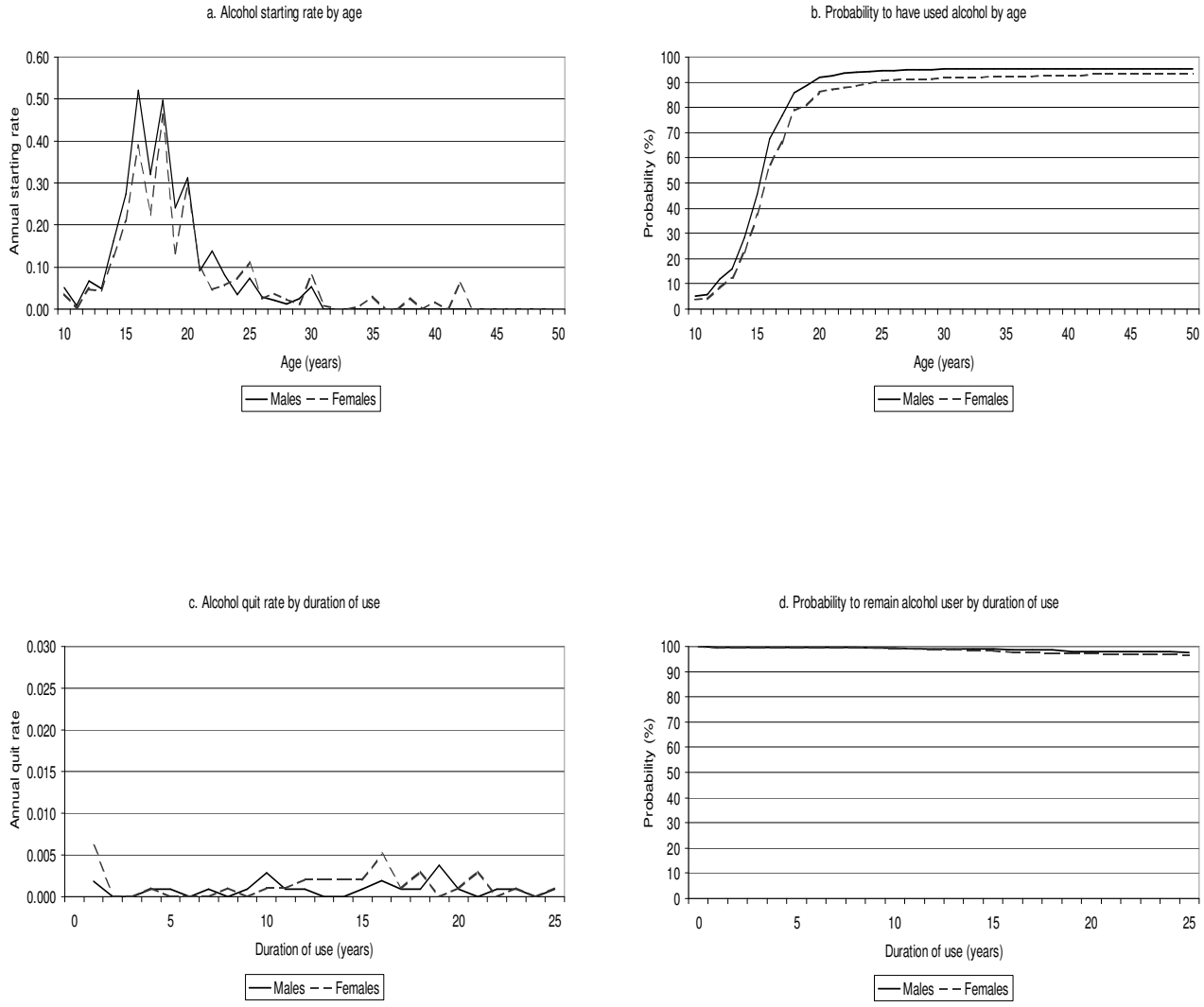

Figure 1: Dynamics in alcohol use

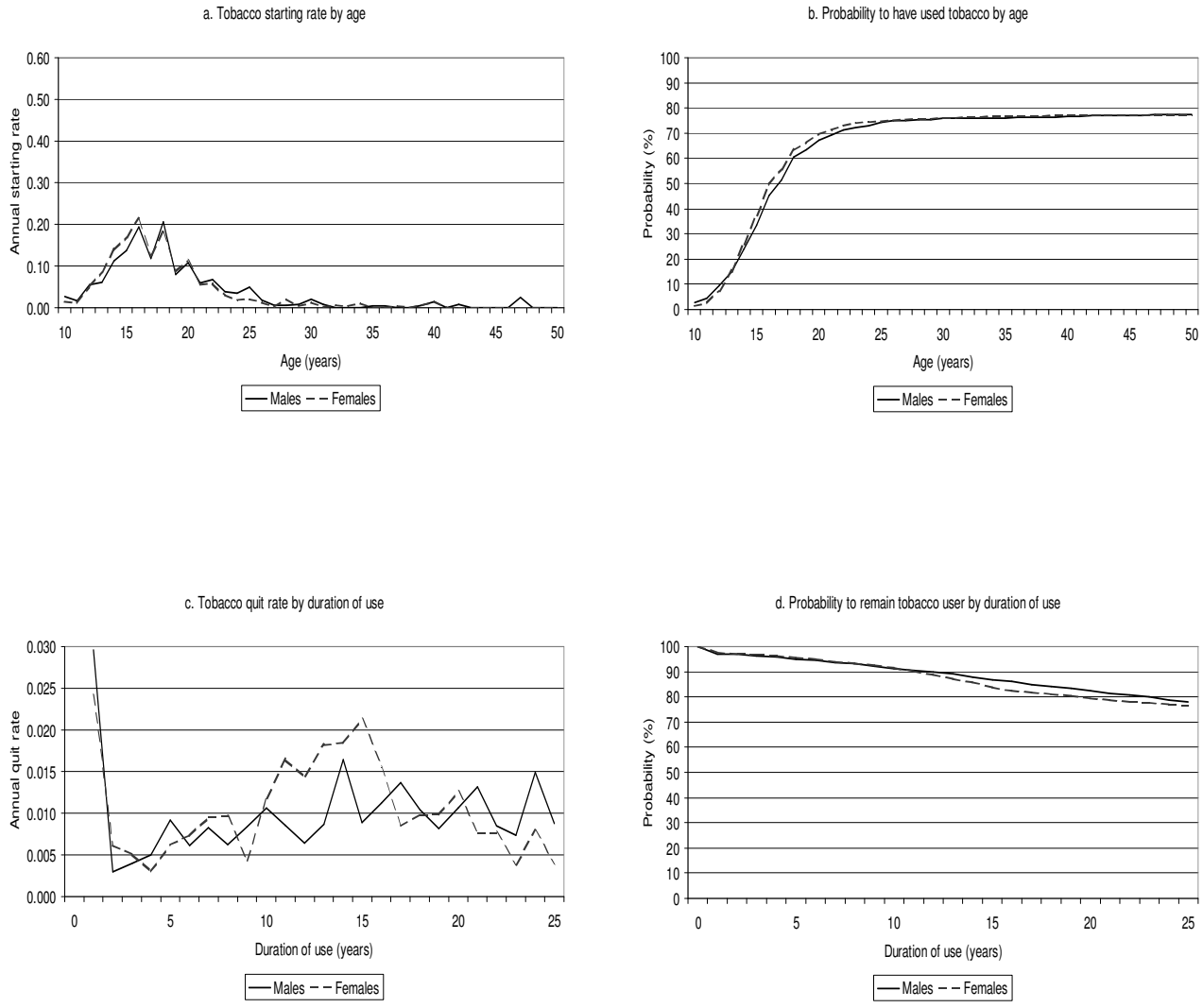

Figure 2: Dynamics in tobacco use

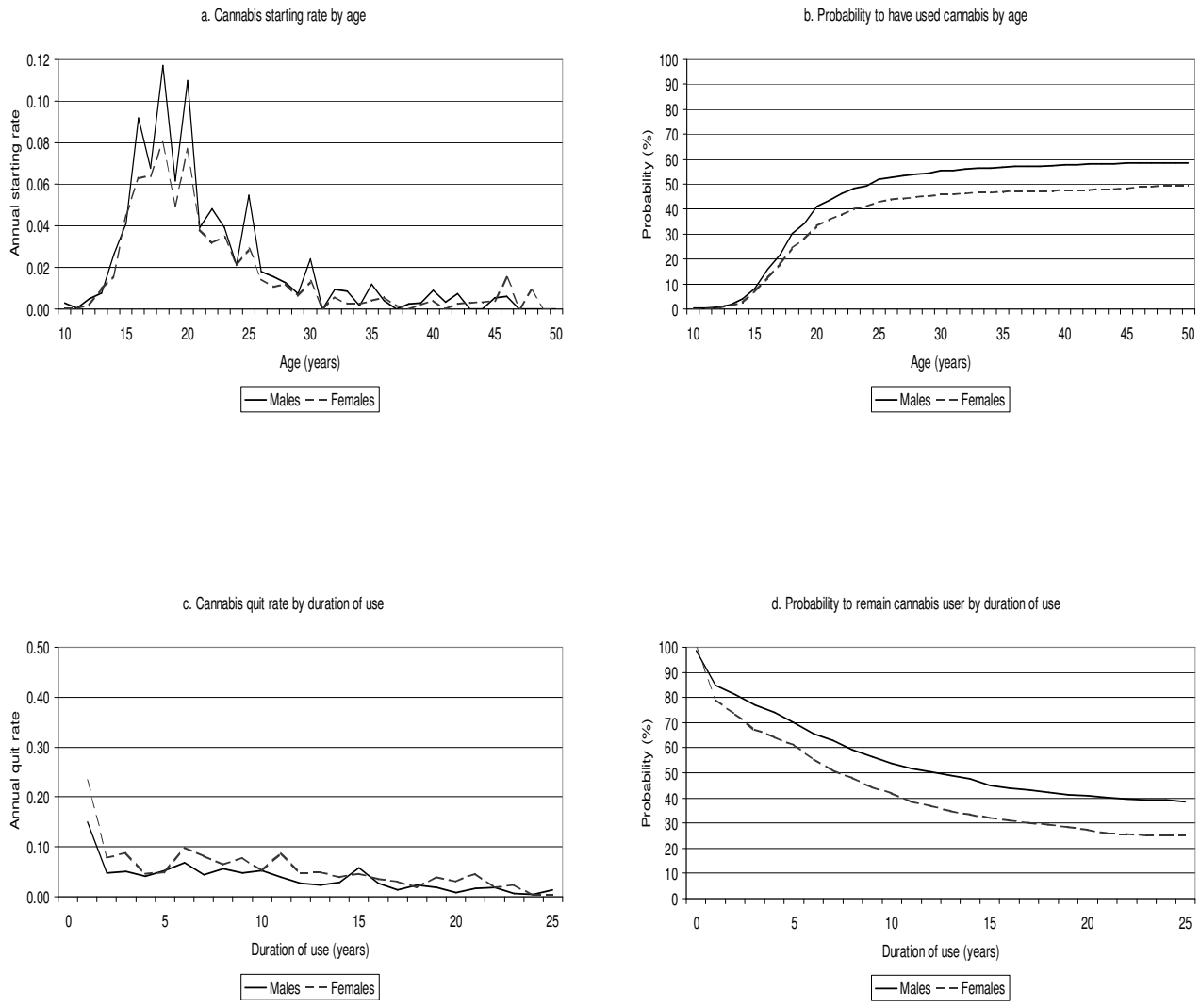

Figure 3: Dynamics in cannabis use

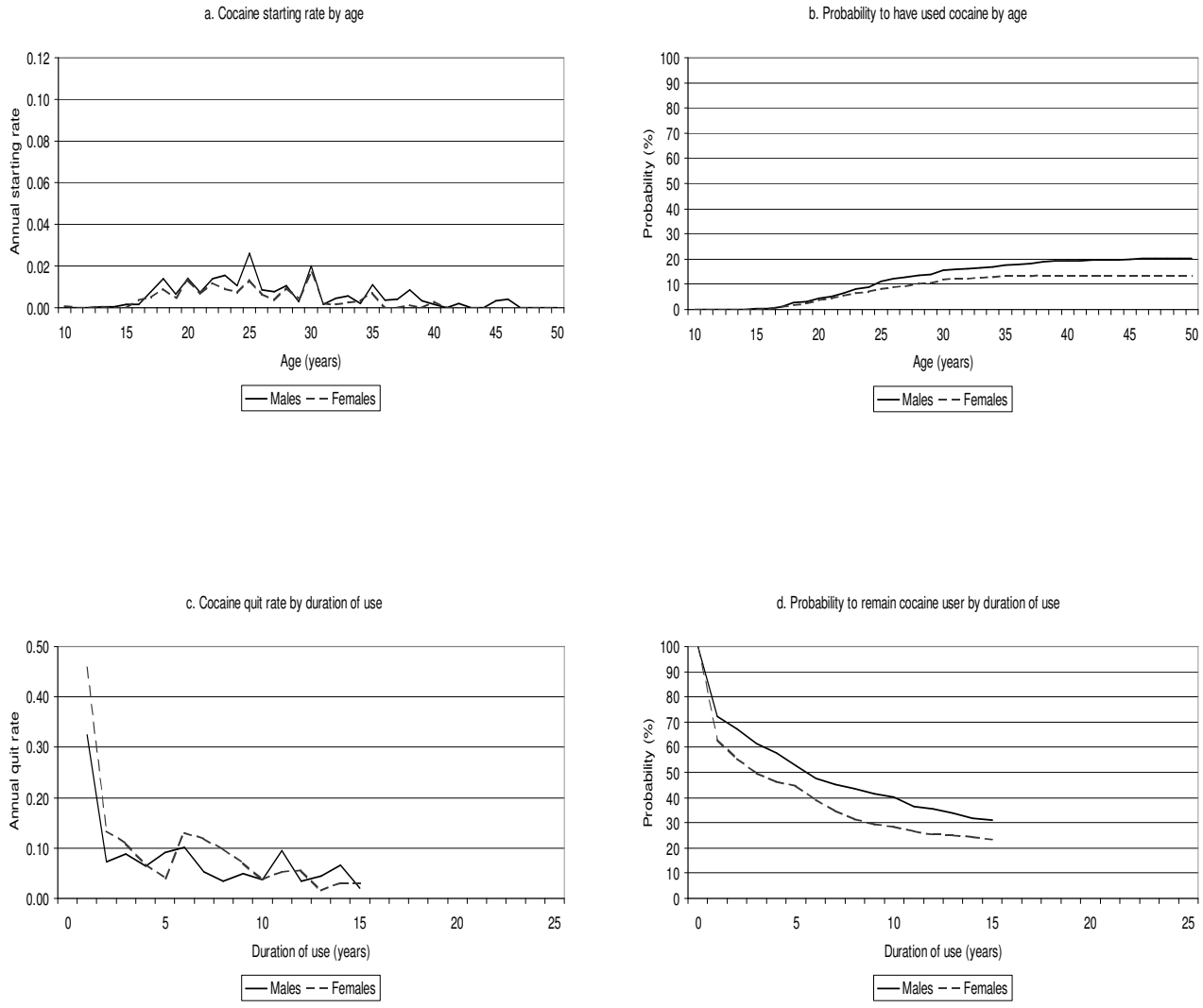

Figure 4: Dynamics in cocaine use

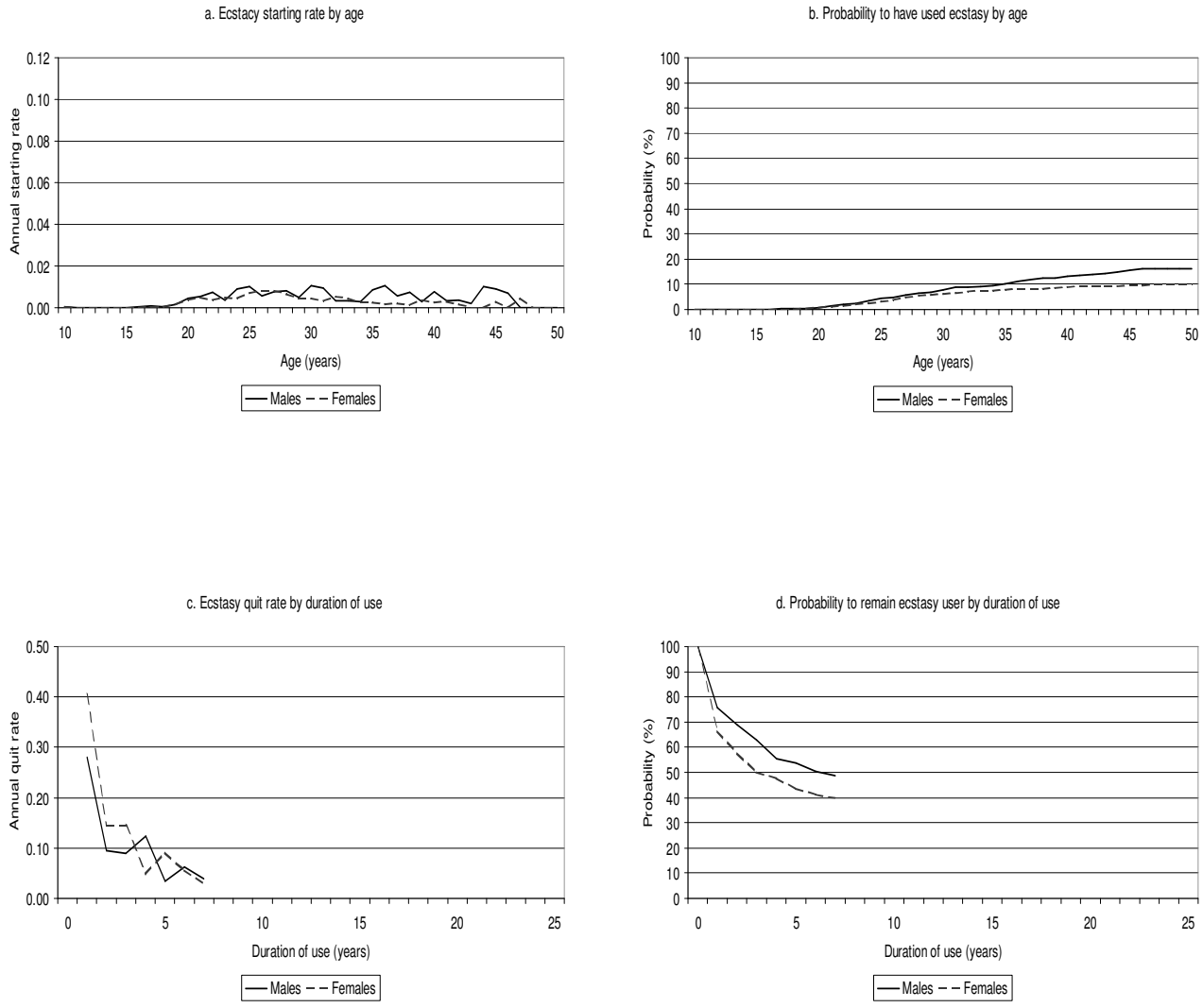

Figure 5: Dynamics in ecstasy use