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Why parents worry: Initiation into cannabis use by youth and their educational attainment

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ABSTRACT

In this paper we use individual level data from the Australian National Drug Strategy Household Survey to study the relationship between initiation into cannabis use and educational attainment. Using bivariate duration analysis we find that those initiating into cannabis use are much more likely to dropout of school, and that the reduction in years of education depends on the age at which initiation into cannabis occurs. We also find that the impact of cannabis uptake is larger for females than males.

1. Introduction

One of parents' greatest fears is that their child will become involved with drugs. Underlying this fear is the belief that drug use could lead to poor educational attainment, subsequent failure in the labor market, and without a good job to anchor their lives, an unhappy future. Viewed within a human capital framework, this scenario may find resonance. For example, drug use could lead teenagers to substitute time spent under the influence of drugs for time spent studying, resulting in poor academic achievement and an early exit from education. This is particularly a concern with cannabis because initiation into its use typically occurs during the teenage years, coinciding with the timing of critical decisions about investment in formal education, both at the extensive and intensive margins. There is, therefore, potential for youthful cannabis use to have a long lasting affect through its impact on the individual's stock of human capital. This paper investigates the extent to which this is the case by examining how the age of initiation into cannabis use effects subsequent educational attainment.

There is substantial evidence that early cannabis use is associated with lower levels of education (Macleod et al., 2004). What is less well understood is the extent to which this association reflects the causal impact of cannabis use on education outcomes. Associations will not reflect causal effects if, for example, those who self-select into cannabis use differ from those who do not use cannabis in ways that also impact on their academic achievement (selection on unobservables). For

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example, cannabis users may be more risk loving or discount the future more heavily than non-users and these attributes could also lead them to leave school early. A further issue in identifying the causal impact of cannabis uptake is that poor educational attainment may be both a cause and a consequence of youthful initiation into cannabis (reverse causality). For example, individuals who have low academic ability may leave school early. With less supervision from adults and more free time than those in school, early school leavers may have greater opportunity to start cannabis use. The presence of either selection on unobservables or reverse causality will render cannabis use endogenous to decisions regarding education. If unaccounted for, this endogeneity will lead to inconsistent estimates of the effect of cannabis use on education. Given the obvious objections to using an experimental approach, economics is particularly well placed to address these issues and hence obtain reliable estimates of the impact of youthful drug use on educational attainment.

Despite this, there are only a handful of relevant studies in the economics literature. These studies, reviewed in the following section, find that drug use during high school reduces the number of years of education completed by between 0.2 and 1 year. None of the previous studies, however, investigate the role of the age at which initiation occurs, nor do they consider whether the effect of cannabis use differs across gender. Thus, there is no evidence on whether initiation into cannabis use at age 14 is more or less damaging in terms of educational outcomes than initiation at age 17, or whether the negative effect is the same for males and females. The aim of this paper is to provide answers to these questions. Knowledge about the relative impact of uptake at different ages and across gender is useful from a policy perspective because it can help in targeting strategies that aim to minimize the harm associated with cannabis use.

In this paper, we adopt a bivariate duration model to investigate the impact of the age at which initiation into cannabis use occurs on the probability of leaving formal education.[1] We find that the age at which initiation occurs matters in terms of educational attainment and that its effect differs across gender. More specifically, we find that uptake of cannabis before the age of 18 for males, and before the age of 20 for females, leads to a reduction in their expected years of completed education and that this reduction is greater for those who initiate earlier. Moreover the magnitude of the effect is larger for females than males.[2] While our data are not rich enough to allow an investigation into why initiation into cannabis use during adolescence has a negative effect on educational attainment, previous studies may provide some insights. Early initiation into cannabis use has been shown to lead to higher levels and longer duration of use by Pudney (2004) and Van Ours and Williams (2007a), respectively. Further, Pacula et al. (2005) reports that it is frequent persistent use that leads to lower educational attainment. Therefore, it may be that starting cannabis use at younger ages leads to heavy persistent use, and it is this mode of use that has a deleterious effect on education.

The rest of this paper is laid out as follows. Section 2 reviews economic studies that investigate the impact of early cannabis use on educational attainment. Section 3 describes the data used in this paper. Section 4 contains the econometric set-up and results for the empirical analysis. Section 5 concludes with a discussion of our findings.

2. Literature review

The focus of this review is on studies from the economics literature, and particularly those which empirically address the potential endogeneity of cannabis use in decisions about formal education. For a wider review of research on the relationship between drug use and education, see Chatterji (2006) or Pacula et al. (2005).

The economics literature on the relationship between youthful cannabis use and education is limited and relies solely on data from the US. The first two published studies focus on the association between drug use and completing highschool. Yamada et al. (1996) report that heavy cannabis use in 12th grade is associated with a reduced probability of graduating, while and Bray et al. (2000) find that initiation into cannabis use prior to age 16–18 is associated with an increased probability of dropping out of highschool at these ages.

An issue not addressed in these early studies is whether the empirical relationship between drug use and educational attainment is causal.[3] Three studies have attempted to address this issue. First, Register et al. (2001) use data on males from the National Longitudinal Study of Youth to examine the impact of drug use by the age of 18 on the number of years of education completed. Using a two-step estimator to account for the potential endogeneity of drug use, they find that on average, male adolescent drug use is associated with a reduction of around 1 year in educational attainment, where this result is driven by the whites in the sample. Unfortunately, the authors report none of the usual specification tests associated with instrumental variable estimation, making it difficult to evaluate the reliability of their estimates.

Chatterji (2006) exploits the unusually rich National Education Longitudinal Study to examine the impact of past month cannabis use in 10th and 12th grade on subsequent years of education completed. In addition to employing an IV approach, Chatterji also attempts to mitigate the potential omitted variable bias associated with OLS estimation by controlling for

[1] In the Discussion Paper version of our paper (Van Ours and Williams, 2007b) we also use an instrumental variable estimation which leads to similar conclusions.

[2] Similar gender differences have been reported in the literature on the effect of alcohol use on educational attainment (Koch and McGeary, 2005). These findings are supported by medical evidence which suggests that women are more sensitive to alcohol related brain/cognitive damage than men (Nixon, 1994; Hommer et al., 2001). Given the similarities in compensating brain activity found in functional magnetic resonance imaging studies of heavy cannabis and alcohol users (Kananyama et al., 2004; Plefferbaum et al., 2001), we speculate that our results indicate a similar differential effect of cannabis on the cognitive abilities of males and females.

[3] Bray et al. (2000) discuss (but do not present results from) efforts to address the potential endogeneity of initiation into drug use.

(typically unobserved) preexisting individual factors that may confound the relationship between drug use in highschool and educational attainment. The results from doing so suggest that past month use of cannabis in the 10th or 12th grade reduces educational attainment by 0.2 years.

The relationship between the intensity and persistence of cannabis use and educational attainment is studied by Pacula et al. (2005). This study uses the RAND Adolescent Panel Survey, which follows individuals who were enrolled in thirty middle schools in California and Oregon from 7th grade through to age of 23. Using an IV approach, the authors find no evidence that participation in cannabis use in the 7th or 12th grade impacts on educational attainment, as measured by highest level of education completed, or by graduation from highschool. Frequency of cannabis use in the 12th grade, and persistent use (defined as using at least 3 times in the month prior to survey in the 10th and 12th grades) is, however, found to reduce educational attainment. For example, persistent use is estimated to reduce educational attainment by 0.7 years.

These studies are unanimous in finding that cannabis use in high school reduces educational attainment. This raises the question of whether use is more harmful in terms of education outcomes at some ages compared to others and whether the magnitude of the effect differs across gender. Providing answers to these questions is the motivation for what follows.[4]

3. Data

3.1. Australian National Drug Strategy Household Survey

This research draws on information collected in the 2001 Australian National Drug Strategy Household Survey (NDSHS). The NDSHS is managed by the Australian Institute of Health and Welfare on behalf of the Commonwealth Department of Health and Ageing. It is designed to provide data on awareness, attitudes and behavior relating to licit and illicit drug use by the non-institutionalized civilian population aged 14 years and older in Australia. A multistage stratified design was used to generate the sample, where stratification was based on geographic region (for details see Australian Institute of Health and Welfare, 2002). In each sampled household, the respondent was the person with the next birthday who was at least 14 years of age. Personal interviews, self-completion questionnaires and computer assisted telephone interviewing methodologies were used to survey respondents, with the bulk of data (85%) collected by self-completion questionnaires. A number of strategies were used to minimize non-response, including sending a letter from the Minister for Health and Ageing assuring contacted households of the Survey's legitimacy and confidentiality, the use of reply paid envelopes (for the self-completion questionnaires) and multiple call-backs, and in the case of surveys administered using personal interviews, a sealed section of the questionnaire which allowed respondents to indicate their drug usage without the interviewer being aware of their answers. The total number of response to the survey is 26,744.

In addition to asking individuals whether they have ever used or currently use various licit and illicit drugs, the NDSHS also asks those who report having ever used each substance the age at which it was first used. This, along with information on the respondents' highest level of schooling and any post-school qualifications make these data useful for examining the impact of the age of initiation into cannabis use on education outcomes.

3.2. Outcomes of interest and sample characteristics

In the analysis that follows, the outcomes of interest are the age of initiation into cannabis use and age at which the respondent left school. Information on age of initiation into cannabis use comes from responses to the question, "About what age were you when you first used marijuana (cannabis)?", which was asked of all those who reported ever using cannabis. We construct the age at which an individual left formal education using information on schooling and post-school qualifications along with historic information on the structure of the education system in each state.[5] For example, if the highest qualification a person achieved is completing high school, they are attributed a school leaving age which is equal to the school starting age (five) plus the number of years of education required to complete high school in their state of residence. If the highest qualification is an undergraduate degree, we add a further 4 years to their school leaving age.[6] A masters degree is assumed to take an additional 2 years after the undergraduate degree, and a PhD a further 3 years (which is the length of government scholarships).

As we wish to ascertain the impact of the age of initiation into cannabis use on the decision to leave formal education, we focus on those who can reasonably be considered to have completed their education. For this reason we limit our sample

[4] Issues of a more methodological nature also arise from the literature. Specifically, as all of the studies that account for the endogeneity of youthful cannabis use rely on the same methodology, instrumental variable estimation, they are all subject to the same frailties. This raises the question of whether their results are robust to alternative identifying assumptions and estimation strategies. We are able to gain insights into this issue through the use of an alternative estimation strategy that relies on a different set of identifying assumptions.

[5] Post-school qualifications gained at institutions other than universities are generally vocational in nature and for this reason are not included in the age left school variable, which reflects formal education only. Differing education systems across states mean that students in Queensland are 17 when they graduate from high school whereas their New South Wales counterparts are 18. The information on the school systems was generously provided by Dr. Chris Ryan from the Australian National University.

[6] A (typical) undergraduate degree takes three years to complete in Australia. We allow four years for completion to account for the longer duration for combined degrees, honors degrees, and to account for the fact that the progression rate from one year to the next is less than 1.

Table 1
Sample means

Variable	Males	Females
Age	38.0	37.0
Age of initiation (conditional on starting)	18.6	19.0
Age left school	17.9	17.9
Ever used Cannabis (%)	54.9	47.0
Graduated from high school (%)	54.8	54.8
Graduated from university (%)	25.5	25.4
Born in Australia (%)	76.9	78.9
Lives in a rural location (%)	25.3	26.8
Number of observations	4912	6881

Note: the age range is 25–50; the age of initiation ranges from 10 to 47 for males and from 10 to 48 for females; the age left school ranges from 13 to 24 for both males and females.

to individuals aged 25–50 years who report that their primary activity is not study. We have observations on 4912 males and 6881 females for whom we have complete data on education, cannabis use, and the other control variables for this age group. Summary statistics for the outcomes of interest and other explanatory variables are reported in Table 1. They show that 55% of males and 47% of females in the sample have used cannabis in their lifetime, and that amongst those who have ever used cannabis, the average age of initiation is 19 years for both males and females. There is little difference across gender in terms of educational attainment. On average, sample members leave school at 18 years of age, with 55% having completed high school (as their minimum level of education), and 25% having an undergraduate or postgraduate degree. In terms of demographic characteristics, the average age of the male and female sub-samples is 38 and 37 years, respectively, 77% of the male sample and 79% of the female sample are Australian born, and 25% of males and 27% of females live in rural locations.

As with previous research on transitions in substance use that utilize retrospectively reported data, this study is subject to potential measurement error problems. The most significant of these is the potential for recall error. Kenkel et al. (2003, 2004) use panel data to explore this issue in the context of participation in cigarette smoking. They find relatively little disagreement in measures of ever smoking and annual smoking status in data collected over the periods 1984–1998, with reporting inconsistencies most likely for respondents who were light smokers in 1984.[7] Nonetheless, even this modest degree of reporting error is shown to produce downward biased estimates of the effect of price in participation in smoking equations (Kenkel et al., 2004). As discussed below, we find some evidence of recall error in the reported age of initiation into cannabis use. This is not surprising as we are dealing with respondents aged 25–50 years, and initiation into cannabis use typically occurs in the mid to late teens. To the extent that respondent's make errors in the age they report first using cannabis, our parameter estimates are likely to be biased towards zero.

The education outcome 'age left education' may also suffer from measurement error. To the extent that individuals repeat grades at school or take longer than the standard time to complete university study, we will tend to under-state the age at which they complete formal education. Also, as is typically the case in studies that use cross-section data to study transitions, the NDSHS does not contain family background or other retrospective information. Consequently, we are unable to control for these factors in modeling the decisions to start cannabis use and leave school. However, the econometric techniques we use attempt to account for omitted variables by allowing the errors in the education and cannabis uptake equations to be correlated. To the extent that these omitted variables are time invariant, allowing for a correlation in the unobservables should ensure consistent estimates of the causal impact of age of initiation into cannabis use on educational attainment.

3.3. Descriptive statistics

Fig. 1 gives a graphical description of the relationship between age and initiation into cannabis use. It graphs the probability of starting cannabis use at each age, conditional on not having been a user up to that age. The figure shows that initiation into cannabis use begins for the sample at age 10, with 0.1% of males and females reporting first use at that age. The first peak in the probability of uptake is at age 16, when 9.2% of males and 6.1% of females who had not previously used cannabis initiate use. The mean peak is at age 18, with 12.3% of males and 9.0% of females initiating use, but there is also a peak of 8.5% for males and 5.6% for females at age 20. Subsequent peaks are at age 25, 30, 35, and 40; these peaks in the age-specific starting probabilities point to bundling in the recollection of the starting age. Fig. 1 also shows clearly that initiation into cannabis use rarely occurs beyond age 25. At age 15, 9.4% of males and 8.2% of females in our sample have started cannabis use. This increases to 43.4% of males and 34.9% of females at age 20 and 50.2% of males and 42.2% of females at age 25. By the age of 50, 54.9% of males and 47.0% of females have used cannabis at some point in their life.

Fig. 2 provides similar information on the relationship between age and the decision to leave formal education. As shown, the graphs for males and females are virtually the same; individuals start leaving the formal education sector at age 13, although the probability of doing so at that age is very small. There is a clear peak in the probability of leaving education at

[7] Kenkel et al. (2003) also find some disagreement in the age of smoking onset as reported in subsequent surveys over a time span of 6 years, with most differences in the range of 1–2 years.

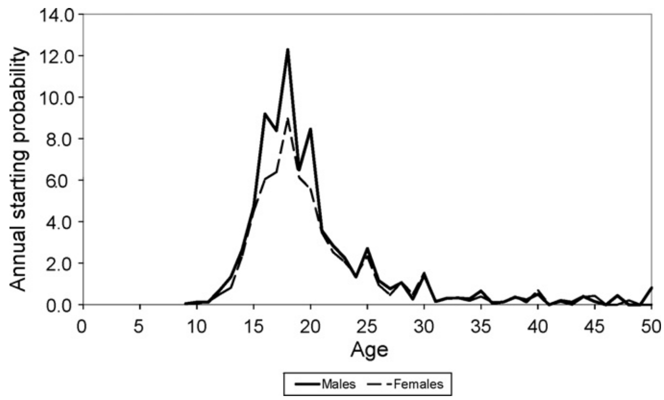

Fig. 1. Annual starting rate cannabis use (%).

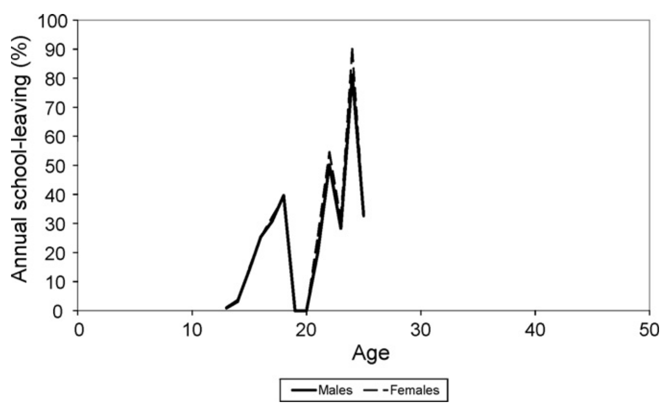

Fig. 2. Annual school leaving rate (%).

Table 2
Joint frequency distribution of initiation into cannabis use and educational attainment; males and females (%)

	Never use	Age ≤ 15	16 ≤ Age ≤ 17	Age ≥ 18	Total
(a) Males					
<High school	20.1	5.4	7.2	12.5	45.2
High school	13.8	2.4	4.4	8.6	29.2
Undergraduate	7.4	1.0	2.4	4.6	15.4
Postgraduate	5.2	0.6	1.1	3.2	10.1
Total	46.4	9.4	15.2	29.0	100.0
(b) Females					
<High school	25.8	4.6	5.1	9.6	45.2
High school	15.4	2.1	3.5	8.4	29.4
Undergraduate	8.6	1.1	1.7	5.4	16.9
Postgraduate	4.4	0.4	0.7	3.0	8.6
Total	54.3	8.2	11.1	26.4	100.0

age 18, which is the age for completing high school in most Australian states. At ages 19 and 20 none of the individuals in our sample are observed to leave education, but there are further peaks at age 22 and 24. This pattern reflects the fact that the NDSHS measures the highest educational qualification attained and not the age the respondent left school *per se*.

The joint distributions of initiation into cannabis use and educational attainment for males and females are reported in Table 2. The null hypothesis that educational attainment and age of initiation into cannabis are independent is strongly rejected by the Pearson χ^2-test, with a p-value of 0.000 for each gender.[8] As shown, the marginal distribution for educational attainment is very similar for males and females but the marginal distribution of age of initiation into cannabis use is different.

[8] The test statistic has a value of 45.04 for males and 106.75 for females compared to the critical value of 16.92 for a χ^2_9 at the 5% level of significance.

Overall, 45% of males and females leave formal education before completing high school and 29% have a level of educational attainment equal to high school graduate. Males have a slightly lower probability of completing an undergraduate degree (15%) compared to females (17%), and a slightly higher probability of having a postgraduate degree (10%) compared to females (9%). In terms of initiation into cannabis, females are more likely to never use than males (54% compared to 46%), and less likely to initiate use before the age of 16 (8% compared to 9%), at age 16 or 17 (11% compared to 15%), or at 18 years of age or older (26% compared to 29%).

The information in Table 2 can also be used to learn about the distribution of educational attainment conditional on age of initiation. For males, 43% (20.1/46.4) of non-users have less than a high school education compared to 47% ((5.4 + 7.2 + 12.5)/(9.4 + 15.2 + 29)) of those who have used cannabis at some point in their life. Closer inspection reveals that the probability of having less that a high school education amongst cannabis users is higher for those who initiate earlier. For example, 57% of males who initiate by the age of 15 fail to complete high school compared with 48% of males who initiate between the ages of 16 and 17. This general pattern is common across all categories of educational attainment and across gender, providing some evidence that the effects of initiating into cannabis use differs by the age of initiation for both genders.

Table 2 also indicates that there are differences across gender in the distribution of educational attainment conditional on using cannabis. For example, 43% of male non-users have less than a high school education compared to 48% of female non-users, while amongst those who have used cannabis at some point in their life, 47% of males have less than a high school education compared to 44% of females. Due to the differences in decisions about starting cannabis use and leaving formal education across gender, the following analysis will be conducted separately for males and females.

4. The bivariate duration model

4.1. Econometric set-up

Previous research by Chatterji (2006), Pacula et al. (2005) and Register et al. (2001) find that early cannabis use reduces educational attainment. This raises the question of whether the adverse consequences of uptake at age 12 are the same as at age 16, and whether this effect persists at older ages. These questions relate to the issue of the timing of events, which is naturally handled within a duration model framework. Therefore, in this section, we model transitions into cannabis use and out of formal education using a bivariate mixed proportional hazard model in which the unobservable components of these transitions are potentially correlated. A major advantage of using the bivariate duration approach is that identification of the treatment effect does not rely on a conditional independence assumption and it is not necessary to have a valid instrument. Rather, identification comes from the timing of events, i.e. the order in which initiation into cannabis use and leaving formal education occurs. Given that economic theory does not suggest a natural instrument, this is a particularly useful feature of this approach. This 'timing-of-events' method has been used in several previous studies that examine the impact of policy interventions on unemployment durations. Van den Berg et al. (2004) and Abbring et al. (2005) for example use a bivariate duration model to study the causal effect of one event (a benefit sanction) on the other event (leaving unemployment). This is very similar to our paper which also studies the causal effect of one event (starting to use cannabis) on another event (leaving school).[9]

Beginning with initiation into cannabis use, we assume that the rate at which individuals start using cannabis is a function of the elapsed duration of time they are exposed to potential use, their observed characteristics, and their unobserved characteristics. Individuals are assumed to be at risk of initiating into cannabis from the age of 12, so the elapsed duration of time since exposure to potential use is age minus 12.[10] The hazard of starting cannabis use at time t conditional on observed characteristics x and unobserved characteristics v is specified as

$$\theta_c(t|x, v) = \lambda_c(t)\ \exp(x'\beta_c + v) \tag{1}$$

where $\lambda_c(t)$ represents individual duration dependence. The observed characteristics are an indicator for Australian born, an indicator for rural residence, a set of dummy variables representing birth cohorts and a set of indicators for state of residence at the time of survey; the unobserved heterogeneity, v, reflects differences in the susceptibility to uptake of cannabis. Duration dependence is modeled using a flexible step function:

$$\lambda_c(t) = \exp(\Sigma_k \lambda_{ck} I_k(t)) \tag{2}$$

where k (=1, . . ., 15) indexes age intervals and $I_k(t)$ are time-varying dummy variables that are one in subsequent age intervals. Of the 15 age intervals, 14 are 1 year in length (age 12, 13, 14, . . ., 25) and the last interval is open: 26+ years. Because a constant

[9] Abbring and Van den Berg (2003) give a formal proof of the identification of the treatment effect in a bivariate duration model. They show that in this framework, identification is achievable without the usual restrictions. An example of a study that applies the bivariate duration approach to dynamics in drug use is Van Ours (2003) who studies whether or not cannabis is a stepping-stone for cocaine.

[10] The age of 12 as a starting point was chosen because dropping out of school never occurs before that age. Furthermore, initiation of cannabis use rarely happens before age 12. There are 14 males and 17 females who indicate cannabis use before age 12. Since this concerns so few individuals and no individuals drop out of school before age 13, the parameter estimates are not affected by this assumption.

term is estimated, λ_{cl} is normalized to zero. The conditional density function for the completed durations until first use can be written as

$$f_c(t|x, v) = \theta_c(t|x, v)\ \exp(-\int_0^t \theta(z|x, v)\,dz) \tag{3}$$

In estimation, we account for the fact that some individuals have not started to use cannabis at the time of survey but may do so in the future by allowing their duration until use to be right censored.

As a starting point, and to simplify notation, we assume that the hazard of leaving formal education at time t depends upon whether initiation into cannabis use has previously occurred, on the observable characteristics x, and unobserved characteristics u as follows:

$$\theta_s(t|x, I_c, u) = \lambda_s(t)\ \exp(x'\beta_s + \delta I_c + u) \tag{4}$$

where I_c is an dummy variable equal to 1 if initiation into cannabis occurred prior to or in the current period and 0 otherwise and u reflects differences in susceptibility to leaving school. Note that, if individuals start using cannabis and leave school at the same age it is assumed that initiation into cannabis use precedes school leaving.[11] The parameter of interest is δ since it determines whether initiation into cannabis has a positive effect on school leaving ($\delta > 0$), a negative effect on school leaving ($\delta < 0$), or whether there is no relationship between the two ($\delta = 0$). In the empirical section we expand this model to allow for the impact of cannabis initiation to vary by the age at which initiation occurs. Duration dependence is again modeled using a flexible step function:

$$\lambda_s(t) = \exp(\Sigma_n \lambda_{sn} I_n(t)) \tag{5}$$

where n is a subscript for age interval and $I_n(t)$ are time-varying dummy variables for 1 year age intervals. We consider school leaving up to age 23. Because a constant term is included in the model, λ_{sl} is normalized to 0. Note that the explanatory variables for the school leaving rate are the same as those for the cannabis starting rate. The conditional density function for the completed durations of education can be written as

$$f_s(t|x, I_c, u) = \theta(t|x, I_c, u)\ \exp(-\int_0^t \theta(z|x, I_c, u)\ dz) \tag{6}$$

Because we censor the duration of time in formal education at age 23 some individuals have completed durations of formal education and others have right-censored durations. This is accounted for in estimation.

The potential correlation between the unobserved components in the hazard rates for cannabis uptake and school leaving is taken into account by specifying the joint density function for the duration of non-use of cannabis t_c and the duration of time individuals spend at school t_s conditional on x and I_c as

$$f(t_c, t_s|x, I_c) = \int_u \int_v f_s(t_s|x, I_c, u) f_c(t_c|x, v)\ dG(u, v) \tag{7}$$

$G(u, v)$ is assumed to be a discrete distribution with 4 points of support (u^a, v^a), (u^a, v^b), (u^b, v^a), (u^b, v^b) reflecting the assumption of two types of individuals in the hazard rate for cannabis uptake (high susceptibility, low susceptibility) and two types in the hazard rate for school leaving (high susceptibility, low susceptibility). The four mass points imply that conditional on observed characteristics there are four types of individuals. The associated probabilities are denoted as follows: $Pr(u = u^a, v = v^a) = p_1$, $Pr(u = u^a, v = v^b) = p_2$, $Pr(u = u^b, v = v^a) = p_3$, $Pr(u = u^b, v = v^b) = p_4$. Because we also estimate constant terms we normalize $u^a = v^a = 0$. Furthermore, p_j ($j = 1, \ldots, 4$)) is assumed to have a multinomial logit specification: $p_j = \exp(\alpha_j)/\sum_j \exp(\alpha_j)$ and the normalization is $\alpha_4 = 0$.

Correlation between the unobserved components of the cannabis starting rate and the school leaving rate indicates that there is an overlap in the susceptibility to cannabis use and the tendency to leave school. Perfect correlation would imply that susceptibilities overlap completely, in which case the distribution of the unobserved heterogeneity has just two points of support. The correlation could be either positive or negative.[12] If the correlation is not accounted for, the estimated effect of cannabis use on school leaving will be biased. In the event that cannabis uptake and school leaving are positively correlated, the effect will be overestimated, while in the case of negative correlation the effect will be underestimated.

[11] We investigated the sensitivity of our results to this assumption by constraining the immediate effect of cannabis use on school leaving to be equal to zero. Under this assumption, cannabis use is only allowed to affect school leaving in the ages following the cannabis starting age. For example, if the individual started using cannabis at age 16, this can only affect school leaving from age 17 onwards. We found that our parameter estimates were not sensitive to the alternative assumption.

[12] The covariance of u and v equals $\text{cov}(u,v) = (p_1 p_4 - p_2 p_3)(u^a - u^b)(v^a - v^b)$. The unobserved components are perfectly correlated if $p_1 = p_4 = 0$ or $p_2 = p_3 = 0$. This would imply that conditional on the observed characteristics there are two types of individuals differing in inclination towards drugs use and school leaving. If positive, individuals who are susceptible to cannabis use are also susceptible to school leaving and individuals who are not susceptible to cannabis use are not susceptible to leaving school either. If the correlation between the unobserved components is negative, individuals who are susceptible to cannabis use are not susceptible to leaving school and individuals who are not susceptible to cannabis use are susceptible to leaving school.

Table 3
Parameter estimates bivariate duration models—starting rates cannabis use and school leaving rates

	Males		Females	
	Cannabis use (1)	School leaving (2)	Cannabis use (3)	School leaving (4)
(a) Correlation				
Born in Australia	0.33 (5.7)*	0.36 (11.6)*	0.38 (6.8)*	0.28 (10.7)*
Lives in rural location	−0.01 (0.2)	0.47 (17.7)*	−0.02 (0.0)	0.28 (10.7)*
Birth year 1970–1974	−0.27 (4.6)*	0.01 (0.3)	−0.23 (4.5)*	0.12 (3.2)*
Birth year 1965–1969	−0.51 (8.3)*	0.14 (3.2)*	−0.37 (6.3)*	0.21 (5.8)*
Birth year 1960–1964	−0.70 (10.3)*	0.07 (1.6)	−0.53 (7.9)*	0.19 (5.2)*
Birth year 1954–1959	−1.62 (19.9)*	0.02 (0.5)	−1.87 (22.7)*	0.35 (9.5)*
Effect cannabis use (δ)	–	0.21 (5.9)*	–	0.41 (12.6)*
Second masspoint (v^b, u^b)	$-\infty$	0.04 (1.0)	$-\infty$	0.36 (12.1)*
Unobserved heterogeneity (α)	0.36(8.6)*		0.03(1.0)	
Probability (p_1)	0.59		0.51	
(b) No correlation				
Effect cannabis use (δ)	–	0.19 (6.8)*	–	0.18 (7.1)*
LR-test no correlation	0.6		85.0*	

The datasets contain 4912 males and 6881 females; Table 4(a) concerns parameter estimates with correlated unobserved heterogeneity; Table 4(b) has the same setup except for the correlation between the unobserved heterogeneity terms which is ignored; all estimates include territories fixed effects (7) both in the cannabis use starting rate and in the school leaving rate; note that the starting rates for cannabis use contains 14 age dummies (annually 13–25 and 25+ years); the rates for leaving school contain 8 age dummies (annually 14–18 and 21–23); absolute *t*-statistics in parentheses; a * indicates that the coefficient is different from zero at a 5% level of significance.

4.2. Parameter estimates baseline model

Table 3 presents estimates of the bivariate duration model of the hazard of initiating cannabis use and the hazard of leaving formal education in which initiation at different ages is constrained to have the same effect on the hazard of leaving education. To save space we do not report the parameter estimates for the state fixed effects included in both transition rates and the age dummies included in the cannabis starting rate.[13]

The top panel of Table 3 reports estimates for models that permit correlation in the unobserved heterogeneity determining the hazard of starting cannabis and the hazard of leaving education. The bottom panel presents estimates when the unobservables are assumed to be uncorrelated. The later estimates provide a benchmark for assessing the bias arising from failing to account for the potential correlation in unobserved characteristics affecting these decisions.

As detailed in the previous section, we allow for the potential correlation in unobservables influencing cannabis uptake and the school leaving using a flexible approach in which unobserved heterogeneity is assumed to follow a discrete distribution with four points of support. However, for both males and females, only two points of support could be empirically identified, implying that the unobserved components in the two transition rates are perfectly correlated. We identify one positive cannabis starting rate and one that is equal to zero. Since the second mass point in the cannabis starting rate is smaller than the first and the second masspoint in the school leaving rate is larger than the first, the unobserved heterogeneity in transition rates for cannabis uptake and school leaving are perfectly negatively correlated. In other words, conditional on the observed characteristics there are two groups of individuals who differ in their susceptibility to cannabis uptake and school leaving. The first group has a relatively high susceptibility for cannabis uptake and a low susceptibility for leaving school; the second group has no susceptibility for cannabis uptake and a high susceptibility for leaving school. A likelihood ratio (LR) test reveals that this correlation in unobservables is only statistically significant for the female sub-sample.[14]

In terms of the distribution of unobserved heterogeneity, the estimates in Table 3 indicate that, conditional on the observed characteristics, 51% of females in the sample belong to the group with a positive cannabis starting rate and a low school leaving rate while 49% belong to the group with a zero cannabis starting rate and a high school leaving rate. The rate at which females who have used cannabis leave formal education is 51% (exp(0.41)) greater than otherwise similar females who have not tried cannabis. Ignoring the negative correlation between the two transition rates leads to an underestimate of the causal effect of initiation into cannabis use on school leaving for females. This is confirmed by the coefficient estimates in the bottom part of Table 3, which are based on models in which the correlation in the unobserved components of the two transitions are constrained to be equal to zero.

For males, conditional on observed characteristics, 59% of the sample belong to the group who have a positive cannabis starting rate and 41% belong to the group who have a zero cannabis starting rate, i.e. who are very unlikely to start using cannabis. Given the lack of a significant correlation between the unobserved components of the transitions into cannabis use and out of formal education, it is not surprising that there is very little difference in the estimated effect of initiation into cannabis use on school leaving across models that do and do not account for correlation in unobservables. Table 3 shows

[13] These are presented in Van Ours and Williams (2007b).
[14] *Note*: under the null hypothesis of no correlation between unobservables, the LR test statistic is distributed as a χ^2_1.

Table 4
Parameter estimates bivariate duration models—starting rates cannabis use and school leaving rates; sensitivity analysis effect cannabis use

	Age 25–50		Age 25–34	
	Males (1)	Females (2)	Males (3)	Females (4)
(a) Effect cannabis use (δ)	0.21 (5.9)*	0.41 (12.6)*	0.35 (5.8)*	0.59 (12.6)*
(b) Age-specific effect				
δ_{12-17}	0.26 (7.1)*	0.48 (14.4)*	0.40 (6.8)*	0.67 (14.2)*
δ_{18-19}	0.07 (1.2)	0.28 (5.2)*	−0.02 (0.2)	0.41 (5.6)*
δ_{20-23}	−0.03 (0.4)	0.09 (1.2)	0.17 (1.1)	0.14 (1.4)
LR-test equal δ's	10.6*	21.8*	12.6*	22.0*

The datasets of the age group 25–34 contain 1667 males and 2799 females; the first row for the age group 25–50 represents the estimates of Table 3; a * indicates that the coefficient is different from zero at a 5% level of significance.

that, conditional on unobserved characteristics, males that start using cannabis have a higher school leaving rate than males that did not do so. Starting to use cannabis increases males' school leaving rate by around 23% (exp(0.21)).

In terms of the impact of observed characteristics, the parameter estimates in Table 3 show that cannabis starting rates are higher for males and females born in Australia and for more recent birth cohorts. School leaving rates for males and females born in Australia and living in rural areas are higher than for their counterparts. For females recent birth cohorts have lower school leaving rates while for males there is hardly any difference between birth cohorts.

4.3. Sensitivity analysis

To investigate the robustness of our results we perform a detailed sensitivity analysis. The first analysis addresses the issue of reverse causality. While the estimates presented in Table 3 account for the potential for unobserved characteristics to jointly influence the decision to start using cannabis and the decision to leave formal education, they do not account for the influence of leaving formal education on cannabis uptake. We explored this issue by augmenting the model for initiation into cannabis as follows:

$$\theta_c(t|x, I_s, v) = \lambda_c(t)\ \exp(x'\beta_c + \gamma I_s + v) \qquad (8)$$

where I_s is a dummy variable equal to 1 if the respondent left school prior to the current period and zero otherwise. The parameter γ determines whether leaving school impacts on the decision to initiate into cannabis use. The results from estimation indicate that leaving formal education has no (statistically significant) impact on the uptake of cannabis by males, but it does have a small positive impact on the uptake by females. Nonetheless, the estimated effect of initiation into cannabis on leaving formal education is not sensitive to accounting for reverse causality.[15]

As discussed above, early cannabis use has previously been found to be causally related to the duration and frequency of use and it may be this mode of use that leads to poor educational outcomes. We attempt to gain further insight into this issue by including indicators for lifetime use of amphetamine, cocaine and heroin, which are correlated with heavy cannabis use, in our model. Adding these three indicators has very little impact on the results. The magnitude of the cannabis use parameter δ increases from 0.21 to 0.23 for males and decreases from 0.41 to 0.40 for females.

The third sensitivity analysis examines whether the impact of cannabis uptake on school leaving differs according to the age of uptake by estimating an expanded bivariate duration model. The results for the expanded model, in which the impact of initiation into cannabis use on leaving formal education is allowed to vary by the age at which initiation occurs, is reported in the lower part of Table 4. To aid in comparing these results with those from our base model, the first row of Table 4 replicates the main results from Table 3. The point estimates suggest that there is a differential impact of starting cannabis use across ages for both males and females. This is confirmed by an LR test which rejects the null hypothesis of equal effects of each age of initiation for both males and females. As shown in Table 4, for males cannabis use only has an effect if initiation occurs before age 18. For females there is an effect if initiation occurs before age 20.

The third and fourth column of Table 4 show parameter estimates obtained by limiting the sample to individuals aged 25–34 (birth cohort 1970–1979). As previously discussed, to the extent that respondents make errors in the age they report first using cannabis, our parameter estimates are likely to be biased towards zero. By restricting the sample to young individuals, recall errors are less likely to occur. As shown in Table 4, we find a larger effect of cannabis use on school leaving rates for estimates based on the sample of 25–34-year olds compared to estimates based on 25–50-year olds. This may reflect recall error in the reported age of first use, in which case our estimates should be considered as lower bounds for the effect of cannabis uptake on educational attainment.[16] Nonetheless, when we allow the impact of uptake to differ by age at first use,

[15] See Van Ours and Williams (2007b) for details.
[16] Alternatively, the larger coefficients may reflect a greater impact of uptake on education for the younger cohort.

the general pattern of results is the same for the full sample and younger sub-sample. Specifically, initiation into cannabis up to age 17 for males and up to 19 for females has a negative impact on educational attainment.

In view of the non-linearity of the estimated model, we use the parameter estimates to give a sense of the magnitude of the effect of starting cannabis on educational attainment. On average at age 13 boys and girls have about 5 years of education remaining and at age 15, they have an average of 3.5 years remaining. On the basis of the parameter estimates reported in Table 4, a boy that starts using cannabis at age 13 is expected to reduce his duration of time in formal education by 1.1 years.[17] Starting cannabis use at age 15 reduces the expected number of years of formal education for males by 0.8 years. For girls initiating into cannabis use at age 13 and at age 15 reduces the expected number of years of education by 1.9 and 1.3 years, respectively.

5. Discussion

In this paper, we investigate the impact of initiation into cannabis use by youth on their educational attainment. Our contribution to the literature is threefold. First, we use the dynamic framework of hazard rate analysis while previous studies rely on an instrumental variable approach. Second, using this dynamic framework we show that the magnitude of the effect of initiation into cannabis use depends on the age of first use. Our third contribution is to show that there are differences across gender in the way that cannabis uptake impacts on educational attainment.

Turning to the broader economic implications of our findings, traditional estimates of the rate of return to education imply that wages increase by 7–10% for every additional year of education. So a reduction in education due to early cannabis use is harmful to the individual because it reduces future earnings substantially. Furthermore, since employment prospects tend to be better for those with more education, future employment is also likely to be negatively affected by early cannabis use. Both earnings and employment effects are not only relevant for the individual but also society as a whole. Having a greater number of workers with a low level of education imposes costs to society in terms of lower employment rates and growth potential.

So how urgent is this issue and what might policy makers do about it? The widespread use of cannabis amongst high school students makes it an urgent issue for policy makers. In the US, prevalence rates for lifetime cannabis use are around 32% for 10th graders and 42% for 12th graders (Johnston et al., 2006). In Europe, prevalence rates amongst 17–18-year old high school students ranges from 59% in France and 49% in Italy to 15% in Greece and Sweden (Andersson et al., 2007). This suggests that in some countries, up to one half of youths may be leaving formal education early because of their cannabis use. While the policy implications of studies into the consequences of drug use are often less than straightforward (Godfrey, 2006), we think that the implications from our study are very clear. They suggest that if governments wish to increase the educational attainment of youth, they should focus efforts on preventing cannabis use. Our research shows that even if the uptake of cannabis cannot be prevented, there are still educational benefits from delaying the age at which it occurs. But how can this be achieved? Despite a significant quantity of research into the determinants of initiation into drug use, the uptake process remains poorly understood (Bretteville-Jensen, 2006). Previous studies do, however, provide evidence that the prevalence of cannabis use in general may be reduced by policies that raise its price (Van Ours and Williams, 2007a), and that the prevalence of cannabis use in schools can be reduced by school based informational campaigns on the risks associated with cannabis consumption (Duarte et al., 2006).

Finally, there are several limitations of this study that should be kept in mind. First, in addition to the age of onset, the frequency and persistence of use are further dimensions of cannabis using behavior that may impact on educational attainment. Unfortunately, we do not have information on these behaviors during the period in which individuals are making decisions regarding their education and so we are unable to explore this issue directly. A further limitation of this study is that, due to the nature of our data, we are unable to tease out the mechanism(s) through which cannabis uptake affects education. For example, it may work through reducing the health stock of the individual, through reducing the time spent studying, or by reducing cognitive ability, or a combination of all three effects. Uncovering the mechanism(s) through which cannabis uptake affects educational attainment remains an important research question, and one that future research should address.

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