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WHY PARENTS WORRY: INITIATION INTO CANNABIS USE BY YOUTH AND THEIR EDUCATIONAL ATTAINMENT

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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 instrumental variable estimation and bivariate duration analysis we find that those initiating into cannabis use early in life are much more likely to dropout of school compared to those who start later on. Moreover, we find that the reduction in years of schooling depends on the age at which initiation occurs, and that it is larger for females than males.

Keywords: cannabis use; age of initiation; educational attainment

JEL codes: C41, D12, I19

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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 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 the educational consequences of drug use beyond the high-school years. 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 there remains a negative effect of use beyond high-school. The aim of this paper is to provide answers to these questions. Knowledge about the relative impact of up-take at different ages 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 two approaches to addressing the potential endogeneity of initiation into cannabis in order to estimate its impact on the decision to leave education. First, we use instrumental variables (IV) estimation. An advantage of this approach is that, since it is used in the previous studies, we are able to compare our results with those in the literature. The IV approach is, however, ill-suited to studying aspects related to the timing of transitions into cannabis use and out of education. These transitions are more naturally viewed within a duration framework. For this reason, our second approach uses 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.

A benefit of using two estimation strategies is that we are able to examine the robustness of our results to the identifying assumptions employed. In the case of IV estimation, identification of the effect of initiation into cannabis use on educational attainment is based on exclusion restrictions, while the duration approach relies on the timing of events. Independent of the estimation strategy and hence identifying assumption employed, we find that initiation into cannabis use, particularly in the early teenage years, is associated with fewer years of education. Also consistent across estimation methods is the finding that the unobserved characteristics that lead females to initiate cannabis use also make them more likely to pursue more formal education. Consequently, failing to account for this correlation leads to an underestimate of the negative impact of initiation into cannabis use on female's educational attainment. Finally, 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 up-take of cannabis before the age of 18 for males, and before the age of 20 for girls, leads to a reduction in their expected years of completed education. Moreover the magnitude of the effect is larger for females than males.[1]

Our main finding is that early up-take of cannabis leads to a higher school-leaving rate, meaning that there is a probabilistic decrease in years of education completed. While our data are not rich enough to allow an investigation into why some youngster's initiation into cannabis use has a negative effect on their educational attainment while for others there is no effect, 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 (2007), respectively. Further, Pacula et al. (2005) reports that it is frequent per-

[1]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.

sistent use that leads to lower educational attainment. Therefore, it may be that those who start cannabis use at younger ages are more likely to be heavy persistent users, 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 presents the IV framework and empirical results on the relationship between youthful initiation into cannabis use and educational success, while section 5 contains the econometric set-up and results for the duration analysis. Section 6 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 high-school. Yamada, Kendix and Yamada (1996) report that heavy cannabis use in twelfth 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, 17 and 18 is associated with an increased probability of dropping out of high-school at these ages.

An issue not addressed in these early studies is whether the empirical relationship between drug use and educational attainment is causal.[2] 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

[2]Bray et al. (2000) discuss (but do not present results from) efforts to address the potential endogeneity of initiation into drug use. No discussion of the variables used to identify the effect of drug use is provided.

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. Information on the statistical merits of their results would be most useful in light of the fact that the impact of adolescent cannabis use is identified from variation in the respondents' religiosity, and it is not obvious that values associated with being religious are orthogonal to educational attainment.

Chatterji (2006) exploits the unusually rich National Education Longitudinal Study to examine the impact of past month cannabis use in 10^{th} and 12^{th} 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 (typically unobserved) preexisting individual factors that may confound the relationship between drug use in high-school and educational attainment. The results from doing so suggest that past month use of cannabis in the 10^{th} or 12^{th} grade reduces educational attainment by 0.2 years. Unfortunately, the instruments employed by Chatterji in the IV estimation are only weakly correlated with the measures of cannabis use.[3] Given the potential biases associated with weak instruments, it is perhaps not surprising that the Hausman test fails to find a significant difference between the OLS and IV estimates in this paper. A further source of concern is that specifications that include pre-existing individual factors produce IV estimates of the impact of cannabis use on educational attainment that are incorrectly signed. This, along with the potential problem of reverse causality, casts some doubt on the reliability of the OLS estimates from

[3] The F-statistics for testing the significance of the instruments in the first stage regressions range from 3.14 to 8.51 when drug use is measured by 10^{th} grade use, and 1.23 to 5.90 when drug use is measured by 12^{th} grade use.

specifications that include these variables.[4]

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 7^{th} grade through to age of 23. Using an IV approach, the authors find no evidence that participation in cannabis use in the 7^{th} or 12^{th} grade impacts on educational attainment, as measured by highest level of education completed, or by graduation from high-school. Frequency of cannabis use in the 12^{th} grade, and persistent use (defined as using at least 3 times in the month prior to survey in the 10^{th} and 12^{th} grades) is, however, found to reduce educational attainment. For example, persistent use is estimated to reduce the educational attainment by 0.7 years. As with Chatterji (2006), weak instruments are an issue in this study.[5] This raises the question of the robustness of inference regarding the impact of frequent drug use.

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. For example, is the reduction in years of educational greater for those who start using cannabis at earlier ages? Or is it up-take at critical ages, such as the age at which final exams for high-school graduation are taken, that is more harmful? 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 empirical methodology, instrumental variable estimation, they are all subject

[4] Some of the variables used to control for pre-existing conditions, such as low 10^{th} grade math score, low 8^{th} grade math score, repeated a grade, number of times parents were called in for problem behavior in the 8^{th} grade, are likely themselves to be endogenous. Since omitted variable bias is being traded for endogeneity bias, it is not clear that the OLS results provide a consistent estimator of the causal impact of drug use on educational attainment.

[5] The F-statistic on the joint significance of the instruments is reported to be 3.36 for the model for the frequency of cannabis use in 12^{th} grade, and 12.92 for participation in use in year 12.

to the same frailties. This raises the question of whether their results are robust to alternative identifying assumptions and estimation strategies. Providing answers to these questions is the motivation for what follows.

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 fourteen 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 lest 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, we make use of two measures of the age of initiation into cannabis use and three measures of educational attainment. 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. The variables we use in our analysis to measure age of first use are an indicator for first use at or before the age of 15 and the age at which initiation was reported to have occurred. The former is used in the IV analysis while the latter is used in the duration analysis.

The three measures of educational attainment we use are: (1) the age at which the respondent left school, (2) an indicator for completing high-school, and (3) an indicator for completing an undergraduate degree. 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.[6] 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 under-graduate degree, we add a further four years to their school-leaving age.[7] A

[6]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.

[7]A (typical) undergraduate degree takes three years to complete in Australia. We allow four

masters degree is assumed to take an additional two years after the undergraduate degree, and a PhD a further three years (which is the length of government scholarships). The indicator for having completed a university degree is constructed from information reported on the highest post-school qualification and is equal to one if the highest post-school qualification is a bachelors degree, a masters degree or a Ph.D. The indicator for completing high-school is equal to one if the respondent has received a bachelor's degree or higher degree (masters or PhD) or if they report that their highest level of schooling is a year 12 certificate, which is the Australian equivalent of graduating from high-school. All three measures of educational attainment are used in the IV estimation, whereas the outcome of interest for the duration analysis is the age at which the individual left school.

As we wish to ascertain the impact of 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 to individuals aged 25-50 years who report that their primary activity is not study. We have observations on 4,912 males and 6,881 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 9% of males and 8% of females in the sample initiated cannabis use by the age of 15, 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 post-graduate 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

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.

27% of females live in rural locations. The IV analysis also makes use of information on cigarette use. As seen form Table 1, 52% of males and 49% of females smoked cigarettes daily at some point in their life and a further 23% of males and 20% of females have smoked cigarettes, but never used them daily. In terms of initiation into cigarette use, 7% of males and 3% of females first smoked a full cigarette by the age of 10, 3% of males 2% of females at the age of 11 and a further 8% of males and 5% of females at the age of 12.

As with previous research studying transitions in substance use using cross-section data, this study is subject to potential measurement error problems. First, using retrospective information about when individuals start cannabis use poses the potential problem of recall error. As discussed below, we find some evidence of recall error in the reported age of initiation into cannabis use for those who initiate into use after the age of 20. This is not surprising as we are dealing with respondents aged 20 to 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. However, since initiation into use after the age of 25 is fairly rare, we do not anticipate large effects from this source of measurement error. 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. However, the other two indicators of educational attainment, completing high-school and completing a university degree, are not subject to these measurement issues. Also, as is typically the case in studies that use cross-section data to study transitions, the NDSHS does not contain information on family background or other retrospective information. Consequently, we are unable to control for these omitted 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

Figure 1 gives a graphical illustration 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 up-take 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. Figure 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.

Figure 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 age 18, which is the age for completing high-school in most Australian states. At age 19 and 20 none of the individuals in our sample are observed to leave education, but there are further peaks at ages 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. Overall, 45% of males and females drop out of 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%). Moreover these proportions are statistically different at the 5% level of significance. 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 difference between males and females in terms of cannabis up-take are significantly different for each category.

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% of non-users have less than a high-school education compared to 47% 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. At the other end of the education spectrum, while 16% of male non-users and 15% of male cannabis users have an undergraduate degree, the probability of a cannabis user graduating from university is much higher for those who initiate into

[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.

use later, say after the age of 17 (16%) compared to those who initiate by the age of 15 (11%). 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.

Given that the marginal distribution of educational attainment is very similar across gender but the marginal distribution of age of initiation into cannabis use differs by gender, it must be the case that the distribution of educational attainment conditional on age of initiation differs across gender.[9] This can be verified using the information in Table 2. For example, as noted above, for males, 43% of non-users have less than a high-school education compared to 47% of those who have used cannabis at some point in their life. By comparison, 48% of female non-users have less than a high-school education compared to 44% of those females who have used cannabis at some point in their life. 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 Instrumental Variables Estimation

4.1 Econometric Set-up

We are interested in estimating the expected impact of initiation into cannabis use (c) on educational attainment (e). Following the previous literature, we specify our model for the production of education as:

$$e_i = \beta_1 + \delta_c c_i + x'_{1i}\beta_2 + x'_{2i}\beta_3 + \epsilon_i \qquad (1)$$

where educational attainment of respondent i (measured by the age at which the respondent leaves school, an indicator for completing high-school, or an indicator for completing a university degree), depends upon the observable variables, c_i, x_{1i} and x_{2i}, and unobservable factors, ϵ_i. In addition to the effect of initiation into cannabis

[9]We have ruled out independence above.

use (measured by δ_c), the production of educational attainment is assumed to depend upon a vector of exogenous individual demographic characteristics, x_1 (age, Australian born, state of residence at time of survey and rural residence) and a vector of variables intended to capture permanent characteristics of the individual, such as the extent to which they discount the future or possess a "curious or adventurous" nature, x_2 (measured by an indicator for having ever smoked cigarettes daily by the time of survey and whether they have ever smoked cigarettes but not been a daily smoker by the time of survey, respectively). The random error term, ϵ_i, captures other unmeasured influences that affect the production of education, such as a taste for risk, or predisposition for non-conformist or deviant behavior (Jessor and Jessor, 1977).

As has been widely discussed in the economics literature, the challenge in ascertaining the causal impact of substance use on education outcomes is overcoming the possibility that substance use is endogenous. This endogeneity may result from academic failure leading to substance use (reverse causality) or from unobserved characteristics that lead teenagers to substance use also leading them to drop out of formal education (selection on unobservables or omitted variables). Failure to address the potential endogeneity of initiation into drug use will lead to biased and inconsistent estimates of its impact on educational attainment. As discussed in section 2, these issues have previously been tackled within the economics literature using an IV approach. In the first instance, we also follow this approach.

The ability of an IV estimator to consistently estimate the causal impact of cannabis use on educational attainment relies on the availability of variables that determine initiation into cannabis use but that can be validly excluded from the education production function. Previous research has sought to identify the effect of substance use, such as drinking, on education using state level policy variables related to substance use (Cook and Moore, 1993; Williams et al., 2003; Koch and McGeary, 2005). However, this identification strategy has come under criticism because (1) the state level policies are often only weakly correlated with substance use; and (2) state level policies may be correlated with unobserved state sentiment that influences both substance use and the economic outcomes of interest (Dee and Evans, 2003).[10] Our identification strategy exploits the well documented sequencing of initiation into substance use, in which the uptake of cigarettes typically precedes the uptake of cannabis (Kandel, 1975; Beenstock and Rahav, 2002).[11] Specifically, we identify the effect of early initiation into cannabis use, measured by an indicator for first use at or before the age of 15, with having previously smoked cigarettes, measured by the set of indicators for having first smoked a full cigarette by the age of 10, having first smoked a cigarette at age 11, and having first smoked a cigarette at age 12. The behavioral assumptions underlying our identification strategy are that (1) the production of euphoria from cannabis consumption is increasing in the individual's ability to inhale smoke, (2) individuals who have previously used cigarettes have learned the technology of inhaling smoke. These assumptions imply that those who have previously smoked cigarettes are more likely to initiate cannabis use compared to those who have not. The crucial econometric assumption underlying identification is that the early use of cigarettes has no impact on educational attainment.[12]

How reasonable are the assumptions on which are identification strategy is based?

[10] Variables used to identify the impact of cannabis use on educational outcomes in the literature include: religiosity (Register et al., 2001), state level drug policies (cannabis decriminalization (Chatterji, 2006; Pacula et al., 2003; Register et al., 2001), criminal penalties for cannabis possession (Chatterji, 2006; Pacula et al., 2005; Pacula et al., 2003)), the price of cannabis (Pacula et al., 2005; Pacula et al., 2003), 8^{th} grade school characteristics (8^{th} grade school principal's perception of whether or not drugs are a moderate to serious problem, whether the school has a policy of expelling students if they are caught with drugs on school property (Chatterji, 2006) and sibling's drug use (Pacula et al., 2005).

[11] The NDSHS also displays this pattern. In our sample, the average age for first smoking a cigarette is 15 years and the average age for first using cannabis is 19 years for both males and females.

[12] We note that our identification strategy does not require that all cannabis users first use cigarettes. It does, however, require that cigarette smokers are more likely to subsequently use cannabis than non-smokers.

The first of these assumptions seems reasonable since over 80% of those who used cannabis in the past year report smoking as the route of administration. The data also appear to be consistent with the second assumption, with 56% of those who have smoked a cigarette subsequently going on to try cannabis, compared to 18% of those who have never smoked a cigarette. The assumption that, conditional on cannabis use, cigarette use has no impact on educational attainment may be problematic if the same unobserved characteristics that lead to early cigarette use, such as a high discount rate or curiosity, also lead to early school leaving. We attempt to account for these (permanent) individual characteristics using indicators for ever been a daily smoker of cigarettes and having tried cigarettes but never smoked daily. Having controlled for these individual characteristics, the indicators for early cigarette use should not have a direct impact on educational attainment and can therefore be excluded from equation 1. We have, nonetheless, attempted to strengthen our case by only considering initiation into cigarette use up to age 12. The validity of the exclusion restrictions is further examined in the empirical section of the paper.

If an IV procedure is to improve upon methodologies that treat drug use as exogenous it is vital that there exists a (sufficiently) strong correlation between the excluded instruments and the variables they are instrumenting. Failure of this condition is referred to as the problem of weak instruments. Unfortunately weak instruments have extremely deleterious effects on the sampling properties of IV estimators, inducing substantial bias in small samples and rendering invalid standard forms of inference such as t-tests and the construction of confidence intervals. Consequently, in what follows we pay considerable attention to the strength of our instruments to ensure that our results are not subject to this problem. We do this through examination of the first-stage regression and by conducting inference on the IV coefficients of interest using the Anderson-Rubin test, which is robust to the presence of weak instruments.

Estimation is carried out using the two-step efficient generalized method of moments (GMM). This method has the advantage of relaxing the assumption of identically and independently distributed error terms required of IV or two stage least squares estimation, and hence is robust to heteroscedasticity.

4.2 GMM Estimation Results

Table 3 contains the results from examining the relationship between initiation into cannabis by age 15 and educational attainment using OLS and GMM estimation. Each of the three columns in Table 3 report results based on a different measure of educational attainment. In the first column, educational attainment is measured by the age at which the respondent leaves formal education, in the second column it is measured by an indicator for completing high-school, and in the third column it is measured by an indicator for completing an undergraduate degree. We present separate estimates for the male and female sub-samples in the top and bottom panels, respectively.[13] For space considerations, only the coefficient estimates on the measure of age of initiation into cannabis use and diagnostic statistics are reported in Table 3. However, all models control for the following characteristics: age, age squared, an indicator for ever being a daily smoker of cigarettes, an indicator for ever being a non-daily smoker of cigarettes, an indicator for being Australian born, an indicator for living in a rural area, and a set of indicators for the respondent's state of residence at time of survey. To the extent that state sentiment regarding cannabis use and education is stable over time and individuals don't move state, controlling

[13]We investigated whether male and female sub-samples could be pooled by estimating models of educational attainment in which the effect of all exogenous variables are allowed to differ by gender and early cannabis use by females and males are treated as separate endogenous variables. Testing the null hypothesis of no differences across gender in the effect of the explanators (endogenous and exogenous) on educational attainment produced a test statistic of 61.06 in the model based on age left school, 45.86 in the model based on completing high-school and 46.48 for the model based on graduating from university. Comparing these test statistics to the critical value of 23.68 for a χ^2 with 14 degrees of freedom leads us to reject pooling across gender for all three educational outcomes.

for state of residence at the time of survey in both equations should account for the effect of state sentiment on cannabis uptake and school leaving decisions.[14] The reported t-statistics are based on heteroscedastic robust standard errors.

Before discussing coefficient estimates, we assess the statistical merits of the GMM estimates. We begin with the strength of the correlation between the measure of initiation into cannabis use and the instruments. For both males and females, the F-statistic for testing the joint significance of the instrument set in the first stage regression is well over the bench-mark value of 10 sometimes used to diagnose weak instruments (Staiger and Stock, 1997). This suggests that the issues associated with weak instruments are unlikely to be a problem in this analysis. Moreover, the first stage regression results show that each of the indicators for the age of first smoking a cigarette are individually statistically significant and correctly signed (see Appendix Table A1). The over-identification restrictions are also always supported for each gender, providing evidence that early cigarettes use (controlling for ever being a non-daily or daily cigarette smoker) are valid instruments for identifying the impact of early initiation into cannabis use.[15] Finally, the Hausman test finds significant differences between OLS and GMM estimates of the impact of initiation into cannabis use on the three measures of educational attainment for females, but not males. This suggests that the OLS estimates are likely to suffer from endogeneity bias in the case of the females sub-sample. However, there is no significant evidence of this problem in the male sub-sample. On this basis, we prefer the GMM estimates in the case of females and OLS estimates in the case of males.

A comparison of the OLS and GMM coefficient estimates for females indicates that ignoring the endogeneity of early initiation into cannabis use leads to an understatement of its negative impact on educational attainment. This suggests that females who are more likely to use cannabis by the age of 15 are also more likely to

[14] A complete set of results (excluding state fixed effects) based on the age at which the respondent left school can be found in Appendix Table A1.

[15] The Hansen J statistic is used to test the over-identifying restrictions. It is distributed as a χ^2-squared with 2 degrees of freedom.

remain at school longer. Focusing now on the GMM parameter estimates, the results in Table 3 suggest that early cannabis use by females reduces the expected age at leaving education by 1.8 years. Similarly, cannabis use by age 15 is expected to reduce the probability that a female completes high-school by 32 percentage points and the probability that she completes college by 21 percentage points. These are large effects given that on average, 55% of females in the sample graduate from high-school and 25% graduate from university. Moreover, the Anderson-Rubin test confirms that, accounting for the potential issue of weak instruments, these effects are statistically significant (although this is only true at the 7% level of significance in the case of completing university).

By comparison, the impact of early initiation into cannabis use has a smaller effect on the educational outcomes of males. The OLS results indicate that first using cannabis by age 15 is expected to reduce the number of years of education completed by males by one third of a year, and reduce the probability of completing high-school and university by 10 and 4 percentage points, respectively. Nonetheless, these are still quite large effects given that 55% of the sample of males graduate from high-school and 26% graduate from university.

In terms of the impact of the control variables, we find that older individuals tend to complete fewer years of formal education, as do Australian born and rural respondents. We also find that individuals who have ever been a daily smoker of cigarettes tend to complete fewer years of education while those who have smoked cigarettes, but never on a daily basis, complete slightly more years of education compared to those who have never smoked cigarettes.

Overall, our findings from IV analysis are in broad agreement with those of the earlier studies, which conclude that early cannabis use reduces educational attainment. Moreover, averaging over the estimated effects of initiation into cannabis use for males and females, we find that cannabis use by the age of 15 is associated with approximately a 1.2 year reduction in years of education, compared to a range of 0.2 to 1 year for the earlier studies.

These finding are useful for at least three reasons. First, they establish a baseline set of results using the same methodology as previous studies based on US data. Second, they establish that the adverse educational effects of early cannabis use are not country specific. Third, given the common findings for the US and Australia based on the IV analysis, the results from the duration analysis on age specific impacts of cannabis uptake are also likely to be of general interest.

4.3 Sensitivity Analysis of the GMM Results

We examined the sensitivity of the GMM results to the potential for omitted variable bias and to the instrument set used to identify the impact of early initiation into cannabis use on educational attainment.[16]

The first sensitivity test we conduct examines the instrument set, which consists of a set of indicators for first smoking a full cigarette prior to the age of 13. This set of variables is intended to capture whether a person has acquired the technology to smoke cannabis. We argue that, while knowledge of such technology is likely to influence whether a person uses cannabis, it is unlikely to have any direct effect on their production of education. However, it may also be argued that early use of cigarettes signals a taste for deviant behavior. If this is the case, the exclusion restrictions may be invalidated. We do, nonetheless, find empirical support for these exclusion restrictions using the overidentification test. But how reliable are these results? In order to answer this question we set up a "straw man" by adding to the list of instruments an indicator for alcohol use by the age of 12.[17] While early alcohol use may signal deviant behavior in youth, it does not impart any technological knowledge useful for smoking cannabis. Therefore, we have no reason to believe that

[16]The estimation results are available on request.

[17]We initially used a set of indicators for early alcohol use defined along the lines as those for early cigarette use. However, following a suggestion of a referee, we investigated and found evidence that multicollinearity may be an issue for this set of variables. For this reason, we collapsed the set of indicators into a single indicator for alcohol use by age 12. We thank the referee for bringing this issue to our attention.

early alcohol use is a valid instrument and any statistical evidence supporting its exclusion from the education production function would cast doubt on our identification strategy based on early cigarette use. When early alcohol use is included in the set of instruments, the over-identification test strongly rejects excluding this set of variables from the education production function for all educational outcomes for females and for all educational outcomes except graduating from university for males. Since the instrument set based solely on early cigarette use comfortably passes the over-identification test in all cases for both males and females, we conclude that the set of indicators for early cigarette use serves as valid instruments.

Our next two robustness checks examine whether our estimates suffer from omitted variable bias because they fail to control for alcohol use. Alcohol use may be correlated with permanent characteristics of the individual, such as their discount rate or whether they have an adventurous nature, which may also impact on their school leaving decisions. We first investigate this issue by including an indicator for whether the respondent is a current alcohol user. This indicator is equal to one if the respondent reported having an alcohol drink of any kind in the past twelve months, and equal to zero if they did not. Including this measure of past year alcohol use had very little impact on the point estimates and no impact on our qualitative findings, leading us to conclude that omitting current alcohol use has not biased our results. We next include both early and past year alcohol use in the set of determinants of the production of education. As above, adding current alcohol consumption had very little impact on the estimated effect of age of initiation into cannabis on education. However, including the indicators for alcohol use by age 12 increases the magnitude of the estimated effects. Nonetheless, it does not alter our basic finding, that early initiation into cannabis use has a significant and detrimental effect on educational attainment.

As a final check, we examined the sensitivity of our results to the estimation sample. In particular, we excluded observations on the 185 males and 193 females who started cannabis use before the age of 15, but who had left formal education prior to initiating into cannabis use. Removing these observations reduced the magnitude of the estimated effect of initiating cannabis use on leaving formal education, but does not otherwise alter our findings.

5 The Bivariate Duration Model

5.1 Econometric Set-up

The results presented in section 4 confirm the findings based on US data by Chatterji (2006), Pacula et at (2005) and Register, Williams and Grimes (2001), that early cannabis use reduces educational attainment. This raises the question of whether the adverse consequences of up-take 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. To study the impact of policy interventions on unemployment durations this so called 'timing-of-events' method is used in several studies. Van den Berg et al. (2004) and Abbring et al. (2005) for example conduct an analysis of the effect of unemployment benefit sanctions on exits from unemployment. Both papers 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).[18]

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.[19] The hazard of starting cannabis use at time t conditional on observed characteristics x and unobserved characteristics v is specified as:

$$\theta_c(t \mid x, v) = \lambda_c(t) \exp(x'\beta_c + v) \tag{2}$$

where $\lambda(t)$ represents individual duration dependence. The observed characteristics are the same as those contained in x_1 in the previous section, excluding age; the unobserved heterogeneity reflects differences in the susceptibility to uptake of cannabis.[20] Duration dependence is modeled using a flexible step function:

$$\lambda_c(t) = \exp(\Sigma_k \lambda_{ck} I_k(t)) \tag{3}$$

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 term is estimated, λ_{c1} is normalized to zero. In estimation, we account for

[18] 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.

[19] 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.

[20] Specifically, x includes an indicator for Australian born, an indicator for rural residence and a set of indicators for state of residence at the time of survey.

the fact that, at the time of survey, some individuals have not yet started to use cannabis but that they 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:

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

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 preceded school leaving.[21] 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 one year age-intervals. In the first instance, we focus on school-leaving up to age 18, taking into account the censoring of durations for individuals who have not left school by age 18. We also consider school leaving up to age 23. Because a constant term is included in the model, λ_{s1} is normalized to 0. Note that the explanatory variables for the school-leaving rate are the same as those for the cannabis starting rate. Because we censor the duration of time in formal education (at age 18 in some

[21] In the sensitivity analysis below we return to this issue of both events occurring at the same age.

specification and at age 23 in others) 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 as

$$f(t_c, t_s|x, I_c) = \int_u \int_v f_s(t_s|x, I_c, u) f_c(t_c|x, v) dG(u, v) \tag{6}$$

$G(u, v)$ 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 their observed characteristics there are four types of individuals. The associated probabilities are denoted as follows: $\Pr(u = u^a, v = v^a) = p_1$, $\Pr(u = u^a, v = v^b) = p_2$, $\Pr(u = u^b, v = v^a) = p_3$, $\Pr(u = u^b, v = v^b) = p_4$. Here p_j $(j = 1, .., 4)$ is assumed to have a multinomial logit specification: $p_j = \frac{\exp(\alpha_j)}{\Sigma_j \exp(\alpha_j)}$ and the normalization is $\alpha_4 = 0$. The covariance of u and v equals $cov(u, v) = (p_1 p_4 - p_2 p_3)(u^a - u^b)(v^a - v^b)$.[22]

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.[23] If the correlation is not accounted for the estimated effect of cannabis use on school leaving will be biased. In case of positive correlation the

[22]The unobserved components are perfectly correlated if $p_1 = p_4 = 0$ or $p_2 = p_3 = 0$ in which case the distribution of unobserved heterogeneity has two points of support. This would imply that conditional on the observed characteristics there are two types of individuals differing in inclination towards drugs use and school-leaving.

[23]If positive, individuals who are susceptible to cannabis use are also susceptible to school leaving

effect will be overestimated, while in the case of negative correlation the effect will be underestimated.

5.2 Parameter Estimates Baseline Model

Table 4 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. Table 5 reports models in which the impact of initiation is allowed to vary by the age at which it occurs. To save space we do not report in Table 4or Table 5 the parameter estimates for the state fixed effects included in both transition rates and the age dummies included in the cannabis starting rate.[24] Separate models are estimated for males and females.[25]

Because of the nature of our data, which consists of detailed information on school leaving by year of school up to the completion of high-school and information on the highest post-school qualification, Table 4 first reports estimates of specifications for leaving education up to age 18 (treating those who graduate from university with undergraduate or graduate degrees as having censored durations). Specifications in which we incorporate the information on post-school qualifications are reported under the heading of 'leaving formal education up to age 23'. The top panel of Table 4 reports estimates for models that permit correlation in the unobserved heterogeneity determining the hazard of starting cannabis and the hazard of

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.

[24]Appendix Table A2 provides a full set of results (excluding state fixed effects) for the bi-variate model focusing on the hazard of school leaving up to age 18.

[25]We examined whether the data support pooling across gender using a likelihood ratio (LR) test. We obtained an LR statistic of 202.0 (213.0) for the model based on school leaving up to 18 (23) years of age, compared to the critical value for the χ^2 with 40 (43) degrees of freedom of 55.8 (59.3). On this basis, we reject pooling and conduct separate analysis for males and females.

leaving education. The bottom panel presents estimates of the impact of initiation into cannabis on the hazard of leaving education 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.

We begin with a discussion of the results based on the specification examining school leaving up to age 18. As detailed in the previous section, we allow for the potential correlation in unobservables influencing cannabis up-take 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 up-take 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, which is consistent with the results of the previous section.[26] Ignoring the negative correlation between the two transition rates leads to an underestimate of the true causal effect of initiation into cannabis use on school-leaving for females (but not males). This is confirmed by the coefficient estimates in the bottom part of Table 4, which are based on models

[26]Note under the null hypothesis of no correlation between unobservables, the LR test statistic is distributed as a χ^2_1. The critical value for the test statistic at the 5% level of significance is 3.8.

in which the correlation in the unobserved components of the two transitions are constrained to be equal to zero.

In terms of the distribution of unobserved heterogeneity, the estimates in Table 4 indicate that, conditional on the observed characteristics, 47% of females in the sample belong to the group with a positive cannabis starting rate and a low school-leaving rate while 53% 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 49% (exp(0.40)) greater than otherwise similar females who have not tried cannabis. Ignoring the correlation in the unobservables produces a downward biased estimate of the effect of initiation into cannabis use on the school-leaving rate of 22%.

For males, conditional on observed characteristics, 54% of the sample belong to the group who have a positive cannabis starting rate and 46% will never use 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 4 shows that, conditional on unobserved characteristics, age and region of residence, 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 27% (exp(0.24)).

In terms of the impact of observed characteristics, the parameter estimates in Table 4 show that cannabis starting rates are higher for males and females born in Australia. The peaks in the cannabis starting rate for males and females at ages 18, 20 and 25 (see Appendix Table A2) coincide with the peaks presented in Figure 1. School-leaving rates for males and females born in Australia and living in rural areas are higher than for their counterparts. The peak in the school-leaving rate at age 18 (see Appendix Table A2) coincides with the peak presented in Figure 3.

The second and fourth columns of Table 4 report parameter estimates for specifications in which school-leaving is modeled up to age 23. As shown in the table, the parameter estimates are not sensitive to whether we consider school-leaving up to 18 years or up to age 23.

5.3 Sensitivity Analysis

To investigate the robustness of our results we perform a detailed sensitivity analysis. We start with investigating the sensitivity of the assumption that cannabis use precedes school-leaving if both events happen at the same age. In our dataset 334 males and 430 females start using cannabis at the same age at which they leave school. In Australia, the academic year coincides with the calendar year. So if an individual leaves school in 2001 at age 16 he will do so in December of 2001. If the individual starts using cannabis at age 16 the likelihood if him doing that so before leaving school depends on his birthday. If his birthday is in the beginning of 2001 it is very likely that cannabis use precedes school-leaving; if however his birthday is at the end of 2001 our assumption is less likely to be valid. Therefore, we performed a sensitivity analysis where we impose the immediate effect of cannabis use on school-leaving to be equal to zero. 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. Our parameter estimates show that the estimated effect of cannabis use on school-leaving doesn't change much under the alternative assumption; all the other parameter estimates are also very similar to the ones presented in Table 4.[27]

Since the specification modeling school leaving up to age 23 is more informative about the impact of cannabis use later in youth on leaving post-school education, it forms the basis of the first part of the next sensitivity analysis contained in Table 5. This table presents the results from estimating an expanded bivariate duration 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. The point estimates

[27] The parameter estimates are available on request.

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 the first column of Table 5, initiating cannabis use up to age 17 has a significantly positive effect on the school-leaving rate of males, and from age 18 onwards it has no significant impact on the hazard of leaving formal education. We examined whether the impact of starting cannabis use was the same for males for each age from 12 to 17, and zero beyond the age of 17 using an LR test. As shown by the test statistic in the bottom part of Table 5, we are unable to reject this hypothesis at conventional levels of significance. Therefore, it appears that starting cannabis use before the age of 18 has a negative effect on educational outcomes for males, where the size of the effect on the school-leaving rate does not depend on the exact age of initiation.[28] Initiation into use after the age of 17 appears to have no effect on the rate at which males leave formal education.

By and large the effect of the age of initiation into cannabis use on the school-leaving rate of females is similar to that for males with two exceptions. First, initiation into cannabis use beyond the age of 17 appears to have an effect on the rate at which females leave school. Second, the magnitude of the estimated effect of initiation on school leaving seems to be larger for females than males. The restricted estimates and the corresponding LR test in the lower part of the second column of Table 5 confirm that initiation up to the age of 19 significantly increases the rate at which females leave formal education compared to those who have not yet started.[29] Therefore, the threshold age for females is 20 (compared to 18 for males). If females start using cannabis before the age of 20, it has a negative effect on their educational

[28]Note however that the effect in terms of the years of schooling is larger for those who start using cannabis at younger ages. This is because the effect of the increased school-leaving rate works over a longer calendar time period.

[29]Females that start using cannabis at age 18 have a significantly higher school-leaving rate than non-cannabis users, but the effect is significantly smaller than the effects related to starting at age 17 or age 19.

attainment, and the size of the effect does not (generally) depend on the exact age of initiation. Initiation into cannabis after the age of 19, however, appears to have no effect on the rate at which females leave formal education.

While the estimates presented in Table 4 and 5 address 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 potential influence of leaving formal education on cannabis up-take. We explored this issue by augmenting the model for initiation into cannabis as follows:

$$\theta_c(t|x, I_s, v) = \lambda_c(t)\exp(x'\beta_c + \gamma I_s + v) \tag{7}$$

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 up-take of cannabis by males, but it does have a small positive impact on the up-take by females. Nonetheless, the estimated effect of initiation into cannabis on leaving formal education is not sensitive to accounting for reverse causality.[30]

In view of the non-linearity of the estimated model, we use the parameter estimates from the lower part of Table 5 to give a sense of the magnitude of the effect of starting cannabis use on the duration of formal education. On average sample members leave school at age 18. So, 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 from the bottom of Table 5, a boy that starts using cannabis at age 13 is expected to reduce his duration of time in formal education by 1.2 years. Starting cannabis use at age 15 reduces the expected number of

[30]For specifications that constrain the impact of initiation to be the same for all ages and consider leaving education up to age 23, the estimated impact of initiating cannabis use for males is 0.22 with a t-statistic of 5.8 when reverse causality is accounted for, compared to 0.22 with a t-statistic of 6.3 when it is ignored. For females, the estimated effect is 0.37 with a t-statistic of 10.8 compared to 0.36 with a t-statistic of 11.2 when reverse causality is ignored.

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 1.7 and 1.2 years, respectively. These estimates are remarkably consistent with those obtained from GMM estimation in the previous section.

6 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, in addition to traditional instrumental variable estimation, we use the dynamic framework of hazard rate analysis. Although each method has a different approach to addressing the potential endogeneity of cannabis use, the results are remarkably robust to the estimation strategy used. Second, we show that although self-selection into cannabis use does not appear to be an issue for males, it is for females. More specifically, we find that females who are susceptible to cannabis use are also more inclined to stay at school longer, while females who are unlikely to start using cannabis tend to leave school earlier. Failing to account for this correlation in unobserved components of the cannabis up-take and school leaving decisions leads to an underestimate of the effects of cannabis use on educational attainment. Our third contribution is to show that the magnitude of the effect of initiation into cannabis use depends on the age of onset. Using the bivariate duration framework, we find that those who initiate into cannabis use early suffer greater adverse effects in terms of educational attainment, whereas initiation at older ages – for males after age 17 and for females after age 19 – does not seem to have harmful effects.

Returning to the title of our paper, our results suggest that parents are right to worry about their children's early use of cannabis, at least with respect to educational attainment. Early initiation into cannabis reduces educational attainment considerably, in the range of 1 to 2 years for females and around a third of a year for males. 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 (and their parents) but also the 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 10^{th} graders and 42% for 12^{th} 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, with the the European Union displaying an overall trend towards increasing lifetime prevalence amongst school students (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 up-take 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 up-take 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, 2007), 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. Given previous research has found that early initiators are more likely to be heavy users and long term users of cannabis, it seems likely that our results reflect, in part, these unobserved dimensions of use. A further limitation of this study is that it is unable to tease out the mechanism(s) through which cannabis up-take 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 is an important research question, but given the nature of the data used for our analysis, is beyond the scope of this study. The contribution of this study lies in identifying the causal impact of age of initiation into cannabis use on education attainment. The conclusions from our analysis are clear and straightforward: Early initiation into cannabis is harmful with respect to educational attainment.

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Figure 1: **Annual starting rate cannabis use (%)**

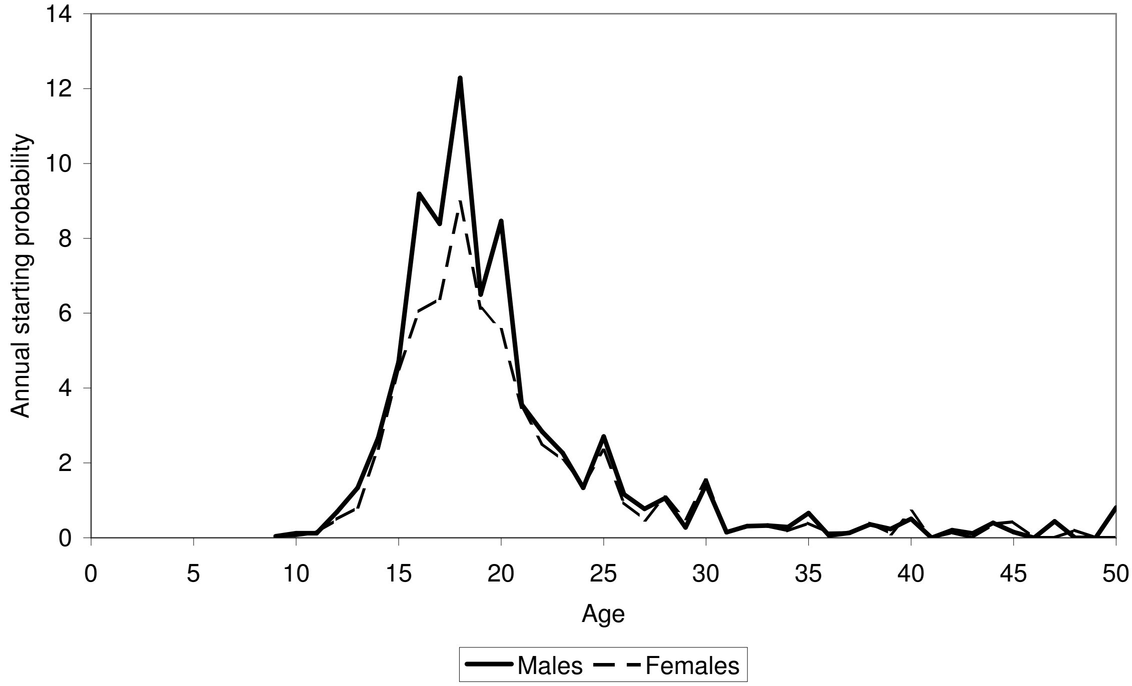

Figure 2: **Annual school-leaving rate (%)**

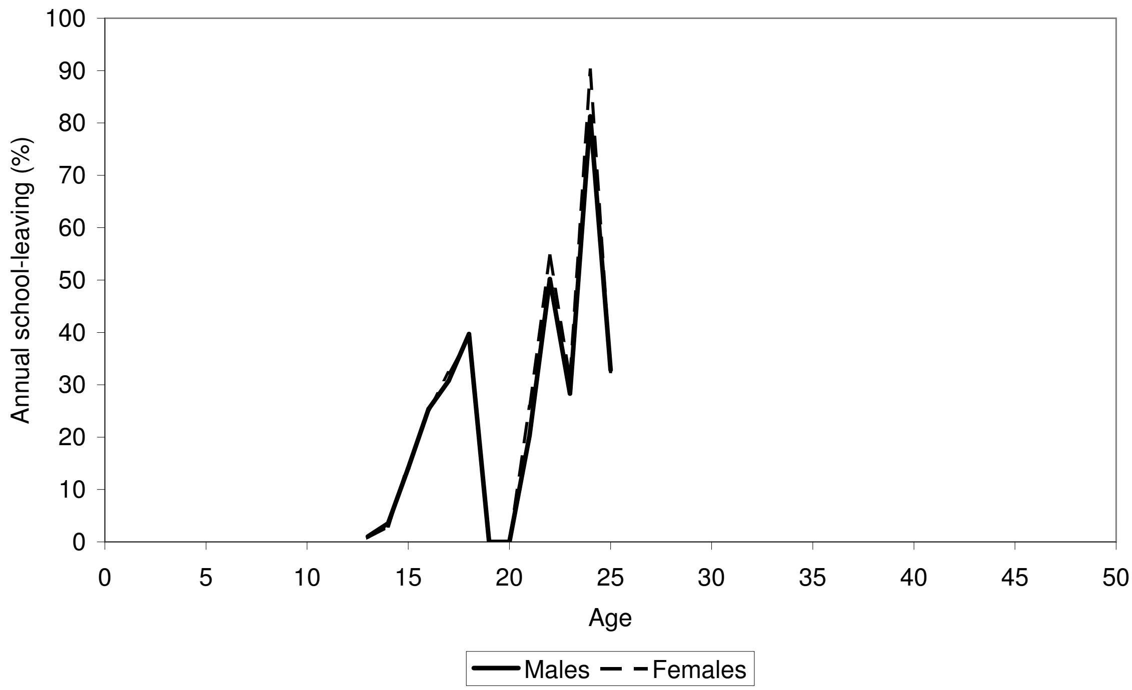

Table 1: **Sample means**

Variable	Full Sample	Males	Females
Cannabis use by age 15	0.090	0.094	0.082
Age of initiation (conditional on starting)	18.780	18.565	18.960
Age left school	17.940	17.981	17.918
Graduated from high school	0.550	0.548	0.548
Graduated from university	0.250	0.255	0.254
Male	0.420	1.000	0.000
Age	37.410	37.955	37.022
Born in Australia (Oz)	0.780	0.769	0.789
Lives in a rural location	0.260	0.253	0.268
Ever smoked cigarettes daily	0.500	0.521	0.492
Ever smoked cigarettes but not daily	0.220	0.230	0.204
Smoked first cigarette by age 10	0.050	0.070	0.031
Smoked first cigarette at age 11	0.020	0.026	0.022
Smoked first cigarette at age 12	0.070	0.080	0.055
Consumed first serve of alcohol by age 12	0.062	0.092	0.041
Consumed alcohol in the past year	0.897	0.922	0.880

Table 2: **Joint frequency distribution of initiation into cannabis use and educational attainment; males and females**

a. Males	Never use	Age<16	15<Age<18	Age>17	Total	Total (%)
< High-school	985	264	356	616	2221	45.2
High school	676	119	218	423	1436	29.3
Undergrad	364	49	119	225	757	15.4
Post-grad	255	29	55	159	498	10.1
Total	2280	461	748	1423	4912	100.0
Total (%)	46.4	9.4	15.2	29.0	100.0	
b. Females						
< High-school	1778	315	353	664	3110	45.2
High school	1063	145	238	575	2021	29.3
Undergrad	590	78	119	374	1161	16.9
Post-grad	302	29	51	207	589	8.6
Total	3733	567	761	1820	6881	100.0
Total (%)	54.3	8.2	11.1	26.4	100.0	

Table 3: **GMM parameter estimates of the effect of starting cannabis by age 15 on age left school**

	Age left school	Complete high school	Complete university
a. Males			
Parameter estimates δ_c (absolute z-scores)			
OLS	-0.33 (2.5)*	-0.10 (4.2)*	-0.04 (2.0)*
GMM	-0.83 (0.9)	-0.36 (2.1)*	0.04 (0.3)
Test statistics (p-value)			
F-test on instruments	19.49 (0.00)	19.49 (0.00)	19.49 (0.00)
Over-identification	0.42 (0.42)	2.80 (0.25)	2.20 (0.33)
Hausman	0.25 (0.61)	2.39 (0.12)	0.41 (0.52)
Anderson-Rubin	2.51 (0.47)	7.54 (0.06)	2.29 (0.51)
b. Females			
Parameter estimates δ_c (absolute z-scores)			
OLS	-0.34 (3.0)*	-0.10 (4.5)*	-0.02 (1.3)
GMM	-1.85 (3.0)*	-0.32 (2.8)*	-0.21 (2.2)*
Test statistics (p-value)			
F-test on instruments	35.12 (0.00)	35.12 (0.00)	35.12 (0.00)
Over-identification	2.28 (0.32)	1.49 (0.47)	2.02 (0.36)
Hausman	5.36 (0.02)	3.82 (0.05)	3.38 (0.07)
Anderson-Rubin	11.70 (0.01)	9.33 (0.03)	6.97 (0.07)

Note: 4912 males and 6881 females; all models control for the following characteristics: age, age squared, an indicator for ever being a daily smoker of cigarettes, an indicator for ever being a non-daily smoker of cigarettes, an indicator for being Australian born, an indicator for living in a rural area, and a set of indicators for the respondent's state of residence at time of survey; a * indicates that the coefficient is different from zero at a 5% level of significance.

Table 4: **Parameter estimates bivariate duration models – starting rates cannabis use and school-leaving rates; school-leaving up to 18 years and up to 23 years**

	Males		**Females**	
a. Correlation	**$\leq$ 18 years**	**$\leq$ 23 years**	**$\leq$ 18 years**	**$\leq$ 23 years**
Cannabis use				
Oz	0.22 (4.2)*	0.22 (4.2)*	0.37 (6.9)*	0.37 (6.9)*
Rural	-0.03 (0.7)	-0.04 (0.7)	-0.06 (1.4)	-0.06 (1.4)
Masspoint 2	$-\infty$	$-\infty$	$-\infty$	$-\infty$
School-leaving				
Oz	0.35 (10.1)*	0.35 (11.4)*	0.25 (8.1)*	0.27 (10.3)*
Rural	0.54 (17.9)*	0.47 (17.6)*	0.30 (12.0)*	0.31 (13.5)*
Masspoint 2-1	0.03 (0.9)	0.05 (1.5)	0.32 (11.1)*	0.32 (11.3)*
Effect cannabis use (δ)	0.24 (6.4)*	0.22 (6.3)*	0.40 (11.1)*	0.36 (11.2)*
Unobs. heterogeneity (α)	0.18 (5.9)*	0.18 (5.9)*	-0.12 (4.7)*	-0.12 (4.6)*
Probability (p_1)	0.54	0.54	0.47	0.47
-Loglikelihood	17,392.0	18,692.5	23,373.8	25,041.3
b. No correlation				
Effect cannabis use (δ)	0.23 (7.2)*	0.19 (7.0)*	0.20 (6.7)*	0.15 (5.9)*
-Loglikelihood	17,392.3	18,693.2	23,418.8	25,088.6
LR-test no correlation	0.6	1.4	90.0*	94.6*

The datasets contain 4912 males and 6881 females; Table 4a concerns parameter estimates with correlated unobserved heterogeneity; Table 4b has the same set-up 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 up to 18 years contain 5 age dummies (annually 14-18); the rates for leaving school up to 23 years 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.

Table 5: **Parameter estimates bivariate duration models – starting rates cannabis use and school-leaving rates; school-leaving up to 18 years – sensitivity analysis effect cannabis use**

	Males	Females
δ_{12-13}	0.44 (6.2)*	0.43 (5.7)*
δ_{14}	0.37 (4.6)*	0.45 (7.0)*
δ_{15}	0.23 (4.1)*	0.50 (10.1)*
δ_{16}	0.23 (4.8)*	0.32 (6.5)*
δ_{17}	0.19 (2.7)*	0.42 (7.4)*
δ_{18}	0.05 (0.7)	0.15 (2.4)*
δ_{19}	0.19 (1.5)	0.47 (5.8)*
δ_{20}	-0.09 (0.5)	0.14 (1.5)
δ_{21}	0.05 (0.3)	0.01 (0.1)
δ_{22-23}	0.15 (0.8)	-0.05 (0.3)
-Loglikelihood	18,683.40	25,026.70
LR-test equal δ's	18.6*	29.2*
Restrictions		
δ_{12-17}	0.26 (7.8)*	-
δ_{18-23}	0 (-)	-
$\delta_{12-17,19}$	-	0.42 (13.1)*
δ_{18}		0.15 (2.3)*
δ_{20-23}	-	0 (-)
-Loglikelihood	18,687.7	25,029.9
LR-test restrictions	8.6	6.4

The datasets contain 4912 males and 6881 females; all estimates include the same explanatory variables, fixed effects and age dummies as in Table 4. The first two and last two age-of-onset categories consist of two years because of the limited number of observations. Note that for females the LR-test of imposing $\delta_{12-17,19}$=δ_{18} equals 11.8, so we cannot reject the hypothesis that the effect of cannabis uptake at age 18 is different; absolute t-statistics in parentheses; a * indicates that the coefficient is different from zero at a 5% level of significance.

Table A1: GMM parameter estimates of the effect of starting cannabis by age 15 on age left school

	Males	**Females**
Cannabis use by the age of 15		
Ever smoked cigarettes daily	0.11 (13.3)*	0.10 (16.2)*
Ever smoked cigarettes but not daily	0.02 (2.6)*	0.01 (2.1)*
Age	-0.02 (2.4)*	-0.01 (2.2)*
Age squared	0.00 (1.3)	0.00 (1.1)
Oz	0.02 (2.2)*	0.00 (0.10)
Rural	-0.01 (1.3)	0.00 (0.4)
Smoked first cigarettes by age 10	0.10 (4.6)*	0.18 (6.0)*
Smoked first cigarettes by age 11	0.11 (3.2)*	0.13 (3.9)*
Smoked first cigarettes by age 12	0.12 (5.7)*	0.17 (7.6)*
Constant	0.45 (3.6)*	0.33 (3.4)*
$\overline{R}^2$	0.10	0.11
Age left school		
Cannabis use by the age of 15	-0.83 (0.9)	-1.85 (3.0)*
Ever smoked cigarettes daily	-1.06 (6.6)*	-0.84 (7.7)*
Ever smoked cigarettes but not daily	0.25 (2.0)*	0.31 (3.1)*
Age	-0.11 (1.8)	-0.06 (1.3)
Age squared	0.00 (1.6)	0.00 (0.1)
Oz	-0.81 (7.6)*	-0.54 (6.3)*
Rural	-0.93 (10.6)*	-0.61 (8.4)*
Constant	22.08 (19.1)*	21.65 (23.2)*
$\overline{R}^2$	0.17	0.12

The datasets contain 4912 males and 6881 females; all estimates include state fixed effects; absolute z-scores in parentheses; a * indicates that the coefficient is different from zero at a 5% level of significance.

Table A2: Parameter estimates bivariate duration model – school-leaving up to 18 years

	Males	**Females**
Cannabis use		
Oz	0.22 (4.2)*	0.37 (6.9)*
Rural	-0.03 (0.7)	-0.06 (1.4)
Age 13	0.33 (1.7)	0.11 (0.6)
Age 14	1.06 (6.3)*	1.23 (7.7)*
Age 15	1.70 (10.8)*	1.95 (13.0)*
Age 16	2.53 (16.8)*	2.35 (16.0)*
Age 17	2.55 (16.8)*	2.53 (17.2)*
Age 18	3.22 (21.7)*	3.12 (21.6)*
Age 19	2.69 (17.2)*	2.90 (19.6)*
Age 20	3.28 (21.4)*	3.02 (20.3)*
Age 21	2.53 (14.8)*	2.71 (17.2)*
Age 22	2.46 (13.8)*	2.54 (15.4)*
Age 23	2.39 (12.8)*	2.48 (14.4)*
Age 24	1.96 (9.0)*	2.23 (11.9)*
Age 25	2.95 (16.4)*	2.98 (17.3)*
Age >25	2.12 (12.3)*	2.25 (13.6)*
Masspoint 1	-3.98 (24.0)*	-4.35 (27.4)*
Masspoint 2	$-\infty$	$-\infty$
School-leaving		
Oz	0.35 (10.1)*	0.25 (8.1)*
Rural	0.54 (17.9)*	0.30 (12.0)*
Age 14	1.98 (12.3)*	2.11 (13.5)*
Age 15	3.52 (24.0)*	3.86 (26.9)*
Age 16	4.27 (29.3)*	4.53 (31.6)*
Age 17	4.65 (32.1)*	4.96 (34.8)*
Age 18	4.96 (34.1)*	5.15 (36.0)*
Masspoint 1	-5.81 (38.0)*	-5.94 (39.7)*
Masspoint 21	0.03 (0.9)	0.32 (11.1)*
Effect cannabis use (δ)	0.24 (6.4)*	0.40 (11.1)*
Unobs. heterogeneity (α)	0.18 (5.9)*	-0.12 (4.7)*
Probability (p_1)	0.54	0.47
-Loglikelihood	17,392.0	23,373.8

The datasets contain 4912 males and 6881 females; all estimates include state fixed effects; absolute t-statistics in parentheses; a * indicates that the coefficient is different from zero at a 5% level of significance.