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Cannabis use and suicidal ideation

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Abstract

Globally, suicide has emerged as the second leading cause of death among youth aged 10-24 years old. In order to better understand the causes of this phenomenon, we investigate the relationship between suicidal ideation and cannabis use. Our empirical analysis is based on a 30 year longitudinal study of a birth cohort. We find that intensive cannabis use – at least several times per week – leads to a higher transition rate into suicidal ideation for males. We find no evidence that suicidal ideation leads to cannabis use for either males or females.

Keywords: cannabis use; suicidal ideation; mental health

JEL codes: C31, I10, I18

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1 Introduction

Adolescence is typically a time of good health. The major threats to health and well being during this period come from injuries, mental health problems, and non-communicable disease risk factors. Amongst 10-24 year olds, suicide is now the second leading cause of death, eclipsed only by motor vehicle accidents (Patton et al., 2009). This has not always been the case. In the US for example, the rate of suicide for adolescents has tripled since 1960, and doubled since 1970. In countries such as Canada, Australia, New Zealand, as well as the US, the suicide rate for 15-24 year olds has now reached 10 deaths per 100,000 in the population or greater (WHO, 2009).[1] In addition to successful suicides, suicidal behaviors include attempted suicide and suicidal ideation (or suicidal thoughts). The incidence of these less visible behaviors is equally shocking. In the US for example, 16% of high school students reported having seriously considered attempting suicide in the past year, 8% reported actually attempting suicide at least once during the same period, while 2% made a suicide attempt that required medical attention (CDC, 2012).

In this paper we seek to determine whether cannabis use plays a causal role in explaining suicidal behavior of youth using longitudinal data on a birth cohort. Over the last 30 years, the proportion of youth who have used cannabis has risen steeply in most developed countries. At the same time, the age at which cannabis is first used has fallen, with uptake now typically occurring in the mid to late teens (Hall, 2006). While most users of cannabis do not suffer any significant ill effects from its consumption, there is mounting evidence that early onset of cannabis use leads to an increased risk of several adverse outcomes including cannabis dependence, early school leaving, and perhaps psychosis. The findings with respect to suicidal behaviors (and other measures of mental health and wellbeing) are less clear cut.

A substantial literature in epidemiology and a smaller one in economics identifies cannabis use as an important risk factor for suicidal behaviors (Fergusson et al., 2000; Beautrais et al., 1999; Reinhertz et al., 1995; Tekin and Markowitz, 2008). These findings raise important questions about the extent to which there is a causal relationship between cannabis use and reduced mental wellbeing. However, studies which seek to establish causality are few and their findings are mixed with some studies reporting a positive effect of substance use on poor mental health outcomes

[1] See: *www.who.int/mental_health/prevention/suicide/country_reports/en/*

and others reporting no effect (Fergusson et al., 1997; Fergusson et al., 2002; Chatterji et al., 2004; Wilcox and Anthony, 2004; Van Ours and Williams, 2011; Van Ours and Williams, 2012).

Understanding the underlying causes of suicidal behaviors is an important, yet understudied area in economics (Marcotte, 2003; Chen et al., 2012). Suicidal behaviors impose significant economic costs on society. For example, the cost of completed suicides by 10-24 year olds in the US in 2005 was estimated to be $6 billion in medical expenses and lost work alone.[2] Non-fatal suicidal behaviors have been shown to reduce the likelihood of young adult's participation in education and employment (Tekin and Markowitz, 2008). Given the enduring impact of education on health, the deficits induced non-fatal suicidal behaviors in youth are likely to have a long lived and cumulative impact on lifetime health and wellbeing (Cutler and Lleras-Muney, 2010). As noted by Heckman (2012), early-life prevention has the dual benefit of extending the quality and length of life and of avoiding costly treatment. It is in this context that we seek to make a contribution by providing new evidence on the causal role of cannabis use in explaining the non-fatal suicidal behavior of youth.

Establishing causality in a relationship between outcomes that result from individual decision-making is an intrinsically difficult task, generally requiring longitudinal information on the outcomes of interest. Even with longitudinal data, the episodic and cyclical nature of suicidal behaviors make identifying the causal effect of cannabis use especially challenging. The innovation of our approach is that it considers the relationship between the onset of suicidal ideation and the uptake of regular cannabis use. The focus on first episodes of suicidal ideation and regular cannabis use affords some confidence that we are able to empirically discern the direction of causal pathways linking substance use and suicidal behavior, and quantify the strength of these effects.

In order to identify the causal effect of cannabis use on suicidal behavior, we address both the potential for reverse causality and common unobserved confounders in this relationship. Ours is the first study to do so. The framework we use is based on a bivariate mixed proportional hazard model in which the transition into cannabis use and into suicidal ideation form a fully simultaneous system. In this system cannabis use is permitted to impact on the onset of suicidal ideation, suicidal ideation is permitted to impact on the uptake of cannabis use, and the unobserved

[2]There are about 4400 lives lost each year to suicide amongst 10-24 year olds in the US.

heterogeneity terms entering each transition rate are potentially correlated. A significant benefit of this framework is that, in addition to providing a reliable estimate of the causal impact of cannabis use on suicidal behaviors, it permits us to establish whether suicidal behavior leads to cannabis use. This is a further contribution of this research.

Our empirical analysis is based on a 30 year longitudinal study of a cohort of children born in 1977 in Christchurch, New Zealand. The Christchurch Health and Development Study (CHDS) is uniquely suited to studying the causal relationship between non-fatal suicidal behaviors and cannabis use, containing annual information on suicidal ideation and annual information on the uptake and intensity of cannabis use for the cohort from the age of 15.[3] Our results reveal that after controlling for personal and family characteristics, there remains a significant correlation in the unobserved heterogeneity terms that enter the hazards for suicidal ideation and cannabis use for both males and females. This renders cannabis use endogenous in the model for the onset of suicidal ideation and suicidal ideation endogenous in the model for the uptake of cannabis. Accounting for this endogeneity, regular cannabis use is estimated to increase the hazard of transitioning into suicidal thoughts for males but not females. Further investigation reveals that that the effect for males is driven by those using at least several times per week. Finally, we find no significant effect of suicidal ideation on the uptake of regular cannabis, for either males or females, once the endogeneity of suicidal ideation is accounted for.

The rest of this paper is laid out as follows. Section 2 provides background information on suicidal behavior, the economics of suicide, and the literature that seeks to identify a causal link from substance use to suicidal behavior and other measures of mental wellbeing. Section 3 introduces the Christchurch Health and Development Study and describes the relevant features of these data. Section 4 lays out our empirical strategy for obtaining causal estimates of the effect of cannabis use on suicidal ideation. Section 5 presents our results and section 6 concludes with a discussion of our findings.

[3]The CHDS also includes annual information on suicide attempts. However, the number of attempts are too few to analyze.

2 Background

2.1 Successful Suicides, Suicide Attempts and Suicidal Thoughts

The World Health Organization estimates that in the year 2000, around 1 million people died from suicide. On average, there are three male suicides worldwide for every female suicide. Only a minority of people who are suicidal actually take their own lives. There is an estimated 10 to 20 people who attempt suicide for each person who dies from suicide (WHO,1999). Suicide attempts are more common among women than men and amongst younger people than older people. Women attempt suicide over their lifetime about two to three times as often as men. It is estimated that for those under the age of 25, there are around 100-200 non-fatal suicide attempts for every fatal one, whereas for those over 65, there are between 2 and 3. Although the extent of suicidal ideation is less clear, the data available indicate that suicidal thoughts are more common among females than males, and among younger people than older people. For example, it is estimated that between 3.5% and 52.1% of adolescents engage in suicidal thoughts compared to between 2.3% and 17% of older adults (WHO, 2002). Amongst high school students in the US, the prevalence of suicidal ideation is estimated to be 19.3% for females and 12.5% for males.

2.2 Risk Factors for Suicide and Suicidal Behaviors

Suicidal behavior has a large number of underlying causes. Often, there will be an event that precipitates suicidal behavior. For adolescents, the most common precipitants are stressful life events such as romantic difficulties, death or loss of a parent or close friend, an argument with a parent, financial or employment problems, or other events that involve humiliation, loss, defeat or threat (Bridge, Goldstein and Brent, 2006; Beautrais et al., 2005). While such events are common experiences in adolescence, only a minority of people are driven to suicide. To act as precipitating factors, these events must happen to someone who is predisposed or otherwise especially vulnerable to self-harm.

Over the last few decades, substantial progress has been made in identifying a large number of predisposing risk factors for suicidal behavior. The strongest risk factor for suicide is the presence of one or more psychiatric disorders (Beautrais et

al., 2005). Mood disorders, especially depression, has consistently been shown to be associated with suicidality.[4] Substance abuse plays a significant role in youth suicide and is also a risk factor for attempted suicide. Moreover, suicide attempters are more likely to have substance abuse/dependence disorders than suicidal ideators, suggesting that substance use may facilitate the transition from ideation to behavior (Bridge, Goldstein and Brent, 2006). Anxiety disorders and conduct disorder are also associated with youth suicide and attempted suicide (Bridge, Goldstein and Brent, 2006; Cash and Bridge, 2009). In an addition to mental disorders, psychological factors such as hopelessness, aggression, impulsivity, and neurotisism are also risk factors for suicidal behavior in youth (Bridge, Goldstein and Brent, 2006). Being physically or sexually abused as a child, a family history of suicide or suicide attempts, parental mental health problems and parental disfunction (such as substance abuse and criminal behavior) are also important risk factors for youth suicidal behaviors (Bridge, Goldstein and Brent, 2006; Beautrais et al., 2005).

Suicidal behavior tends to be recurrent, and especially amongst youth, tends to escalate from ideation, to attempt to completion. The strongest predictor of attempted suicide is suicidal ideation, with the likelihood of an attempt eventuating increasing in the severity and pervasiveness of the suicidal ideation. A prior suicide attempt is the single most potent risk factor for completed suicide amongst youth, elevating the risk of a subsequent completion 10-60 fold (Bridge, Goldstein and Brent, 2006).

2.3 The Economics of Suicide and Suicidal Behaviors

The distinctive feature of the economic approach to suicide is that it views individuals as making choices that maximize their welfare given the circumstances and constraints they face.[5] Hamermesh and Soss (1974) were the first to apply this framework to suicide, focusing on completed suicides of older males.[6] In their model,

[4]Depression is the mental disorder most often associated with suicide. Among children and adolescents, the nature of depression usually differs from that found in adults. Depressed young people tend to exhibit more acting-out — such as truancy from school, declining school grades, bad behavior, violence and abuse of alcohol or drugs (WHO, 2002).

[5]A full review of this literature can be found in Chen et al. (2012).

[6]In their model, individuals (remaining) lifetime utility depends on their age, their permanent income, and their taste for living.

suicide is chosen when the discounted value of remaining life is zero.[7]

Noting that suicide attempts by youth outstrip suicide completions by at least 100 to 1, Cutler, Glaeser and Norberg (2001) reason that not all youth who attempt suicide actually want to die. They also deduce from the very different trends in youth and adult suicide observed over the period 1950-1990, that the factors precipitating suicidal behavior in youth and older adults may not be the same. For example while the rational theory of suicide focuses on the role of permanent income in generating happiness for adults, youths' happiness is likely to be affected by engaging in risky behavior, such as using drugs, as well as the consequences that may follow. Specifically, in the event that the adverse outcome associated with the risky behavior is realized, the negative utility from the present pain may exceed the discounted present value of future utility even if in the future, the pain has passed (Cutler, Glaeser and Norberg, 2001). Hyperbolic discounting exacerbates this scenario, as it places higher weights on the present pain relative to future utility compared to exponential discounting.[8] The empirical investigation finds that engaging in risky behaviors, including drug use, is strongly correlated with suicide attempts. This is consistent with the rational, or happiness, theory of suicide. It is unclear, however, whether the relationship uncovered is causal or reflects other unmeasured influences that impact on both suicidal and risky behaviors.

2.4 Substance Use and Suicidal Behaviors

The association between suicidal behavior and substance use has been well established. However, there are several potential explanations for the observed correlations. As discussed above, Cutler, Glaeser and Norberg (2001), applying the happiness (or rational) model of suicidal behavior to youth predict that substance use will lead to suicidal behaviors in the event that the adverse outcome associated with substance use is realized. This suggests a causal pathway from substance use to suicidal behavior. An alternative explanation is that suicidal individuals self-medicate

[7] A key prediction of this model is that suicide is a decreasing function of permanent income. The authors find support for this prediction using cross-sectional state level data (for 1960) and time series data (for 1947-1964) for males in the US.

[8] The authors also explore other theories of suicidal behavior including the strategic theory whereby youthful suicide attempts are motivated by a desire to resolve conflicts, or garner attention from family or friends. Similar to the strategic motivation for suicide attempt, Marcotte (2003) hypothesizes that attempted suicide is motivated by a "cry for help", intended to elicit attention or resources, rather than a desire to end an unhappy life.

by using illicit substances (McGee et al., 2000). This implies that causation runs in the reverse direction, from suicidal behavior to substance use. A third explanation is that the empirical correlation between substance use and suicidal behaviors is spurious, reflecting common unobserved confounders.

We are aware of only a few studies that seek to tease out the causal relationship between substance use and suicidal behaviors, or mental wellbeing more broadly defined. Chatterji et al. (2004) investigate the impact of binge drinking on suicide attempts. The primary analysis, based on the Youth Behavioral Risk Survey, leads the authors to conclude that binge drinking is unlikely to causally affect suicidal attempts. However, using a much smaller sample of females from the National Comorbidity Survey, the authors do find some evidence that clinically defined alcohol use disorder is causally related to suicide attempts. The relationship between cannabis use and mental health is examined in two papers by Van Ours and Williams (2011, 2012). The former paper is based on the Australian National Drug Strategy Household Survey while the latter uses Dutch data. Both studies find that cannabis use reduces mental wellbeing (measured by the K10 and SF36 mental health score, respectively), particularly amongst high frequency users (Van Ours and Williams, 2011). A shortcoming of these three studies is that they all use cross-sectional data. This is an issue because mental illness and suicidal behaviors tend to be episodic, making it difficult (in the absence of longitudinal data) to know whether cannabis use preceded or followed poor mental health, and thereby satisfactorily account for reverse causality.

This issue is partly addressed by Fergusson et al. (1997), Fergusson, Horwood and Swain-Campbell (2002), and Wilcox and Anthony (2004). Fergusson et al. (1997) consider the impact of early cannabis use on later suicide attempts (as well as major depression, and anxiety disorder) using the CHDS. The authors find no evidence that using cannabis before the age of 16 increases the odds of suicide attempts (or major depression or anxiety disorder) over the ages of 16-18. Along similar lines, Wilcox and Anthony (2004) consider the impact of any cannabis use before the age of 16 on the onset of suicidal ideation in late adolescence. They conclude that the association between these variables is likely to reflect unmeasured common confounders unaccounted for in their analysis. Whilst the potential for reverse causality is minimized by the design of these two studies, the potential for common unobserved factors remains a caveat in giving the findings a causal interpretation.

Also using the CHDS, Fergusson, Horwood and Swain-Campbell (2002) address the potential for common unobserved confounders in the relationship between cannabis use and suicidal behavior using a conditional fixed effects logit model. They find that the likelihood of suicidal behaviors is increasing in the frequency of cannabis use, with the effect larger for younger individuals (aged 14-15) than older ones (aged 20-21). As noted by the authors, a caveat to this study is that it does not account for the potential for reverse causality in studying the contemporaneous relationship between cannabis use and suicidal behaviors.

The current research builds on these earlier studies by accounting for both reverse causality and common unobservables. Our approach uses a bivariate hazard framework and focuses on the onset of suicidal ideation and the uptake of regular cannabis use. The empirical analysis is based on the Christchurch Health and Development Study.

3 Data

3.1 The Christchurch Health and Development Study

The data used in our analysis were gathered over the course of the Christchurch Health and Development Study (CHDS). The CHDS is a longitudinal study of a birth cohort of 1265 children born in the urban region of Christchurch, New Zealand in 1977. The cohort have been studied at birth, four months, one year and at annual intervals to the age of 16 years, and again at ages 18, 21, 25 and 30. Information was obtained from a variety of sources including parental interviews, teacher reports, self-reports, psychometric assessments, medical and other recorded data. An overview of the study design and methodology can be found in Fergusson et al. (1989) and Fergusson and Horwood (2001).

The core of the data used in this paper relates to information gathered when the respondents were aged 15-30 years. During this time, participants were interviewed up to 6 times at ages 15, 16, 18, 21, 25 and 30. As far as possible participants were interviewed around the time of their birthday, or if this was not possible, they were asked to respond in relation to their birthday. Our analysis is based on 938 individuals (479 females and 459 males), which represents 74% of the original birth cohort. The sample size reflects the number of observations for which we have

non-missing data on the full set of covariates.[9]

3.2 Onset of Suicidal Ideation

Suicidal ideation is defined as thinking about taking your own life. At the age 15 assessment, sample members were asked whether they had ever thought of taking their own lives by suicide. At each subsequent assessment, sample members were questioned about having suicidal thoughts in the interval since the previous assessment. So for example, the age 16 assessment asked about the period 15-16 years of age. For assessments at ages 18, 21, 25 and 30, the period since the last assessment was divided into one year age intervals and respondents were asked about each age interval. Respondents who reported having suicidal thoughts were also asked about whether they had made a suicide attempt during the interval.[10] This information permits the creation of each individual's history of suicidal ideation and suicide attempts up to the age of 30.

Table 1 shows the distribution of the age at which suicidal thoughts are first reported. This information is displayed in the form of the hazard rate for the transition into suicidal thoughts in panel b of Figure 1. This graph shows that the hazard rate for suicidal ideation is especially high at young ages for females. For example at age 15, almost 12% of females report suicidal ideation. This spike is due in part to the censored nature of the data since reports at the age 15 assessment refer to having ever had suicidal thoughts. Left censoring of the onset of suicidal ideation is clearly an issue for females and we address it in our empirical strategy. Left censoring does not appear to be an issue for males. Only around 3% of males report having ever had suicidal thoughts at age 15, and there are peaks in the hazard

[9] A total of 200 cohort members drop out of the study at age 18 once they (rather than their parents) become the respondents. The large majority of observation loss arises from missing observations on parent reported behavior, for example on parental alcohol abuse. The issue of sample attrition and missing data has been previously examined by Fergusson and Horwood (1997). They find that there is a tendency for these issues to produce a sample that slightly under-represents children from socially disadvantaged backgrounds. Fergusson et al. (2005) carried out an extensive examination of the impact of sample attrition and missing data in their study of the impact of cannabis use on psychotic symptoms. They found that their results were robust to their efforts to account for these issues, suggesting that the effects of missing data and attrition are minimal. In a sensitivity analysis presented below we show that our main findings are also robust to the inclusion of a dummy variable for missing information on parent reported behavior.

[10] For example, the 18 year assessment included questions on suicidal ideation over the periods 16-17 and 17-18, and the 21 year assessment asked about suicidal ideation over the periods 18-19, 19-20 and 20-21 years.

rate for suicidal ideation for males at ages 16 and 19 of around 6%.

Table 1 also shows the age of onset for suicide attempts. A total of 48 females and 27 males in the sample attempted suicide. This represents, 10.0% of females and 5.9% of males in the sample. As these numbers are too small to perform an analysis of the determinants of suicide attempts in relation to prior cannabis use, the remainder of this paper focuses on suicidal ideation.

3.3 Uptake of Cannabis Use

Cohort members were questioned about the frequency of their cannabis use at ages 15, 16, 18, 21, 25 and 30. At each assessment, individuals are asked about use since the last assessment. So, for example the age 15 assessment asked about the period 14-15 years of age. As with suicidal ideation, the period since the previous assessment was divided into one year age intervals and respondents were asked about each age interval at age 18, 21, 25 and 30 assessments. In this way, the data collection provides individual level information on cannabis use annually over the ages of 14-15 to 29-30 years old.

Table 1 shows the age distribution for the uptake of cannabis for several measures of frequency of use. Specifically, we show the distribution of age at which cannabis is first used monthly, first used at least weekly, first used more than weekly but less than daily, first used daily, as well as ever use. As can be seen from the table, the transition to ever use typically happens at earlier ages than the transition into monthly use, which occurs prior to the transition into weekly use, which in turn precedes the transition onto more than weekly and daily use. Bearing in mind that our aim is to determine the impact of cannabis uptake on the transition into suicidal ideation, and the average age for first having suicidal thoughts (amongst those who are observed to do so by the age of 30) is 16.9 for females and 18.2 for males (see Table 2), we focus on the uptake of monthly cannabis use in our baseline model. We explore models based on more frequent cannabis use in our sensitivity analysis.[11]

[11]One may be concerned that regular uptake may occur before the first measurement at age 14-15. This does not appear to be much of a problem in practice as only 11 females and 6 males report monthly cannabis use at age 14-15. Nonetheless, we further explore this issue by using information from the age 14 survey, which covers the period 13-14 years. This assessment does not provide information on frequency of use, but simply asks respondents whether they have used cannabis in the 12 months prior to survey. Only 14 females and 11 males report using cannabis over the ages of 13-14. Moreover, given that only 1 in 3 females and less than 1 in 4 males who report any cannabis use at age 14-15 report using it monthly, it seems that measurement error in

The information on the transition into monthly cannabis use in Table 1 is displayed graphically in the form of the hazard rate for males and females in Figure 1. Panel a of Figure 1 shows that there are spikes in the transition rate to monthly cannabis use at age 17 and 19. The spikes are more pronounced for males than females.

3.4 Covariates

The CHDS includes information on many of the key risk factors known to affect the uptake of cannabis and the onset of suicidal ideation. These risk factors include characteristics of the individual, their parents and the socio-economic background of the family. We control for the individual's mental wellbeing over the ages of 7 to 9 years using separate indexes of their level of anxiety and their level of behavioral problems; sexual abuse and physical abuse with separate indicators for each type of abuse over the ages 0-16 years; parents' use of illicit drugs, abuse of alcohol, and criminality with three separate indicators for parental use of drugs, parental alcohol abuse or dependence, and parental offending history; mother's education; father's education; decile of the distribution of family income averaged over ages 0-10 years; and family socio-economic status at the time the individual was born.

The CHDS also collected information on various stressful or adverse events from the age of 15. Table 5 shows the distribution of the age at which stressful or adverse financial/employment events, relationship events, illness or death events, victimization events, and pregnancy related events are first reported.[12] As shown, many of the stressful or adverse life events first occur at a young age, usually 16-18. The exceptions are victimization, which has a median age of 19 for males and 21 for females and pregnancy related events, which has a median age greater than 30. Our baseline model will account for stressful or adverse life events that first occur at the age of 15. We examine whether events that first occur at subsequent ages impact on the onset of suicidal ideation and cannabis uptake in the sensitivity analysis. Details on the definition of the control variables are contained in the Appendix. Sample means are reported in Table 2.

regular use prior to age 14-15 is unlikely to have much of an impact on our estimates.

[12]Individuals may have experienced more than one event at the same age.

3.5 Descriptive Statistics

Figure 2 shows the cumulative probability distributions for the onset of suicidal ideation and the uptake of monthly cannabis use. It shows that both the onset of suicidal ideation and the uptake of monthly cannabis use are unlikely to occur after the age of 25. This suggests that there are (at least) two distinct types with respect to susceptibility to suicidal ideation and cannabis use: those who are susceptible to the behavior and those who are not. As shown in Table 2, 38% of females in the sample have experienced suicidal thoughts and 62% have not and are unlikely to do so. For males, 31% have experienced suicidal thoughts while 69% have not. There exists a similar dichotomy for monthly cannabis use, with 37% of females and 53% of males using cannabis at least monthly at some point in the sample period. The average starting age for suicidal ideation is 16.9 for females and 18.2 for males, substantially below the average starting age for monthly cannabis use, which is 19.3 for females and 19.1 for males. The onset of more frequent cannabis use occurs at older ages. For example, the average starting age for daily cannabis use is 21.6 for females and 21.1 for males.

Table 3 shows the joint distribution of (ever having) suicidal thoughts and (ever) using cannabis. Cannabis use is defined as using monthly or more often in panel *a*, as weekly or more often in panel *b*, as using at least several times a week in panel *c*, using at least daily in panel *d*, and any cannabis use in panel *e*. Strikingly, the tabulations in Table 3 show that, while females are much more likely to experience suicidal thoughts, both male and female cannabis users are roughly twice as likely to have suicidal thoughts relative to the comparison group irrespective of frequency with which cannabis use is measured. For example, the probability of experiencing suicidal thoughts for females who have never used cannabis monthly is 26.9% compared to 57.3% of females who have. For males, 21.4% of those who have not used cannabis monthly have experienced suicidal thoughts compared to 40.2% of those who have used cannabis monthly. Similarly, the probability of experiencing suicidal ideation amongst those who have not used cannabis daily is 35% for females and 25.5% for males compared to 74.4% and 50.9% respectively for female and males who have used cannabis daily. In addition, Table 3 shows that the probability of experiencing suicidal ideation increases with the frequency of cannabis use. Overall, there appears to be evidence of correlation between suicidal ideation and cannabis

use in general, with the strength of this relationship increasing with more frequent cannabis use.

If the correlation between cannabis use and suicidal ideation represented a causal relationship from cannabis use to suicidal ideation, then the onset of cannabis use should, on average, precede the onset of suicidal ideation. Table 4 investigates this issue, tabulating the probability associated with the possible combinations of timing of events with respect to the onset of suicidal ideation and cannabis uptake. Consider the uptake of monthly cannabis use. Table 4 shows that only 4.4% of females and 9.4% of males used cannabis monthly prior to having suicidal thoughts, that 3.8% of females and 2.6% of males started monthly cannabis use and began having suicidal thoughts at the same age, while 13.2% of females and 9.4% of males first used cannabis monthly after they had their first suicidal thought.[13] The likelihood that cannabis uptake occurs prior to the onset of suicidal ideation is smaller for cannabis use measured as at least weekly, more than weekly and daily. Overall, this information provides no clear cut evidence on the nature of the relationship between cannabis use and suicidal ideation.

In the empirical analysis that follows we focus on monthly cannabis use and assume that only monthly cannabis use that begins prior to the age of onset of suicidal ideation can potentially have a causal effect. Similarly, we only allow suicidal ideation that occurs at an age prior to the onset of monthly cannabis use to have a causal impact on the uptake of monthly cannabis use. As part of a sensitivity analysis we also investigate the relationship between more frequent cannabis use and suicidal ideation.[14]

4 Set-up of the Empirical Analysis

The aim of this paper is investigate whether the uptake of cannabis use leads to the onset of suicidal ideation. To do so, we use a bivariate mixed proportional hazard framework. In order to establish whether there exists a causal relationship running from cannabis use to suicidal ideation, our methodology must account for the possi-

[13]It is noteworthy that 16.9% of females and 20% of males experienced suicidal ideation but have never used cannabis monthly.

[14]As is clear from Table 4 identification of the impact of daily use for females is problematic as there are only only 4 females who start using cannabis daily before they start having suicidal thoughts and this is too few observations to identify an effect.

bility that suicidal ideation leads to the uptake of cannabis, and that the correlation between cannabis use and suicidal ideation may reflect common confounding factors. This is achieved by modeling the two transitions as a fully simultaneous system in which the unobserved heterogeneity terms entering the transition rates are correlated. To be specific, prior suicidal ideation is permitted to impact cannabis uptake and prior cannabis uptake enters the hazard for transitions into suicidal ideation. Because the unobserved heterogeneity terms determining each transition rate are assumed to be jointly distributed, our specification accounts for endogeneity arising from reverse causality and common unobserved confounders. A major advantage of using this bivariate duration approach is that, as shown by Abbring and Van den Berg (2003), 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, that is the order in which initiation into cannabis use and suicidal ideation occurs.[15]

In modeling the uptake of regular cannabis use, we assume that potential exposure to cannabis occurs from the age of 15. The starting rate for regular cannabis use at time t (t =0 at age 15) conditional on observed characteristics x, the age of onset of suicidal ideation t_s and unobserved characteristics u is specified as

$$\theta_c(t \mid x, t_s, u) = \lambda_c(t) \exp(x'\beta_c + \delta_s I(t_s < t) + u) \tag{1}$$

where $I(t_s < t)$ is an indicator function equal to one if suicidal ideation first occurred prior to time period t, $\lambda_c(t)$ represents individual duration dependence and β_c represents a vector of parameters to be estimated.[16] Unobserved heterogeneity accounts for differences in individuals susceptibility to cannabis use. We model duration (age) dependence in a flexible way by using a step function $\lambda_c(t) = \exp(\Sigma_k \lambda_{c,k} I_k(t))$, where k (= 1,..,7) is a subscript for age categories and $I_k(t)$ are time-varying dummy variables that are one in subsequent categories. We specify 7 age dummies, 6 of which are for individual ages (age 15, ..,20) and the last interval is for ages $\geq$21 years.

[15] 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.

[16] As we only know the age at which each event first occurs and not the actual date, we are unable to determine whether suicidal ideation occurred first if both the onset of suicidal ideation and cannabis use occurred at the same age. It is for this reason that we allow suicidal ideation to impact on cannabis uptake if and only if it occurred in a previous period.

Because we also estimate a constant term, we normalize $\lambda_{c,1} = 0$. Our explanatory variables are defined in the appendix.

The parameter δ_s is of particular interest as it indicates whether previous suicidal ideation has a positive effect on cannabis uptake as would occur under reverse causality ($\delta_s > 0$), a negative effect on cannabis uptake ($\delta_s < 0$), or no effect on cannabis uptake ($\delta_s = 0$). The conditional density function for the completed durations until the uptake of cannabis use can be written as

$$f_c(t \mid x, t_s, u) = \theta_c(t \mid x, t_s, u) \exp(-\int_0^t \theta_c(s \mid x, t_s, u)ds) \tag{2}$$

Similarly, we model the onset of suicidal ideation at time t conditional on observed characteristics x, prior cannabis use t_c and unobserved characteristics v as

$$\theta_s(t \mid x, t_c, v) = \lambda_s(t) \exp(x'\beta_s + \delta_c I(t_c < t) + v) \tag{3}$$

where $\lambda_s(t)$ represents individual duration dependence which is modeled using a step function. To account for left censoring in the onset of suicidal ideation, we assume that individuals are at risk of transitioning into this behavior from age 14 and that the risk is constant at ages 14 and 15.

The effect of previous cannabis use on the onset of suicidal ideation is measured by δ_c. This is the key parameter of interest as it informs us as to whether previous cannabis use increases the risk of suicidal ideation ($\delta_c > 0$), reduces the risk of risk of suicidal ideation ($\delta_c < 0$), or has no direct effect on the likelihood of experiencing suicidal ideation ($\delta_c = 0$). The conditional density function for the completed duration until first suicidal ideation can be written as

$$f_s(t \mid x, t_c, v) = \theta(t \mid x, t_c, v) \exp(-\int_0^t \theta(s \mid x, t_c, v)ds) \tag{4}$$

The potential correlation between the unobserved components in the hazard rates for cannabis uptake and suicidal ideation is taken into account by specifying the joint density function for the duration of time until cannabis uptake t_c and the duration of time until suicidal ideation t_s conditional on x as

$$h_{c,s}(t_c, t_s \mid x) = \int_u \int_v f_c(t \mid x, t_s, u) f_s(t \mid x, t_c, v) dG(u, v) \tag{5}$$

$G(u, v)$ is assumed to be a discrete distribution with 4 points of support (u_1, v_1), (u_2, v_1), (u_1, v_2), (u_2, v_2) reflecting the finding of two types of individuals in the hazard rate for cannabis uptake (high susceptibility, low susceptibility) and two types in the hazard rate for suicidal ideation (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:

$$\Pr(u = u_1, v = v_1) = p_1, \quad \Pr(u = u_2, v = v_1) = p_2$$
$$\Pr(u = u_1, v = v_2) = p_3, \quad \Pr(u = u_2, v = v_2) = p_4$$

with $0 \leq p_j \leq 1$ for $j = 1, .., 4$, $p_4 = 1 - p_1 - p_2 - p_3$. These probabilities are modeled using a multinomial logit specification.

5 Empirical Results

5.1 Parameter Estimates

The parameters of the simultaneous bivariate hazard model for the uptake of cannabis use and the onset of suicidal ideation are estimated separately for males and females using maximum likelihood. The main parameters of interest in this research are the coefficient on regular cannabis use in the equation for suicidal ideation, and the coefficient on suicidal ideation in the cannabis uptake equation. The first row of Table 6 reports these key parameter estimates for the uptake of monthly cannabis and the onset of suicidal ideation assuming the unobserved heterogeneity terms in these processes are correlated.

The estimates indicates that for males, after accounting for the potential endogeneity of cannabis use, the rate at which monthly cannabis users first experience suicidal ideation is 100% (100(exp(0.70)-1)) greater than otherwise similar males who have not used cannabis monthly. For females, we find no direct effect of monthly cannabis use on the onset of suicidal ideation once we have accounted for its potential endogeneity. The results also show that we find no evidence of reverse causality.

Specifically, after accounting for its potential endogeneity, suicidal ideation has no direct effect on the uptake of monthly cannabis use for males or females.

The joint distribution of unobserved heterogeneity is found to have 4 masspoints for both males and females:[17]

		Females (%)			Males(%)		
Cannabis use		Ever	Never	Total	Ever	Never	Total
Suicidal	Ever	25	20	45	21	10	31
Ideation	Never	15	40	55	33	36	69
	Total	40	60	100	54	46	100

The distribution of unobserved heterogeneity implies that 21% of the male sample and 25% of the female sample belong to the Type 1 group, having a positive cannabis starting rate and a positive starting rate for suicidal ideation (u_1, v_1), 10% of males and 20% of females belong to the Type 2 group with a zero cannabis starting rate and a positive starting rate for suicidal ideation (u_2, v_1), while 33% of males and 15% of females are from the Type 3 group and have a positive cannabis starting rate and a zero starting rate for suicidal ideation (u_1, v_2). Finally, 36% of the males and 40% of the females have a zero starting rate for both cannabis use and suicidal ideation (u_2, v_2).

In order to compare the estimates with the raw data, we must consider the marginal distributions of types in terms of their susceptibility to cannabis use and suicidal ideation. The estimates imply that, conditional on observed characteristics, 45% of females are the type who will experience suicidal ideation compared to 38% in the raw data. This suggests that our method for accounting for left censoring works reasonably well.[18] Conditional on observed characteristics, 31% of males are estimated to be the type who will experience suicidal thoughts, which matches the sample proportion. In terms of cannabis uptake, the estimates imply that 40% of

[17]We investigated the existence of an additional masspoint u_3, v_3. We started with a small probability attached to this masspoint and starting values which were slightly different from u_1, v_1. The location of this fifth mass point converged to one of the existing masspoints, i.e. the optimal value of the loglikelihood function does not improve compared to the model with four masspoints.

[18]If we ignore the left censoring in suicidal ideation of females, the estimated probability of being the type who will experience suicidal ideation is 0.60. The upward bias in the estimated probability of being this type induces a strong negative age effect in the baseline hazard. However, it does not much affect the parameter estimates of interest.

females and 54% of males are of the type who will, at some point in their life, use cannabis regularly. The corresponding sample proportions are 37% for females and 53% for males.

Although not reported, our findings with regard to the determinants of the transition into suicidal ideation are in broad agreement with previous research. For example, sexual abuse is found to increase the transition rate into suicidal ideation as does having a parent who reports a history of alcohol abuse or dependence at the age 15 interview. A greater level of conduct problems in childhood is associated with a higher transition into suicidal thoughts as is experiencing stressful life events related to relationships (for females), illness or death of family members or close friends (for females), or being a victim of crime (for males), at age 15.

5.2 Sensitivity Analysis

5.2.1 Intensity of cannabis use

Our analysis has found that using cannabis at least monthly leads to the onset of suicidal ideation in males. It may be however, that the causal impact of cannabis use on the transition into suicidal ideation depends on the intensity with which cannabis is used. For example, our findings may be entirely driven by daily cannabis users, or there may be a heterogeneous response with more intense use leading to a faster transition into suicidal thoughts. In order to investigate this issue, we estimate models based on alternative definitions of cannabis use that reflect greater intensity of use.

Rows 2 to 4 of panel *a* in Table 6 report the results for models in which cannabis uptake is defined to be at least weekly, several times per week, or daily, respectively. Both the model for the transition into cannabis use and the effect of cannabis on the uptake of suicidal ideation are specified in terms of at least weekly use (row 2), several times per week (row 3), or daily (row 4). No results are reported for daily cannabis use for females because the number observed to have used at this frequency is insufficient for the model to converge.

As can be seen from Table 6 panel *a*, irrespective of the measure of intensity of cannabis use considered, the findings are consistent with those reported for the baseline specification: the onset of cannabis use increases the hazard rate of suicidal ideation for males but not females and the onset of suicidal ideation has no significant

effect on the hazard rate for transitioning into cannabis use for either males or females. Importantly, we find for males that the magnitude of the effect of cannabis use on the transition into suicidal ideation increases with the intensity of cannabis use.

5.2.2 Independent or Correlated Processes?

Up until this point, all specifications presented have assumed that the unobserved components of the transition into cannabis uptake and suicidal ideation are correlated. We now examine whether the data support this error structure.

Key results for the case in which unobserved heterogeneity in the transition into cannabis use and suicidal ideation is assumed to be independent are contained in Panel *b* of Table 6.[19] As with panel *a*, row 1 shows the coefficient estimates when cannabis use is defined as at least monthly while rows 2-4 report the results for models in which cannabis uptake is defined to be at least weekly, several times per week, or daily, respectively. The null hypothesis of independent errors is examined using a Likelihood Ratio test. The level of significance at which the null hypothesis of independent transitions is rejected is indicated by the stars following the value of the log likelihood in panel *b* of Table 6. For both males and females, irrespective of the intensity of cannabis use considered, we reject the null hypothesis at the 5% level of significance and conclude that the unobserved heterogeneities determining the onset of suicidal ideation and regular cannabis use are not independent.[20]

A comparison of the point estimates in panels *a* and *b* of Table 6 reveals that failing to account for the correlation in unobserved heterogeneity produces an overestimate of the causal effect of cannabis use on suicidal ideation, indicating a positive correlation in unobserved heterogeneity. For males, ignoring the correlation between the two transition rates leads to an (over)estimate of the causal effect of weekly cannabis use on suicidal thoughts of 256% (100(exp(1.27)-1)), compared to an estimate of 186% from the fully simultaneous model. Similarly for females, failing to account for its endogeneity leads to the conclusion that weekly cannabis use increases the rate of onset of suicidal ideation by 183% (100(exp(1.04)-1)), whereas

[19]The estimated effects of the covariates in the cannabis uptake and the onset of suicidal ideation equations are not sensitive to whether the unobserved heterogeneity terms are modeled as correlated or not.

[20]The LR test statistic for the null hypothesis that the unobserved heterogeneity terms are independent is distributed as a chi-squared with 1 degree of freedom.

no direct causal effect is found in the fully simultaneous model.

It is also clear from comparing the results in panels *a* and *b* of Table 6 that ignoring the endogeneity of suicidal ideation in the hazard for cannabis uptake produces an upward bias, significantly positive estimate of the impact of suicidal ideation for all intensities of cannabis use for females and for the uptake of daily cannabis use for males. Once its endogeneity is accounted for, suicidal ideation is found to have no direct effect on the uptake of cannabis for males or females, irrespective of the measure of cannabis use.

On the basis of these findings, the sensitivity analysis that follows focuses on investigating the robustness of the estimated impact of prior cannabis use on the onset of suicidal ideation for males only.

5.2.3 Time varying covariates

So far, the empirical specification we employ accounts for a rich set of determinants of cannabis use and suicidal ideation that are time invariant. These determinants include stressful or adverse life events at the age of 15. However, the existence of omitted time varying common confounders may compromise the reliability of our estimates. To mitigate this issue we introduce three time varying covariates into the hazard model for the onset of suicidal ideation. The first measures the onset of stressful life events related to relationships from the age of 16, the second measures the onset of stressful life events related to deaths and illness of family and friends from the age of 16, and the third measures the onset of stressful life events related to being a victim of crime from the age of 16. These three variables are included in addition to the three indicators for stressful life events that first occur at age 15. The key results from estimating this extended model are reported in panel *b* of Table 7. Panel *a* repeats the key findings from panel *a* of Table 6, which we take as our baseline model.

As can be seen from comparing the estimates reported in panels *a* and *b* of Table 7, adding the time varying covariates for adverse life events does not affect our main parameter estimates. Moreover, these three variables are jointly insignificant at the 5% level of significance.[21]

[21]The Likelihood Ratio test statistic equals 1.0. The critical value for a $\chi^2_{0.05}$ for 3 degrees of freedom is 7.8.

5.2.4 Missing information

Missing information on parent reported behavior such as parental alcohol use leads to a substantial reduction in the size of the sample used for estimation. To investigate whether our findings are affected by selection into the estimation sample on the basis of complete information on parent reported behavior, we perform a sensitivity analysis in which we re-introduce these observations and include an indicator for them having missing information. This expands our dataset from 479 to 630 females and from 459 to 635 males. Panel *c* of Table 7 shows the relevant parameter estimates. The results suggest that including the observations dropped due to missing parental information does not have a large effect on the main parameter estimates.

5.2.5 Combining various intensities of cannabis use

By way of a final sensitivity analysis, we investigate whether different intensities of cannabis use have statistically different effects on the rate of onset of suicidal ideation by simultaneously including several intensities of use in the model for the onset of suicidal ideation. The various specifications reported in panels *d* to *f* of Table 7 are based on a bivariate simultaneous hazard model in which the cannabis outcome is the transition into(at least) monthly cannabis use. In panel *d*, we categorize the intensities of cannabis use that may impact on the onset of suicidal ideation as at least monthly but less than weekly, at least weekly but less than several times per week, several times per week but less than daily, and at least daily. We test the null hypothesis that the four intensities have equal effects using an LR test, where the restricted model of equal effects is the baseline model in row *a*. The LR test statistic has a value of 42 which is larger than the critical value of a $\chi^2_{0.05}$ with 3 degrees of freedom, which is 7.8. This leads us to conclude that the different intensities of cannabis use do not have equal effects on the onset of suicidal ideation.

The results in row *d* suggest that the lesser intensities of use may not directly impact on suicidal ideation. We take a stepwise approach to investigating this by restricting the effect of monthly use but less than weekly use to be zero in row *e*, and then additionally restricting the effect of at least weekly but less than several times a week to be zero in row *f*. A LR test of the restriction that at least monthly but less than weekly use has no effect on the onset of suicidal ideation is supported by

the data.[22] Similarly, the null hypothesis that the effect of using at least weekly but less than several times per week has no effect on suicidal ideation is also supported by the data.[23] As a consequence, the model reported in row f emerges as our preferred model. In this model, using cannabis several times a week but less than daily increases the rate of onset of suicidal ideation by 120% compared to someone who uses less often, while daily use increases the transition into suicidal thoughts by 2,257% compared to someone who uses less often than several times a week. Thus, it is intensive cannabis use, defined as using at least several times per week that is driving the causal impact of cannabis use on the onset of suicidal ideation among males.

5.2.6 Magnitude of the effects

To illustrate the magnitude of the impact of intensive cannabis use on suicidal ideation we perform a number of simulations using the parameter estimates corresponding to the model represented by row f of Table 7. These simulations are presented in Table 8. They show the cumulative prevalence of suicidal ideation among the group males who are susceptible to suicidal ideation, which represents around 31% of males, from ages 17 to 30. Note that since the probability of being susceptible to suicidal ideation does not depend on cannabis use, altering the age that cannabis is first used and the intensity with which it is used does not affect the proportion of the population who are susceptible to suicidal ideation.

The first column shows the simulated average cumulative probability of having suicidal thoughts for a reference male, who did not use cannabis or used at a frequency of less than several times per week, but has otherwise average characteristics. We will refer to this scenario as the non-cannabis using scenario for simplicity. In this case, the prevalence of suicidal ideation increases from 46% at age 17 to 96% at age 30. This implies that, if no males used cannabis (or used at an intensity less than several times a week), the population prevalence of suicidal ideation for males would grow from 14% for 17 year olds to 30% for 30 year olds.

Columns 2 and 3 show the prevalence of suicidal ideation in the susceptible group

[22] LR test statistic is 1.6 which is smaller than the critical value for a $\chi^2_{0.05}$ for 1 degree of freedom, which is 3.8.

[23] LR test statistic is 0.4 which is smaller than the critical value for a $\chi^2_{0.05}$ for 1 degree of freedom, which is 3.8.

that arises if all males start using cannabis at least several times a week but less than daily at the age of 17, and start using daily at the age of 17, respectively. This affects the onset of suicidal ideation from the age of 18. As can be seen, the impact of the uptake of cannabis at these intensities at an early age has a large impact on the rate at which susceptible males transition into suicidal ideation. Column 2 shows that by the age of 18, using several times a week (from the the age of 17) leads to 77% of the susceptible group having had suicidal thoughts, while at age 21, 99% of this group have had suicidal thoughts. This translates into a population prevalence of 24% and 31% respectively. Column 3 shows that starting daily use at the age of 17 leads to 99% of the susceptible group having suicidal thoughts by the age of 18 and 100% having suicidal thoughts by the age of 21, which corresponds to around 31% of he population having suicidal thoughts by the age of 18. By comparison, under the non-cannabis use scenario, 50% of males in the susceptible group had suicidal thoughts by age 18 and 79% had them by the age of 21, which translates to population prevalence rates of 15% and 24% respectively.

The next two columns of Table 8 repeat the exercise assuming that the uptake of cannabis occurs at the age of 20. By construction, this impacts on the transition into suicidal ideation from the age of 21. The simulations show that the transition into using cannabis more than weekly but less than daily, and to using daily at the age of 20 increases the proportion of the susceptible group who have had suicidal thoughts by the age of 21 from 79% (in the non-cannabis using scenario) to 91% for those using several times a week, and to 99% for those using daily. This translates into a population prevalence for males at age 21 of around 31% for daily users and 28% for those using several times a week compared to 24% in the non-cannabis use scenario. By the age of 25, 90% of the vulnerable group have had suicidal thoughts in non-cannabis using scenario compared to 100% in either the daily or several times per week cannabis using scenarios. This leads to population prevalence rates of 28% in the non-cannabis use scenario and 31% in either of the two cannabis using scenarios.

This exercise makes one point very clear: While all in the susceptible group will eventually have suicidal thoughts, using cannabis earlier and more intensely will hasten the onset of suicidal thoughts substantially.

6 Discussion

This research aims to shed light on the links between cannabis use and suicidal behavior. In particular, we wish to determine whether (1) regular cannabis use leads to the onset of suicidal ideation, and (2) whether suicidal ideation leads to the uptake of cannabis use. We focus on the onset of suicidal ideation and the uptake of cannabis use so as to avoid issues related to cycles in suicidal behavior and substance use. In order to account for their potentially bidirectional relationship, we use a fully simultaneous bivariate mixed proportional hazard framework to model the transitions into cannabis use and into suicidal ideation. In this system, cannabis use is permitted to impact on the onset of suicidal ideation, suicidal ideation is permitted to impact on the uptake of cannabis use, and the unobserved heterogeneity terms entering each transition rate are permitted to be correlated.

Our empirical investigation, based on a 30 year longitudinal study of a birth cohort, provides two main findings. First, after accounting for the endogenous relationship between cannabis use and suicidal ideation, we find that using cannabis at least several times a week leads to suicidal ideation in susceptible males. Second we find that, after accounting for its endogeneity, suicidal ideation does not lead to cannabis use for either males or females. Our results also indicate that (1) the earlier that intense use first occurs, the faster susceptible individuals start having suicidal thoughts, and (2) the higher the frequency of cannabis use, the faster susceptible individuals start having suicidal thoughts.

As with any empirical study, there are several caveats that need to be imposed on our conclusions. First, our analysis is based on self-reported information on suicidal ideation and cannabis use. As such there is the possibility of measurement error that may impact on the estimates. Second, the relationship between cannabis use and suicidal behavior is clearly a complex one, potentially involving cycles and escalation in behavior. Our analysis limits itself to the first episode of suicidal ideation and the first episode of regular cannabis use, and therefore cannot capture the complexities of these inter-related behaviors. However, by avoiding these issues, we are able to empirically discern the direction of causal pathways linking cannabis use and the onset of suicidal ideation.

An important question raised by our research is why we find that the uptake of intensive cannabis use increases the risk of onset of suicidal ideation for males

but not for females. We hypothesize that gender differences in the onset of suicidal ideation and the uptake of intensive use of cannabis creates a power issue for our analysis. In particular females have both an earlier onset of suicidal ideation and are less likely to use cannabis intensively than males, and this results in too few observations to be able to empirically discern the effect of intense cannabis use on the onset of suicidal ideation for females. For this reason, our view is that the most likely interpretation of the findings is that they suggest the possibility a causal relationship from intensive cannabis use to suicidal ideation for both males and females, but because we observe few females starting intensive cannabis use before having their first suicidal thoughts, we simply do not have sufficient power to detect the effect for females in our sample. Future research should consider the effect of cannabis use on subsequent bouts of suicidal ideation in order to determine whether the harmful effects beyond the first suicidal thoughts are similar for males and females.

One of the contributions of our research is that it provides a framework for viewing the sometimes conflicted literature. Unsurprisingly, our findings correspond closely to those of Fergusson, Horwood and Swain-Campbell (2002), who find that cannabis use leads to suicidal behaviors, with larger effects at younger ages and at higher frequencies of use. We conjecture that the lack of significant findings in Fergusson et al. (1997), who look at the impact of cannabis use before the age of 16 on suicidal behavior over the ages 16-18, may be related to too few individuals using cannabis before the age of 16 at a sufficiently high intensity to induce suicidal behavior over the ages 16-18. The finding from our research that it is intensive and regular substance use only that leads to suicidal behaviors is consistent with Chatterji et al. (2004) who report that clinically defined alcohol abuse is causally related to suicidal behavior but less intensive problematic drinking is not. Along similar lines, Van Ours and Williams (2012) report that while (lifetime) cannabis use reduces mental wellbeing, its effect is small, similar in magnitude to having a migraine. A dose response relationship is reported by Van Ours and Williams (2011), who find that current cannabis use has a larger detrimental effect on mental health than past use and that the magnitude of the effect of current use increases with the intensity of use. The results from the current study complement these findings, showing that extreme psychological distress (as measured by suicidal ideation) is not sensitive to casual cannabis use but is sensitive to intense cannabis use.

An important contribution of our research is that it finds strong evidence that suicidal behavior does not lead to substance use. This is significant because previous studies have generally focused on addressing endogeneity arising from common unobserved confounders but have been unable to address the potential for endogeneity resulting from reverse causality. By finding no empirical evidence of reverse causality, our study supports a causal interpretation for the findings of previous research.

So, what are the policy implications of our paper? First and foremost, our research provides new evidence that intensive cannabis use that starts at a young age increases the rate at which susceptible young people start having suicidal thoughts. This is of significant policy interest since it provides clear information for the targeting of youth suicide prevention programs, identifying behaviors and ages that produce large increases in the risk of transitioning into suicidal behavior. At a broader level, our research adds to a body of work which finds that, for a small minority, cannabis use carries substantial risks. Previous research has established that early and intense cannabis use induces educational deficits and perhaps psychosis. Our paper provides credible evidence that the early onset of suicidal ideation is a further adverse outcome of youthful cannabis use for these vulnerable individuals.

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Appendix – list of variables

- Suicidal ideation: dummy variable for the presence of suicidal ideation in the past 12 months; available for each year from age 15 to 30 years.

- Regular cannabis use: Frequency of cannabis use in the past 12 months is at least monthly; available for each year from age 15 to 30 years.

- Casual cannabis use: Frequency of cannabis use in the past 12 months is at least once or twice; available for each year from age 14 to 30 years.

- Education mother (father): assessed at the survey child's birth and score on a 3-level classification as follows: 1 = no formal educational qualifications, 2 = high school qualifications, 3 = university degree, tertiary technical diploma.

- Childhood conduct problems is a continuous scale score measure of the extent of conduct disordered or oppositional behavior problems displayed by the child in middle childhood. It is based on a combination of items from the maternal and teacher report versions of the Rutter and Conners child behavior rating scales assessed at ages 7, 8, 9 years. The score on each item ranged from 0 for a child with no problem to 2 for a child with a great deal of problems. Parent and teacher reports were summed at each age and the resulting scores then averaged over the 3 years to provide a measure of the childs general tendency for conduct problems. See Fergusson, Horwood and Lloyd (1991) for the items that comprise the scales; Fergusson, Horwood and Ridder (2005) for further information on the combined scale. In our data the score ranges from 41 to 97, with low scores implying fewer problems.

- Childhood anxiety is a continuous scale score measure of the extent to which the child displayed problems relating to anxiety, withdrawal, shyness, depression and related behaviors in middle childhood. It is based on a combination of items from the maternal and teacher report versions of the Rutter and Conners child behavior rating scales assessed at ages 7, 8, 9 years. The score on each item ranged from 0 for a child with no problem to 2 for a child with a great deal of problems. Parent and teacher reports were summed at each age and the resulting scores then averaged over the 3 years to provide a measure of the childs general tendency for anxiety/withdrawal. See Fergusson, Horwood

(1993) for the items that comprise the scales; Fergusson, Horwood and Ridder (2005) for further information on the combined scale. In our data the score ranges from 20 to 48, with low scores implying fewer problems.

- SES2 (SES3): family socio-economic status at the time of the child's birth; 1 = professional, managerial, 2 = clerical, technical, skilled, 3 = semi-skilled, unskilled, unemployed.

- Average income: average family income decile measured over the ages 0-10 years; based on estimates of the family's gross income for the past 12 months that were obtained at annual intervals from when the survey child was aged 1 to 10 years; range 1.0-10.0 with larger numbers indicating higher average incomes.

- Parental illicit drug use: dummy variable – based on parental reports of any illicit drug use by either parent obtained when sample members were aged 11 years.

- Parental alcohol problems: dummy variable – based on parental reports of a history of alcohol problems or alcohol dependence for either parent obtained when sample members were aged 15 years.

- Parental criminality: dummy variable – based on parental reports of a history of involvement in criminal offending for either parent obtained when sample members were aged 15 years.

- Childhood sexual abuse: dummy variable – based on retrospective reports of exposure to childhood sexual abuse (0-16 years) with sexual abuse defined as being either contact sexual abuse not involving attempted/completed intercourse or attempted/completed sexual penetration.

- Childhood physical abuse: dummy variable – based on retrospective reports of exposure to childhood physical abuse (0-16 years) with physical abuse defined as at least one parent regularly used physical punishment or at least one parent used physical punishment too often/too severely.

- Stressful or adverse life events: dummy variables – whether or not they occurred in the past 12 months for every age between 15 and 30 years:

- Financial/employment life events: include changes of job, redundancy, unemployment, and serious financial problems.
- Relationship life events: include changes of partner, relationship problems with boy/girlfriends, partners, parents, other relatives or friends, and related difficulties.
- Illness/death life events include life events included serious illness or accident of respondent, close family members or friends, death of a close family member or friend.
- Victimization life events: include having something stolen or vandalized, being burgled, being physically or sexually assaulted.
- Pregnancy related life events: include getting pregnant/getting a partner pregnant, becoming a parent, abortion and miscarriage.

Table 2 provides means of variables.

Table 1: **Starting ages suicidal ideation, suicide attempts and cannabis use**

	Suicidal ideation		Suicide attempts		Cannabis use frequency – at least									
					Monthly		Weekly		More than weekly		Daily		Ever	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
14	–	–	–	–	–	–	–	–	–	–	–	–	14	11
15	53	13	15	0	11	6	2	3	1	3	0	1	34	27
16	39	28	3	4	12	17	7	7	4	4	4	2	51	51
17	31	23	7	2	33	56	19	42	16	40	4	19	94	102
18	8	11	9	5	27	32	9	16	9	14	3	6	37	41
19	5	23	4	5	28	52	24	52	17	43	0	0	37	67
20	8	7	2	1	18	18	3	15	2	12	2	27	27	19
21	9	5	5	5	13	18	7	12	5	12	2	5	11	13
22	7	9	0	1	14	24	14	30	12	18	12	14	17	20
23	7	9	0	1	3	6	6	7	2	6	0	3	7	4
24	2	2	0	0	3	5	4	6	3	3	4	5	7	4
25	3	1	2	1	5	5	4	4	2	3	1	58	4	4
26	1	2	1	0	9	3	8	6	6	7	4	18	4	6
27	0	1	0	0	0	0	1	0	0	0	0	0	2	0
28	0	2	0	2	0	0	1	0	0	0	1	1	1	3
29	1	2	0	0	1	1	2	1	2	0	1	0	4	1
30	2	1	0	0	1	1	1	0	1	0	1	0	2	1
Never	303	320	431	432	301	215	367	258	397	294	440	353	126	85
Total	479	459	479	459	479	459	479	459	479	459	479	459	479	459

Table 2: **Means of variables**

	Females	Males
Suicidal ideation		
Prevalence (%)	38.2	31.4
Starting age	16.9	18.2
Prevalence cannabis use (%)		
Ever	73.7	81.5
At least monthly	37.1	53.2
At least weekly	23.3	43.8
Several times per week	17.1	36.0
Daily	8.1	23.1
Starting age cannabis use		
Ever	18.2	18.2
At least monthly	19.3	19.1
At least weekly	20.4	19.6
Several times per week	20.2	19.5
Daily	21.6	21.1
Explanatory variables		
Education mother	1.72	1.72
Education father	1.69	1.71
Childhood anxiety/10	2.61	2.58
Childhood conduct problems/10	4.82	5.12
SES2	0.54	0.55
SES3	0.23	0.26
Average income	5.24	5.10
Parental illicit drug use	0.26	0.22
Parental alcohol problems	0.12	0.12
Parental criminality	0.12	0.12
Childhood sexual abuse	0.17	0.04
Childhood physical abuse	0.16	0.19
Stressful or adverse life events at age 15		
Relationship	0.49	0.39
Illness/death	0.11	0.12
Victimization	0.06	0.07
Observations	479	459

Table 3: **Cross-tabulation ever had a suicidal ideation and ever used cannabis by intensity of cannabis use (percentages)**

a. Cannabis use at least monthly

	Females		Males	
Suicidal ideation	No cannabis	Cannabis	No cannabis	Cannabis
No	220 (73.1)	76 (42.7)	169 (78.6)	146 (59.8)
Yes	81 (26.9)	102 (57.3)	46 (21.4)	98 (40.2)
Total	301 (100.0)	178 (100.0)	215 (100.0)	244 (100.0)

b. Cannabis use at least weekly

	Females		Males	
Suicidal ideation	No cannabis	Cannabis	No cannabis	Cannabis
No	261 (71.1)	35 (31.2)	201 (77.9)	114 (56.7)
Yes	106 (28.9)	77 (69.8)	57 (22.1)	87 (43.2)
Total	367 (100.0)	112 (100.0)	258 (100.0)	201 (100.0)

c. Cannabis use several times per week

	Females		Males	
Suicidal ideation	No cannabis	Cannabis	No cannabis	Cannabis
No	273 (68.8)	23 (28.1)	226 (76.9)	89 (53.9)
Yes	124 (31.2)	59 (72.0)	68 (23.1)	76 (46.1)
Total	397 (100.0)	82 (100.0)	294 (100.0)	165 (100.0)

d. Daily cannabis use

	Females		Males	
Suicidal ideation	No cannabis	Cannabis	No cannabis	Cannabis
No	286 (65.0)	10 (25.6)	263 (74.5)	52 (49.1)
Yes	154 (35.0)	29 (74.4)	90 (25.5)	54 (50.9)
Total	440 (100.0)	39 (100.0)	353 (100.0)	106 (100.0)

e. Cannabis use ever

	Females		Males	
Suicidal ideation	No cannabis	Cannabis	No cannabis	Cannabis
No	95 (75.4)	201 (56.9)	71 (83.5)	244 (65.2)
Yes	31 (24.6)	152 (43.1)	14 (16.5)	130 (34.8)
Total	126 (100.0)	353 (100.0)	85 (100.0)	374 (100.0)

Table 4: **Suicidal ideation and cannabis use – timing of events (percentages)**

	Cannabis use			
	At least monthly		At least weekly	
	Females	Males	Females	Males
Cannabis use first	21 (4.4)	43 (9.4)	14 (2.9)	33 (7.2)
Cannabis use same age	18 (3.8)	12 (2.6)	6 (1.2)	12 (2.6)
Cannabis use later	63 (13.2)	43 (9.4)	57 (11.9)	42 (9.2)
Suicidal ideation, no cannabis	81 (16.9)	46 (10.0)	106 (22.1)	57 (12.4)
Cannabis, no suicidal ideation	76 (15.9)	146 (31.8)	35 (7.3)	114 (24.8)
No cannabis, no suicidal ideation	220 (45.9)	169 (36.8)	261 (54.5)	201 (43.8)
Total	479 (100.0)	459 (100.0)	479 (100.0)	459 (100.0)

	More than weekly		Daily	
	Females	Males	Females	Males
Cannabis use first	9 (1.9)	30 (6.5)	4 (0.8)	14 (3.1)
Cannabis use same age	4 (0.8)	11 (2.4)	1 (0.2)	9 (2.0)
Cannabis use later	46 (9.6)	35 (7.6)	24 (5.0)	31 (6.8)
Suicidal ideation, no cannabis	124 (25.9)	68 (14.8)	154 (32.1)	90 (19.6)
Cannabis, no suicidal ideation	23 (4.8)	89 (19.4)	10 (2.1)	52 (11.3)
No cannabis, no suicidal ideation	273 (57.0)	226 (49.2)	286 (59.7)	263 (57.3)
Total	479 (100.0)	459 (100.0)	479 (100.0)	459 (100.0)

	Ever	
	Females	Males
Cannabis use first	49 (10.2)	72 (15.7)
Cannabis use same age	34 (7.1)	15 (3.3)
Cannabis use later	69 (14.4)	43 (9.4)
Suicidal ideation, no cannabis	31 (6.5)	14 (3.1)
Cannabis, no suicidal ideation	201 (42.0)	244 (53.2)
No cannabis, no suicidal ideation	95 (19.8)	71 (15.5)
Total	479 (100.0)	459 (100.0)

Table 5: **Starting ages stressful or adverse life events**

	Financial/ employment		Relationship		Illness/death		Victimization		Pregnancy related	
	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
15	0	0	235	178	54	53	29	34	1	0
16	0	0	92	78	46	46	16	21	8	6
17	138	153	43	68	103	89	40	58	10	3
18	166	138	45	34	120	112	66	92	17	12
19	62	69	13	29	26	23	24	28	33	10
20	23	16	9	12	24	23	38	39	26	12
21	16	17	5	9	28	40	53	49	19	14
22	15	14	0	3	11	1	14	15	9	22
23	7	8	4	5	5	6	11	6	18	15
24	9	5	5	4	7	5	12	2	9	24
25	4	6	2	7	8	11	16	12	23	19
26	2	2	0	1	3	4	0	2	10	5
27	1	2	1	1	0	4	7	5	9	11
28	1	1	1	2	5	1	5	6	17	20
29	3	1	0	0	3	2	5	1	13	19
30	0	0	1	1	2	5	3	8	14	23
Never	32	27	23	27	34	34	140	81	243	244
Total	479	459	479	459	479	459	479	459	479	459
Median age	18	18	16	16	18	18	21	19	>30	>30

Table 6: **Parameter estimates Mixed Proportional Hazard models**

	Females			Males		
Cannabis use	Effect Cannabis Use on Suicidal Ideation	Effect Suicidal Ideation on Cannabis use	-Loglikelihood	Effect Cannabis Use on Suicidal Ideation	Effect Suicidal Ideation on Cannabis use	-Loglikelihood
a. Bivariate MPH Model						
1. At least monthly	0.12 (0.3)	0.23 (1.1)	1396.5	0.70 (2.5)**	-0.03 (0.2)	1372.8
2. At least weekly	0.58 (1.4)	0.50 (1.4)	1197.7	1.05 (3.8)**	-0.20 (0.9)	1287.7
3. Several times per week	0.84 (1.4)	0.07 (0.2)	1092.0	1.33 (5.1)**	-0.01 (0.0)	1187.9
4. Daily	–	–	–	2.81 (7.4)**	-0.08 (0.2)	1048.2
b. Independent MPH Models						
1. At least monthly	0.59 (2.0)**	0.39 (2.1)**	1410.0**	0.92 (3.5)**	-0.00 (0.0)	1379.8**
2. At least weekly	0.94 (3.2)**	1.04 (4.2)**	1204.0**	1.27 (4.7)**	-0.16 (0.8)	1296.4**
3. Several times per week	0.98 (3.1)**	1.27 (2.5)**	1094.7**	1.59 (6.3)**	0.03 (0.1)	1196.3**
4. Daily	–	–	–	3.02 (9.6)**	0.52 (1.8)*	1053.5**

Note that in addition to the parameters presented all estimates contain the explanatory variables and stressful or adverse life events at age 15 reported in Table 2. The structure of age dependence was as follows in estimates 3: for both males and females age dummies 16, 17, 18, 19, 20, 21+. In estimates 4 the structure of age dependence was as follows: for females age dummies 17, 18-19, 20, 21+; for males age dummies 16, 17, 18-19, 20, 21+; samples of 479 females and 459 males; absolute t-statistics in parentheses; a ** (*) indicates significance at 5% (10%). For the ** (*) indicated for the loglikelihoods these refer to Likelihood Ratio test comparing panels a and b (1 degree of freedom; critical $\chi^2_{0.05}$-value=3.8.

Table 7: **Additional parameter estimates bivariate MPH model; effect cannabis use on suicidal ideation – various sensitivity analyses for males**

	Effect		-Loglikelihood
a. Baseline	0.70	(2.5)**	1372.8
b. More stressful events	0.74	(2.5)**	1372.3
c. Including missing information	0.62	(2.2)**	1617.4
d. At least monthly but less than weekly	0.03	(0.1)	
At least weekly but less than several times per week	-0.36	(0.5)	
Several times per week but less than daily	0.80	(1.2)	
Daily	2.83	(2.1)**	1393.8
e. At least weekly but less than several times per week	-0.36	(0.5)	
Several times per week but less than daily	0.76	(2.0)**	
Daily	2.76	(3.2)**	1394.6
f.Several times per week but less than daily	0.79	(2.2)**	
Daily	3.16	(9.4)**	1394.8

Note that in all estimates we model the uptake of regular (at least monthly) cannabis use. In panels d to f the uptake of suicidal ideation is allowed to be influenced by various intensity of cannabis use indicators ; also note that in addition to the parameters presented all estimates contain the same explanatory variables and structure of age dependence as in Table 6; samples of 459 males (except estimate c: 635 males); absolute t-statistics in parentheses; a ** (*) indicates significance at 5%

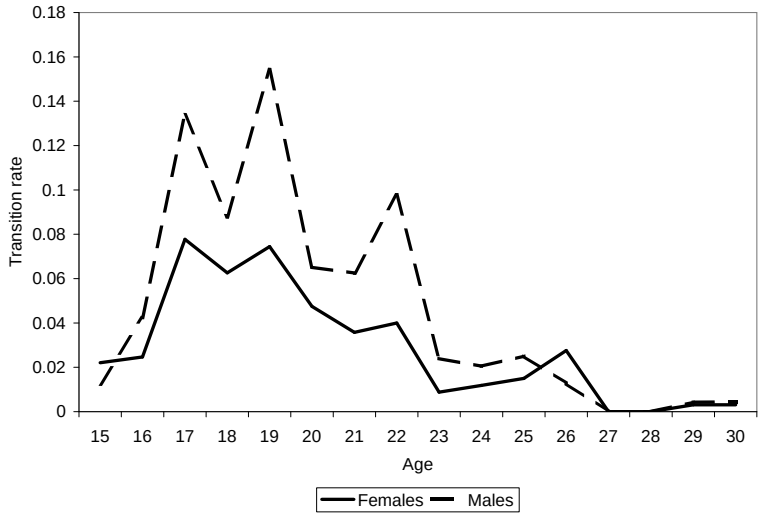
Table 8: **Effect on cumulative probability of suicidal ideation for the susceptible group of males; simulations (%)**

		Cannabis use at age 17		Cannabis use at age 20	
	No	More than weekly		More than weekly	
Age	cannabis	Less than daily	Daily	Less than daily	Daily
17	46	46	46	46	46
18	50	77	98	50	50
19	70	94	100	70	70
20	75	98	100	75	75
21	79	99	100	91	99
25	90	100	100	100	100
30	96	100	100	100	100

Note: The simulations are based on parameter estimates related to the results reported in Table 7f. The simulations are based on means of variables, except for cannabis use; the susceptible group contains 31% of the males.

Figure 1: Transition rates for the uptake of monthly cannabis use and the onset of suicidal ideation by age and gender

a. Transition rates for the uptake of monthly cannabis use



b. Transition rates for the onset of suicidal ideation

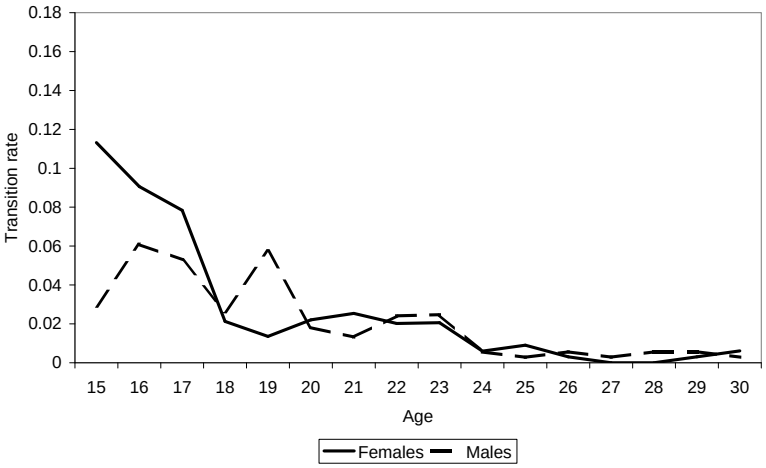
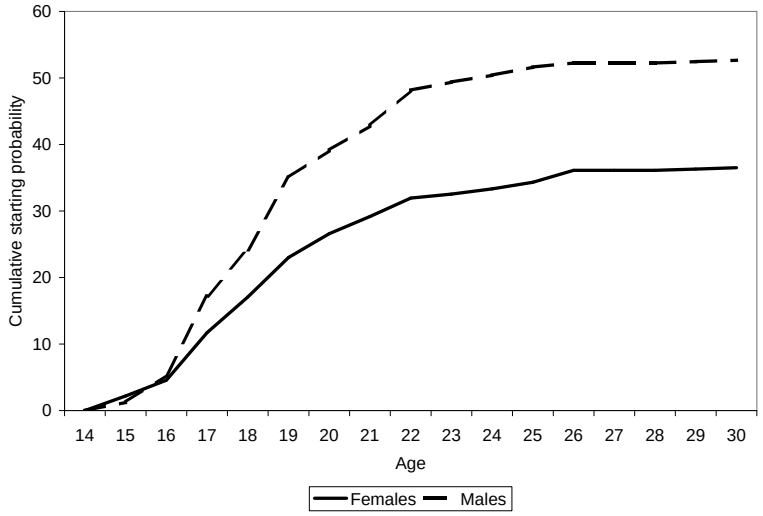


Figure 2: Cumulative starting probabilities for the uptake of monthly cannabis use and the onset of suicidal ideation by age and gender

a. Cumulative starting probability for the uptake of monthly cannabis use



b. Cumulative starting probability for the onset of suicidal ideation