The Effects of Cannabis Use on Physical and Mental Health

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Abstract

This paper investigates whether cannabis use affects physical and mental health. To do so, we use information on prime aged individuals living in Amsterdam in 1994. Accounting for the potential endogeneity of cannabis use and shared frailties in mental and physical health, we find that cannabis use leads to worse mental health and worse physical health for men. For women, cannabis use is found to result in worse mental health but has no significant impact on physical health. The average effect of cannabis use on mental wellbeing is estimated to be similar to aging a man by eleven years and aging a woman by twenty years. The average effect on the physical health of a man is to age him by eight years.

Keywords: cannabis use; physical health, mental health; duration models

JEL codes: C41, D12, I19

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1 Introduction

Cannabis users account for 80% of the 200 million illicit drug users in the world (UNODC, World Drug Report, 2005). In countries such as the US, the UK and Australia, over 30% of the population have used cannabis.[1] In part, its widespread use reflects the common belief that cannabis is not a particularly harmful drug.[2] The weight of evidence supports this belief, finding that the harms associated with cannabis use are much less serious than those associated with "hard" drugs such as cocaine or heroin and may even be smaller than those associated with alcohol and cigarettes (Nutt et. al, 2010; Nutt et al. 2007; Hall et al. 1999). And while it is widely acknowledged that there are risks associated with long term heavy use of cannabis, most of those who have used cannabis do not become long term heavy users and little is known about the health risks that typical users face. This lack of knowledge is unfortunate for users, potential users, policy makers, and society in general because, as shown by Orphanides and Zervos (1995), when there are uncertainties about the risks associated with using a drug public information about these risks can reduce demand and improve welfare.[3] It is in this context that we seek to make a contribution by studying the mental and physical health consequences of cannabis use.

In addition to considering the health impacts of a more general class of cannabis use than is typically studied, this paper is the first to account for the potential for common unobserved confounders linking both physical and mental health in studying the health effects of cannabis use. This represents a significant contribution given the potential for shared frailties underlying both physical and psychological well being. We are able to deal with this in our modeling framework by using the discrete factor approach and allowing for unobserved time invariant heterogeneity determining physical health, mental health and the dynamics of cannabis use to

[1] Its legal status was established almost globally under the 1961 Single Convention on Drugs (UN 1961) when cannabis use was uncommon in most western countries.

[2] This view was espoused in the prestigious journal, Lancet's editorial in 1995, where it was stated "The smoking of cannabis, even long term, is not harmful to health." (p. 1241 Editorial).

[3] Pudney (2010) provides some empirical evidence that public information about the health risks of drug use is an effective tool for demand reduction.

be correlated. In addition to addressing shared frailties in the two dimensions of health, this set-up accounts for the potential endogeneity of cannabis use that arises through common unobserved confounders.

Despite the potential welfare benefits of reliable information on the health consequences of cannabis use, there are very few contributions from the economics literature on this issue. Previous studies from economics that do attempt to tease out causal effects suggest that there may be risks to both mental and physical health from using cannabis. For example, Williams and Skeels (2006) find that consuming cannabis weekly or more often reduces self-assessed health status while Van Ours and Williams (2010) report that past year cannabis use reduces mental health.

There is a more substantial literature documenting the relationship between health and cannabis use contributed by medicine and epidemiology. The literature on the physical health effects of cannabis use has focussed on studying the impact on specific diseases, such as cancers, chronic obstructive pulmonary disease and emphysema, all of which take many years to develop.[4] As a consequence, these analyses examine long term heavy cannabis use and find robust evidence that long term daily use of cannabis is causally related to the development of several kinds of cancers and respiratory diseases. There is less consensus from the medical and epidemiology literature about the mental health impact of cannabis use. In a recent review of the literature, Moore et al. (2007) concludes that cannabis use increases the risk of psychotic outcomes (which includes disorders that involve delusions, hallucinations, or thought disorders) but not affective outcomes (which includes affective, mood or bipolar disorder, depression, suicidal behavior, anxiety, neurosis and mania). The 2004 review by McLeod et al., does not reach the same conclusion. Rather, it finds the available evidence is not sufficient to support the existence of a causal relationship running from cannabis use to psychological problems.[5]

[4]For a good review see Hall and Pacula (2003).

[5]Their concerns include unobserved common confounders, the potential for reverse causality as well as population patterns in mental health. Most notably, while cannabis use has increased substantially over the past 30 years, the incidence of schizophrenia has been stable or slightly decreased over the same period, casting doubt on a causal relationship running from cannabis to schizophrenia.

Interestingly, there appears to be no attempt in either the economics or epidemiology literature to account of the potential for shared frailties in physical and mental health when considering the health effects of cannabis use. This appears to be an important gap in the literature as there is significant evidence of a correlation between poor physical and mental health (Aneshensel, Frerichs and Huba, 1984).[6] The impact of failing to account for this in studying the effect of cannabis use on a single dimension of health will, in the very least, impact of the efficiency of estimation and hence bias results towards finding no significant effect of cannabis use. In the case of non-linear models such as those used here, failing to account for shared frailties in health may also lead to unreliable estimates of the health effects of cannabis use.

We address the potential for shared frailties in physical and mental health as well as the potential endogeneity of cannabis consumption by using a discrete factor approach (Heckman and Singer, 1984). Specifically, we jointly estimate a four equation system consisting of an equation for physical health, an equation for mental health, the hazard rate for starting cannabis use, and the hazard rate for quitting cannabis use where each equation includes an unobserved heterogeneity term that is drawn from a joint discrete distribution. By allowing these heterogeneity terms to be correlated across the four equations, we account for both the potential for shared frailties across the two domains of health and the endogeneity of cannabis use in the health equations.

Our empirical analysis is based on prime age individuals living in Amsterdam. Dutch data offer a clear advantage in estimating the health impacts of cannabis use because, as explained below, the legal status of cannabis in the Netherlands ensures that the estimates are free from confounding with the physical and psychological effects of engaging in a criminal activity. This is especially relevant given the move in recent years to more liberal cannabis policy regimes in the US and Europe. Our results suggest that for men, cannabis use has a detrimental effect on both mental and physical health. While cannabis use is also found to lead to worse mental health for women, it does not seem to impact on their physical wellbeing.

The rest of the paper is laid out as follows. Section 2 provides information on the

[6]This may be attributed to common unobserved confounders such as stress or a lack of social support, or it may reflect a causal link.

legal system governing cannabis use in the Netherlands and describes the data used in our analysis. Section 3 contains the empirical analysis and section 4 discusses our findings.

2 Cannabis use in Amsterdam

2.1 Data

The Netherlands has a special type of drug policy. The main aim is to protect the health of drug users, the people around them and society as a whole.[7] Regulations on drugs are laid down in the Opium Act, which draws a distinction between hard drugs, such as cocaine and heroin, and soft drugs such as cannabis. The possession of hard drugs is a crime. However, a policy of tolerance is applied to soft drugs. Under this policy, while the possession of small quantities of cannabis for personal use is a misdemeanor (and potentially punishable by a fine) official guidelines prescribe that these offences are not prosecuted. The policy of tolerance has been in place since 1976. It has also been applied to the sale of cannabis by house dealers since 1979, and subsequently"coffee shops", meeting strict criteria: no overt advertising, no hard drugs, no nuisance, no underage clientele, and no large quantities (Korf, 2002). Consequently, both the use and procurement of cannabis can be can be achieved without turning to illicit markets and without fear of prosecution. This is a distinctive feature of the Dutch system and one that enables us to estimate the health consequences of cannabis use free from the confounding effects attributable to engaging in illegal behavior.

We use data from Amsterdam, which has a population of 700,000 inhabitants and around 300 recognized, so-called "coffee-shops" where cannabis can be purchased. The individual level survey data were collected in 1994 and are representative of inhabitants of Amsterdam aged 12 years and older.[8] The Municipal Population Registry of Amsterdam was used as the sampling frame and the survey was con-

[7] An international perspective on Dutch drug policy is given in Boekhout van Solinge (1999).

[8] Information on cannabis use has been collected in other years as well, but the 1994 survey was unique in the collection of health information; see Abraham et al. (2003) for a detailed description.

ducted between April and August 1994. Although the response rate was just over 50%, the sample appear to be a good representation of the population (Sandwijk et al., 1995).[9] Moreover, individuals who originally declined the survey or were repeatedly not at home were re-approached to investigate the source of the low response rate and whether they were very different from those who did participate in the survey. This revealed that indifference was the main reason for the non-response, that there was not substantial differences between those who did not respond to the original survey and those who did, and that the prevalence of cannabis use was lower amongst non-responders than amongst those who did respond to the initial survey. However, the overall prevalence rate for cannabis use was not significantly affected by differences between response and non-response groups (Sandwijk et al., 1995).

Our analysis is based on information on 834 men and 889 women. The data on cannabis use are based on self-reported information, which is the norm for analyses of drug consumption. We focus on prime age individuals, i.e. individuals aged 26 to 50 years. Because immigrant groups tend to underreport cannabis use the analysis is restricted to native Dutch inhabitants of Amsterdam. Definitions of variables used in the analysis can be found in Appendix A; Table 1 presents the means of the variables. As shown in Table 1 the average age of the individuals in our sample is about 36.5 years, about 40% of men and women are single, and about 30% of the men and 40% of the women have children. Slightly more men than women have secondary education and slightly more women than men have higher education. In terms of cannabis use, 49% of men have used cannabis in their lifetime, 20% have done so in the last year and 13% in the month prior to being surveyed. For women in the sample, 41% have ever used cannabis, 8% used in the past year and 3% in the past month. Amongst those who have ever used cannabis, the average age at first use is about age 19.5 years.

[9]The only substantial difference is that people originating from Turkey, Morocco, Surinam and the Antilles are under-represented. Our analysis is confined to native Dutch inhabitants of Amsterdam.

2.2 Stylized facts

In the following analysis we differentiate between cannabis users who have used in the twelve months prior to survey, whom we refer to as current users, and those who have used at some point in the past but stopped using more than 12 months prior to survey, whom we refer to as past users. Current users can also be described as those who have started to use cannabis and have not yet quit, while past users are those who have both started and quit use. Characterizing cannabis use status in terms of the dynamics of cannabis use lends itself to analysis in terms of the rate at which people start and stop cannabis use. In modeling these rates, the outcomes of interest are the age at which the respondent first used cannabis and, amongst those who have used cannabis, the age at which they quit use.

Figures 1*a* and *b* show the starting rates of cannabis use and quitting rates, respectively, for men and women in the sample. Figure 1*a* shows the starting rates, which are transition rates from non-use to use for each particular year of age, conditional on not having used up until that age. In calculating age-specific starting rates, those who have not started to use cannabis at the time of survey are considered to have a duration until use that is right censored. As can be seen in Figure 1*a*, the hazard of starting cannabis use peaks at 18 years old for men and women. The starting rate increases from age 12, reaching a maximum at age 18 and drops off dramatically after the age of 20.

Figure 1*b* shows the quit rates, defined as the probability of ceasing to use cannabis at a particular duration of use, given that the individual has not stopped up until that duration. If an individual is still using cannabis at the time of survey, their duration of use is considered to be right censored. As shown in Figure 1*b*, the quit rate for cannabis use is very high in the first year of use after which it remains fairly constant.

Our measures of health come from the SF-36. We use the Physical Functioning Index to represent physical health and the Emotional Wellbeing Index to represent mental health.[10] These indices are scaled such that larger numbers represent better

[10]The physical functioning index is constructed uses 10 item from the SF-36 and the emotional well being index is constructed using 5 items. The indices were constructed using the scoring rules

health status and are normalized to have a sample mean of 50 and standard deviation of 10. Figure 2 graphs the distribution of both health indicators for males and females in our sample. Indeed, most women and the majority of men are in good physical health while only few women and men have bad physical health. Mental health is more evenly distributed but again there are more people in good mental health than in bad mental health. While the distribution of the index of mental health displays greater variation than the physical health index, the two indexes are positively correlated, with a correlation coefficient of 0.3.

Table 2 shows the average value of the Physical Functioning Index and the Emotional Wellbeing Index (index of physical and mental health hereafter) for males and females by their cannabis use status. Cannabis use status is categorized as current user (defined as use in the last year), past user (defined as used in lifetime but not in the past year), and never used. Table 2 shows that for both males and females, there is very little difference in the average physical health score for those who have never used cannabis and those who have used (either in the past or currently). In fact, the average physical health scores are not significantly different across user type. In contrast, the average mental health scores of men and women are highest for never users and lowest for current users, and the difference across user types are generally significant.[11] The evidence in Table 2 suggests that cannabis use may impact on the mental health but not physical health of both men and women. However, this descriptive analysis fails to account for the correlation in the distributions of physical and mental health indices, and it does not account for the potential correlation of unobserved characteristics determining health and cannabis use outcomes. We address these issues in the following section.

for the RAND 36 Item Health Survey 1.0.

[11]For males, the differences between never use and past user as well as never user and current user are significantly different, while for females the average mental health score of current users is significantly different from past and never users.

3 Empirical analysis

Our goal is to estimate the impact of cannabis use (past and current) on physical and mental health. To do so, we jointly estimate a four equation system consisting of an equation for physical health, an equation for mental health, the hazard rate for starting cannabis use, and the hazard rate for quitting cannabis use. In order to account for the potential for unobserved common confounders impacting on cannabis use and health status, each equation includes an unobserved heterogeneity term that is drawn from a joint discrete distribution. This structure allows us to account for shared frailties across the two domains of health as well the potential endogeneity of cannabis use. We build up our empirical model in three steps. First, we model the dynamics of cannabis use (section 3.1). Next we model physical and mental health, treating cannabis use as exogenous (section 3.2). We then bring cannabis use dynamics together with the health equations in section 3.3.

3.1 Cannabis use

Most people use cannabis without becoming addicted. If they knew that they would become addicted, most people would never use cannabis. In practise, however, information about ones addictive "type" is not known before the decision to use is made. Orphanides and Zervos (1995) show that if there is uncertainty with regard to ones own addictive nature, then the decision to use a drug is based on balancing the instant pleasure derived from using an addictive substance against the probabilistic disutility incurred if one becomes addicted. If an individual is not the addictive type, they may use cannabis at low levels infrequently without becoming addicted and hence without incurring the disutility of the harms associated with addiction. If the individual is the addictive type and they learn this before becoming addicted, they will quit use. Otherwise, if they learn too late that they have an addictive personality with respect to cannabis, they will continue to use and do so at a higher level (Orphanides and Zervos, 1995). With this in mind, we study the dynamics of cannabis use accounting for unobserved characteristics that may be correlated across the uptake and quitting decisions.

Specifically, the determinants of the starting rates and quit rates for cannabis use are investigated using the mixed proportional hazard model with flexible baseline hazards (see for an example: Van Ours, 2006). Differences between individuals in the rate at which they start using cannabis are characterized by observed characteristics, elapsed duration of time they are exposed to potential use and unobserved characteristics. Age 12 is assumed to be the time at which individuals are first exposed to cannabis. The starting rate for cannabis at age t conditional on observed characteristics x and unobserved characteristics u^s is specified as (omitting a subscript for individual):

$$\theta^s(t \mid x, v) = \lambda^s(t) \exp(x'\beta + u^s) \tag{1}$$

where $\lambda^s(t)$ represents individual age dependence, and the superscript s refers to starting. We model flexible age dependence by using a step function:

$$\lambda^s(t) = \exp(\Sigma_k \lambda_k^s I_k(t)) \tag{2}$$

where k (= 1,..,N) is a subscript for age-intervals and $I_k(t)$ are time-varying dummy variables for subsequent age-intervals. Age intervals are specified to be one year up until age 30, and the last interval refers to ages over 30. Because a constant term is also estimated, λ_1^s is normalized to 0.[12]

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

$$f^s(t \mid x, u^s) = \theta^s(t \mid x, u^s) \exp(-\int_0^t \theta^s(s \mid x, u^s) ds) \tag{3}$$

The quit rates are also assumed to have a mixed proportional hazard specification. The quit rate for cannabis at duration of use τ conditional on observed characteristics z and unobserved characteristics u^q is specified similarly as:

$$\theta^q(\tau \mid z, u^q) = \lambda^q(\tau) \exp(z'\gamma + u^q) \tag{4}$$

where z contains the age at which the individual started using cannabis in addition to the variables contained in x, $\lambda^q(\tau)$ represents individual duration dependence

[12]The cannabis uptake and quitting equations can be considered reduced forms as neither physical nor mental health enter these equations.

and the superscript q refers to quit.[13] Duration dependence is again modeled as piecewise constant:

$$\lambda^q(\tau) = \exp(\Sigma_m \lambda^q_m I_m(\tau)) \tag{5}$$

where m (= 1,..,M) is a subscript for duration of use-intervals and $I_m(\tau)$ are time-varying dummy variables that are one in subsequent duration intervals. The conditional density functions for the completed durations of drug use can be written as

$$f^q(\tau \mid z, u^q) = \theta^q(\tau \mid z, u^q) \exp(-\int_0^\tau \theta^q(s \mid z, c)ds) \tag{6}$$

Individuals who have not used cannabis at the time of the survey are assumed to have a right-censored duration of non-use. Similarly, individuals who have started cannabis use and are still using at the time of the survey have a right-censored duration of use.

The main parameter of interest in the quit rate is the coefficient on the age of onset. However, if the parameters of the quit rate are estimated separately from the parameters of the starting rate, the influence of the age of onset may not reflect a causal effect since unobserved personal characteristics that affect both the starting rate and the quit rate are not accounted for. This is addressed by specifying the joint density function of the durations of non-use and the durations of use conditional on z and x as

$$f^{sq}(t, \tau \mid x, z) = \int_{u^q} \int_{u^s} f^s(t \mid x, u^s) f^q(\tau \mid z, u^q) dG(u^s, u^q) \tag{7}$$

where $G(u^s, u^q)$ is assumed to be a discrete distribution with s points of support. In practice, we are able to identify three points of support in the joint distribution, (u^s_1, u^q_1), (u^s_2, u^q_2), (u^s_3), with $u^q_2 = u^s_3 = -\infty$ to allow for the possibility of zero starting rates and zero quit rates. The specification of the distribution of unobserved heterogeneity implies that conditional on the observed personal characteristics (including age and duration of use) there are three types of individuals. The first type

[13] Note that quits are assumed to be permanent. Once individuals have decided to quit use they don't return to use again in this model.

represents the "experimenters" who have a positive starting rate and a positive quit rate. The second type represents the "persistent users" who have a positive starting rate and a zero quit rate. Individuals in this group start using and do not stop. The third type are "abstainers". They have a zero starting rate, and therefore the quit rate is non-existent.

The associated probabilities are denoted as

$$\Pr(u^s = u_1^s, u^q = u_1^q) = p_1 \qquad \Pr(u^s = u_2^s, u^q = u_2^q = p_2 \qquad \Pr(u^s =_3= p_3$$

and are assumed to have a multinomial logit specifications $p_n = \frac{\exp(\alpha_n)}{\Sigma_n \exp(\alpha_n)}$, with $n = 1, 2, 3$ and α_3 normalized to zero.

To understand the dynamics of cannabis use, information about the past is required. Specifically, information is needed on characteristics and circumstances faced from the time the individual was potentially first confronted with the choice to start to use cannabis, and conditional on using cannabis, from the time the individual was first confronted with the decision to quit. Ideally, the information is time-varying over the relevant period of life, reflecting the changing circumstances shaping individuals choices. Information that could be important includes family situation, experiences at school, changing cannabis supply conditions, and the price of cannabis as well as the price of substitutes and complements. Unfortunately, this type of information is rarely available, and this is the case in the current analysis.[14]

The observable characteristics that we control for are indicators for educational attainment (secondary education and tertiary education with primary education as the omitted category), and cohort indicators (born in the 1950's, born in the 1960's with born prior to 1960 as the omitted category). These individual characteristics are assumed to be known at the time an individual first faces the decision of whether to start using cannabis. Although the highest level of education may be attained long after the use of cannabis started one might assume that this level represents ability rather than educational investment. In the interpretation of the parameter estimates

[14]Variables that indicate personal characteristics at the time of the survey, such as marital status and presence of children, are not very useful because, in addition to being potentially endogenous, the do not reflect circumstances at the time individuals first face the decision of whether or not to use cannabis. Or, conditional on using cannabis whether or not to stop using.

of the starting rates and quit rates it is assumed that educational level represents ability, and this is taken to be exogenous with respect to drug use and ignores the possibility that cannabis use has an effect on the educational level attained (See Van Ours and Williams, 2009).

The parameters of the models are estimated using the method of maximum likelihood and are reported in Table 2.[15] The general picture that emerges from the parameter estimates in Table 2 is that males and females from more recent birth cohorts with a greater level of education have a higher starting rate for cannabis use compared to those from earlier cohorts and with lower levels of education. For men, those with a secondary level of education and born in the 1950's have a lower quit rate compared to men with a lower level of education and those born more recently. For women, quit rates are higher for those born in the 1960's (compared to earlier cohorts) and those who started using cannabis at older ages. The later effect is also found for Australian men and women (see Van Ours and Williams, 2007).

The results in Table 2 also shows that unobserved heterogeneity is important and that three types of individuals can be distinguished. Conditional on observed characteristics, the estimates imply that 48% of males and 51% of females are of the type who have a positive starting rate and a positive quit rate (type 1 - the experimenters); 8% of males and 3% of females are of the type who have a positive starting rate and a zero quit rate (type 2- persistent users); and 44% of males and 47% of females are of the type who have a zero starting rate (type 3 - never users).[16]

3.2 Health

The starting point for the analysis of the determinants of physical health and mental health are linear equations in which the error term contains two components, ϑ_j and ϵ_j. Each of the error components are assumed to be uncorrelated with the variables contained in x^h. The first component, ϑ_j, is assumed to be drawn from a discrete distribution with an unknown number of points of support and is potentially

[15]The parameters on the age dependence terms in the starting rate and the duration dependence variables in the quit rates are not reported in the table but are available on request.

[16]We tried to identify additional masspoints in the discrete distribution of unobserved heterogeneity but didn't succeed.

correlated with the unobserved heterogeneity impacting on the dynamics of cannabis use. The second component of the error term, ϵ_j is assumed to be drawn from a normal distribution and uncorrelated with cannabis use. For the moment we assume that the use of cannabis is exogenous to health (ϑ_j is uncorrelated with (u^s, u^q)), so we don't account for potential selectivity. Omitting the subscript for individual we assume the following relationship:

$$h_j = \beta_j x^h + \delta_j^c cc + \delta_j^p cp + \vartheta_j + \epsilon_j \qquad \text{for} \quad j = p, m \tag{8}$$

where h represents the health status of the individual, x^h represents the personal characteristics which may affect health (age, education, marital status, presence of children in the household), cc is an indicator for being a current cannabis user and cp is an indicator for being a past cannabis user. Furthermore, j is an indicator that has two values, $j = p$ if the equation relates to physical health and $j = m$ if it relates to mental health. Finally, β_j is a vector of parameters, δ_j^c and δ_j^p are parameter that measure the impact of current and past cannabis use on health, respectively.

In practice we find that the ϑ_j's $j = p, m$ each have two points of support $(\vartheta_{j,1}, \vartheta_{j,2})$. Thus, allowing for correlation across these unobserved heterogeneity terms for physical and mental health, the joint distribution has up to four points of support with

$$\Pr(\vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,1}) = p_1 \quad \Pr(\vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,2}) = p_2$$
$$\Pr(\vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,1}) = p_3 \quad \Pr(\vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,2}) = p_4$$

where p is assumed to have a multinomial logit specification. This implies that, conditional on the observed characteristics and cannabis use, there are four types of individuals which differ both in physical and mental health.[17]

This bivariate system is estimated using maximum likelihood and the results are reported in Table 3. We can clearly distinguish four groups with differing unobserved physical and mental health characteristics. More than three-quarters of the men and women are of the type with good physical and mental health, around 1% males and 5% of females are of the type with good mental health and poor physical health, 18% of men and 13% of women are of the type poor mental health and good physical,

[17]So, across these types physical health and mental health are correlated, but not perfectly.

while 4% of males and 5% of females have poor physical and mental health. As shown in panel *b* of Table 3, using an LR test we reject the null hypothesis that the unobserved heterogeneity terms are uncorrelated across mental and physical health measures, indicating the presence of shared frailties.

Treating cannabis use as exogenous, we find that current use has a significantly negative effect on the physical health of men and that both past and current use has a significantly negative effect on the mental health of men and women. Conditional on their personal characteristics, current cannabis use reduces males' index of physical health by 0.127 standard deviations while past use has no significant effect. Nonetheless, the coefficients on past and current use are imprecisely estimated and not significantly different from each other. Conditional on their personal characteristics, women that currently use cannabis have a 0.36 of a standard deviation lower value for the mental health index than never users, while past female users have 0.165 of a standard deviation lower value for the mental health index. For men, current and past users of cannabis are estimated to have a 0.24 and 0.27 lower value of their mental health index respectively. The point estimates suggest that for women, current use has a larger effect than past use on mental health whereas for men the opposite appears to be the case. However, these effects are not precisely estimated and although (for both men and women) the estimated coefficients on current and past cannabis use in the mental health equation are significantly different from zero, they are not statistically different from each other. As shown in panel *c* of Table 3, on the basis of an LR test, we are unable to reject the null hypothesis of equal effects for past and current use on the mental and physical health indices of both men and women.

The estimates also show that age has a negative effect on physical and mental health and that education has a positive effect on physical health for both men and women. Education is found to have a generally insignificant effect on mental health, with the exception of tertiary education, which is found to have a negative effect on the mental health of males. While marital status is not significantly associated with physical health, being single is associated with a lower level of mental health for both males and females. Having children in the household is associated with better mental health status of men and women as well as better physical health status for

women.

Given that we fail to find any significant differences in the impact of past and current cannabis use on mental health and physical health for both males and females, we combine these user categories in the following analysis.

3.3 Cannabis use and health

As indicated above, we cannot rule out the possibility that cannabis use and health are both influenced by unobserved characteristics which cause a spurious correlation if not accounted for. To investigate this possibility in more detail we estimate a model that allows for the possibility that the random effects in the health equations are correlated with the random effects in the equations for cannabis use dynamics. Combining the three "types" in the unobserved heterogeneity for cannabis use dynamics with the four "types" in the joint distribution of unobserved heterogeneity for physical and mental health implies a joint discrete distribution of unobserved heterogeneity with 12 points of support:

$$\Pr(u^s = u_1^s, u^q = u_1^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,1}) = p_1 \quad \Pr(u^s = u_2^s, u^q = u_2^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,1}) = p_2$$
$$\Pr(u^s = u_3^s, u^q = u_3^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,1}) = p_3 \quad \Pr(u^s = u_1^s, u^q = u_1^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,2}) = p_4$$
$$\Pr(u^s = u_2^s, u^q = u_2^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,2}) = p_5 \quad \Pr(u^s = u_3^s, u^q = u_3^q, \vartheta_m = \vartheta_{m,1}, \vartheta_p = \vartheta_{p,2}) = p_6$$
$$\Pr(u^s = u_1^s, u^q = u_1^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,1}) = p_7 \quad \Pr(u^s = u_2^s, u^q = u_2^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,1}) = p_8$$
$$\Pr(u^s = u_3^s, u^q = u_3^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,1}) = p_9 \quad \Pr(u^s = u_1^s, u^q = u_1^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,2}) = p_{10}$$
$$\Pr(u^s = u_2^s, u^q = u_2^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,2}) = p_{11} \quad \Pr(u^s = u_3^s, u^q = u_3^q, \vartheta_m = \vartheta_{m,2}, \vartheta_p = \vartheta_{p,2}) = p_{12}$$

The p_n $(n = 1, .., 12)$ are assumed to have a multinomial logit specification.

The four equation system, consisting of the equation for the duration until uptake of cannabis, the duration until quitting cannabis, the equation for mental health and the equation for physical health, is estimated jointly using maximum likelihood. Table 4 panel *b* shows the resulting parameter estimate for the coefficient on cannabis use in the physical and mental health equations for men and women respectively.[18] Table 5 and Appendix B provide more detailed information. For the purpose of comparison, Panel *a* of Table 4 repeats the estimated coefficients on cannabis use

[18]Past and current user groups have been combined.

in the case where the dynamics of cannabis use are assumed to be independent of physical and mental health, as reported in Table 3 panel *c*.

The last row of panel *b* of Table 4 contains the LR test statistic for the null hypothesis that cannabis dynamics and health are independent. Independence of cannabis use and health is rejected for men at the 5% level of significance. After taking the correlation of unobserved heterogeneity into account, the effect of cannabis use on physical health increases in magnitude (and significance). This suggests that the unobserved heterogeneities are negatively correlated, so that, conditional on observed characteristics, those who are of the type less likely to use cannabis are also more likely to be in good physical health. In terms of the magnitude of the effect, on average cannabis users' physical health status is estimated to be 0.09 of a standard deviation below the average health index of a male who has never used cannabis.

Accounting for unobserved heterogeneity reduces the estimated effect of cannabis use on mental health for men, but the point estimate remains significantly different from zero. This suggests a positive correlation in unobservables, consistent with those with better mental health selecting into cannabis use. For women we are unable to reject the null hypothesis of independent unobserved heterogeneity components in the cannabis dynamics and health. Indeed, the parameter estimates of the effects of cannabis use on physical and mental health are not much affected when we allow for correlated error terms. We estimate that male and female cannabis users have a mental health status that is 0.16 standard deviations and 0.18 standard deviations, respectively, lower than the mental health of individuals who have never used cannabis.

For illustrative purposes we do a simple within-sample comparison between the effect of cannabis use and the effect of personal characteristics (such as age and marital status) on the health indicators. We find that the effect of cannabis use on mental health is somewhat smaller than the magnitude of the effect of being single (as compared to be part of a multi-person household) but it is larger than the effect of not having children. Furthermore, for men the effect of cannabis use on mental health is comparable to an 11-year aging effect. For women it is a 20-year aging effect. There is also a significant negative effect of cannabis use on the physical health of men which is of a similar magnitude as aging by 8 years or reducing

educational attainment from secondary to primary school.

In panel c of Table 4 we revisit the issue of whether past and current cannabis use have different effects on the various dimensions of health. For both men and women making this distinction does not improve the estimation results and we cannot reject the hypothesis that the effects of past and current cannabis use are equal. Panel d further refines the distinction between past and current user by additionally accounting for the duration of past use and the duration of current use. The joint null hypothesis of equal coefficients for past and current use and zero coefficients for durations of past and current use in the mental and physical health equations cannot be rejected on the basis of the LR test, whose test statistic is reported in the last row of panel d. Finally, we build on the model in panel c (which differentiates between past and current use) by including the duration since quitting for past cannabis users. The key results for this specification can be found in panel e. As can be seen from the LR test statistic reported in the last row of panel e, we are unable to reject the null hypothesis that the coefficients on past and current use are equal and that the coefficient on the duration since past use is zero for both mental and physical health equations for both males and females.

4 Conclusions

In this paper, we account for the potential for shared frailties in mental and physical domains of health as well as endogenous selection into cannabis use in studying the health effects of cannabis. We find evidence that individuals differ in unobserved ways in terms of their vulnerability to starting and stoping cannabis use and in their unobserved mental and physical health frailties. Moreover, the unobserved characteristics impacting on cannabis dynamics and health are found to be correlated. Accounting for selectivity affects the estimated impact of cannabis use on the mental and physical health of men but not women. However, after accounting for the correlation in these unobserved tendencies, cannabis use is still found to have a direct negative effect on the mental health of men and women and the physical health of men.

Of course there are several caveats to bear in mind when considering the findings

of this research. First, we use retrospectively reported information on the age at which individuals started and stopped using cannabis and this information may be subject to recall errors. The likely impact of these errors is to bias the estimated effect of cannabis use on health towards zero. For this reason, our estimates should be considered lower bounds on the health effects of cannabis use. A further reason for caution is that our results indicate that past and current cannabis use have statistically indistinguishable effects on health. In addition to expecting the health effects of current cannabis use to be greater than the effects of past use, one would also reasonably conjecture that the effects of cannabis use accumulate with duration of use and that the effects of past use fade over time. While each of these hypotheses were investigated, we were unable to find any evidence in support of them. This would seem to reflect limitations in our data's ability to make these distinctions rather than providing evidence of a lack of differential effects. Nonetheless, the data do provide robust evidence that cannabis use reduces the mental wellbeing of men and women and the physical wellbeing of men.

An important question is whether we should care about the negative health effects of cannabis use. Clearly, they are non-trivial. Compared to abstainers, current and past male cannabis users are estimated to have a mental health score that is reduced by a similar amount as having aged by eleven years. For women, the reduction is similar to aging by twenty years. There is also an effect of cannabis use on the physical health of men that is comparable to being eight years older. Focussing on the comparison with age, one could summarize our findings as cannabis use causing accelerated aging. Aging coincides with increasing physical and mental health problems and cannabis use adds substantially to these processes. Men and women who prefer to stay young, or prefer not to age rapidly should worry about cannabis use as this causes them to be substantially older than their counterparts who abstain from cannabis use.

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Appendix A: Variables used in the analysis

A1: Personal characteristics

- Age: Age of individuals at the time of the survey.
- Secondary education: Dummy variable with value 1 if the individual attended secondary general or vocational education, and value 0 otherwise. Secondary education refers to intermediate vocational or secondary general education.
- Tertiary education: Dummy variable with value 1 if the individual attended higher vocational or academic education, and value 0 otherwise. Since there are three dummy variables for education the overall reference group consists of individuals with only basic education.
- Born 1950s (1960s): Dummy variable with value 1 if the individual was born in the 1950s (1960s).
- Single: Dummy variable with value 1 if the individual is living alone and value 0 if the individual is part of a multi-person household.
- Children: Dummy variable with value 1 if the individual has children and value 0 otherwise.

A2: Physical and mental health

The SF-36 questionnaire is used to establish individual health situations. We use two scales which represent physical health (Physical Functioning) and mental health. Both scales are normalized separately both for the males as well as the females in our sample such that the means are equal to 50 and the standard deviations are equal to 10. Figure 2 gives a graphical representation of the distribution of both health indicators in our samples. These distributions are discussed in more detail in the main text.

A3: Cannabis use

The information concerning the age of onset is based on the question addressed to individuals who indicated previous use of particular drug (for example cannabis): "At what age did you start using cannabis?". The information concerning the quit age is based on the question addressed to individuals who indicated previous use of a particular drug but not current use: "At what age did you use cannabis for the last time?" The duration of use is calculated as the difference between the quit age and the starting age. Current use of cannabis is defined as last year prevalence; past use of cannabis is defined as life time prevalence but no use in the last year.

Appendix B: Full report of parameter estimates

Table 5 show the parameter estimates of the model with correlated unobserved heterogeneity in more detail. As shown the joint distribution of unobserved heterogeneity has 11 points of support for men and 12 points of support for women. The lower Table provides details of both distributions, from which it is clear that the marginal distributions correspond to those in tables 2 and 3. The same holds for the effect of the observed characteristics. The parameter estimates in Table 5 are very much the same as those presented in Tables 2 and 3.

Table 1: **Means of variables**[a)]

	Men			Women		
	Mean	Min	Max	Mean	Min	Max
Mental health[b)]	50.0	8.2	63.8	50.0	13.0	64.8
Physical health[b)]	50.0	-19.6	54.4	50.0	-1.0	55.8
Age	36.5	26	50	36.7	26	50
Born 1950s	0.38	0	1	0.38	0	1
Born 1960s	0.45	0	1	0.43	0	1
Single	0.39	0	1	0.43	0	1
Children	0.31	0	1	0.41	0	1
Secondary education	0.28	0	1	0.22	0	1
Tertiary education	0.44	0	1	0.47	0	1
Past cannabis use	0.29	0	1	0.33	0	1
Current cannabis use	0.20	0	1	0.08	0	1
of which:						
Last year – not last month	0.07	0	1	0.03	0	1
Last month	0.13	0	1	0.05	0	1
Starting age[c)]	19.5	12	45	19.7	12	46

	Never Used	**Past User**	**Current User**
Males			
Physical health score	49.79	50.70	49.51
Mental health score	51.93	48.88	46.82
Females			
Physical health score	49.16	51.42	50.34
Mental health score	50.77	49.64	45.98

[a)] Based on 834 men and 889 women (except for "starting age").
[b)] Variable normalized to means 50.0 and standard deviation 10.0.
[c)] Based on 413 men and 365 women.

Table 2: **Cannabis starting rate and quit rate**

	Men		Women	
	Start	Quit	Start	Quit
Secondary education	0.78 (4.2)**	-0.54 (2.1)**	0.66 (2.9)**	-0.32 (1.3)
Tertiary education	1.04 (5.8)**	-0.37 (1.6)	1.22 (6.8)**	-0.13 (0.7)
Born 1950s	1.30 (5.2)**	-0.52 (2.1)**	1.01 (3.8)**	-0.01 (0.1)
Born 1960s	1.88 (7.6)**	-0.17 (0.7)	1.38 (5.2)**	0.41 (1.7)*
Starting age/10	–	0.09 (0.4)	–	0.36 (1.8)*
Unobserved heterogeneity				
Mass point 1	-6.96 (19.2)**	-1.42 (2.0)**	-6.93 (18.5)**	-2.21 (3.9)**
Mass point 2	-4.42 (13.6)**	$-\infty$	-3.83 (6.5)**	$-\infty$
Mass point 3	$-\infty$	–	$-\infty$	–
α_1	0.08 (0.8)		0.08 (0.6)	
α_2	-1.75 (8.5)**		-2.90 (8.5)**	
Probabilities (%)				
p_1	48.1		50.6	
p_2	7.7		2.6	
p_3	44.2		46.8	
-Loglikelihood	2478.6		2442.9	

Note: Absolute t-statistics in parentheses; a ** (*) indicates significance at a 95% (90%) level. The cannabis starting rate contains 17 age categories (12-15, annually from 16-30 and 30+ years), the cannabis quit rate contains 4 duration dependence intervals (1, 2, 3-10, 10+ years).

Table 3: **Physical health and mental health**

	Men		Women	
	Physical health	Mental health	Physical health	Mental health
a. Correlated heterogeneity				
Past cannabis use	-0.51 (1.0)	-2.69 (3.2)**	0.57 (1.1)	-1.65 (2.5)**
Current cannabis use	-1.27 (2.2)**	-2.36 (3.2)**	0.52 (0.6)	-3.61 (3.3)**
Age	-0.13 (4.2)**	-0.14 (3.6)**	-0.12 (4.2)**	-0.10 (2.3)**
Secondary education	1.21 (2.3)**	-1.25 (1.6)	0.84 (1.5)	0.56 (0.7)
Higher education	1.58 (2.9)**	-1.58 (2.2)**	2.18 (4.5)**	0.81 (1.1)
Single	-0.52 (1.1)	-2.27 (3.9)**	0.44 (1.0)	-2.70 (4.2)**
Children	0.01 (0.0)	1.23 (1.8)*	1.36 (3.1)**	1.34 (2.1)**
σ	5.55 (49.3)**	6.13 (29.5)**	5.32 (42.2)**	6.94 (25.3)**
Unobs. heterogeneity				
Masspoint 1	56.13 (41.8)**	62.06 (36.5)**	55.03 (42.2)**	57.65 (32.8)**
Masspoint 2	18.51 (13.8)**	44.31 (23.2)**	27.48 (21.5)**	39.89 (20.9)**
α_1	2.95 (12.8)**		2.75 (12.5)**	
α_2	-1.55 (2.7)**		-0.05 (0.2)	
α_3	1.52 (6.3)**		0.95 (4.2)**	
Probabilities (%)				
p_1	76.7		77.4	
p_2	0.8		4.7	
p_3	18.5		13.0	
p_4	4.0		4.9	
-Loglikelihood	5752.2		6231.4	
b. Independent heterogeneity				
Past cannabis use	-0.50 (0.9)	-2.64 (4.1)**	0.58 (1.1)	-1.62 (2.5)**
Current cannabis use	-1.35 (2.3)**	-2.29 (3.1)**	0.61 (0.7)	-3.59 (3.3)**
-Loglikelihood	5776.6		6248.7	
LR test	48.8**		34.6**	
c. Equal effects past and current cannabis use				
Cannabis use	-0.80 (1.7)*	-2.56 (4.5)**	0.56 (1.2)	-2.01 (3.3)**
-Loglikelihood	5753.0		6232.8	
LR test	1.6		2.8	

Note: Absolute t-statistics in parentheses; a ** (*) indicates significance at a 95% (90%) level.

Table 4: **Sensitivity analysis effects cannabis use on physical and mental health**

	Men		Women	
	Physical health	Mental health	Physical health	Mental health
a. Independent process				
Cannabis use	-0.80 (1.7)*	-2.56 (4.5)**	0.56 (1.2)	-2.01 (3.2)**
-Loglikelihood	8231.6		8675.7	
b. Correlated heterogeneity				
Cannabis use	-0.97 (2.1)**	-1.55 (2.5)**	0.51 (1.0)	-1.78 (2.4)**
-Loglikelihood	8216.5		8674.0	
LR test independence	30.2**		3.4	
c. Past and current use				
Past cannabis use	-0.66 (1.2)	-1.93 (2.8)**	0.51 (1.0)	-1.58 (2.1)**
Current cannabis use	-1.35 (2.2)**	-1.04 (1.3)	0.50 (0.5)	-3.38 (2.8)**
-Loglikelihood	8215.3		8673.2	
LR test different effects	2.4		1.2	
d. Duration of use				
Past cannabis use	-0.23 (0.3)	-1.65 (1.7)*	0.54 (0.8)	-1.92 (2.0)*
Duration past cannabis use	-0.05 (0.8)	0.03 (0.4)	-0.00 (0.1)	0.05 (0.6)
Current cannabis use	0.89 (0.4)	0.75 (0.4)	-2.16 (1.0)	-0.57 (0.3)
Duration current cannabis use	-0.12 (1.3)	-0.10 (1.0)	0.16 (1.3)	-0.19 (1.3)
-Loglikelihood	8212.8		8672.3	
LR test	7.4		3.4	
e. Duration since use	Men		Women	
Past cannabis use	-0.97 (1.2)	-2.13 (2.0)**	-0.24 (0.3)	-2.65 (2.5)**
Duration since past cannabis use	0.03 (0.5)	-1.04 (1.3)	0.07 (1.2)	0.09 (1.2)
Current cannabis use	-1.37 (2.2)**	-1.04 (1.3)	0.48 (0.5)	-3.47 (2.9)**
-Loglikelihood	8215.1		8671.2	
LR test	0.4		4.0	

Note: Absolute t-statistics in parentheses; a ** (*) indicates significance at a 95% (90%) level.

Table 5: **Joint estimates of cannabis starting rate, cannabis quit rate, physical health and mental health**

	Men		Women	
	Cannabis Start	Cannabis Quit	Cannabis Start	Cannabis Quit
Secondary education	0.71 (3.8)**	-0.53 (2.1)**	0.65 (2.8)**	-0.33 (1.4)
Tertiary education	0.99 (5.6)**	-0.38 (1.7)*	1.20 (6.6)**	-0.12 (0.7)
Born 1950s	1.34 (5.5)**	-0.51 (2.0)**	0.99 (3.8)**	0.02 (0.1)
Born 1960s	1.97 (8.0)**	-0.19 (0.8)	1.38 (5.2)**	0.42 (1.8)*
Starting age/10	–	0.11 (0.4)	–	0.37 (1.9)*
Mass point 1	-6.98 (19.3)**	-1.44 (2.0)**	-6.91 (18.2)**	-2.23 (4.0)**
Mass point 2	-4.38 (13.3)**	$-\infty$	-3.78 (6.6)**	$-\infty$
Mass point 3	$-\infty$	–	$-\infty$	–
	Physical health	Mental health	Physical health	Mental health
Age	-0.12 (3.6)**	-0.14 (3.3)**	-0.12 (4.1)**	-0.09 (2.1)**
Secondary education	1.29 (2.4)**	-1.36 (1.8)*	0.81 (1.4)	0.56 (0.7)
Higher education	1.70 (3.1)**	-1.64 (2.3)**	2.17 (4.4)**	0.77 (1.0)
Single	-0.56 (1.1)	-2.43 (4.1)**	0.45 (1.0)	-2.67 (4.1)**
Children	-0.11 (0.2)	1.17 (1.7)*	1.33 (3.0)**	1.30 (2.0)**
Cannabis use	-0.97 (2.1)**	-1.55 (2.5)**	0.51 (1.0)	-1.78 (2.4)**
σ	5.58 (45.3)**	6.21 (28.7)**	5.32 (41.0)**	6.90 (24.7)**
Masspoint 1	55.76 (39.8)**	61.23 (35.7)**	55.09 (41.4)**	57.49 (32.3)**
Masspoint 2	17.62 (12.3)**	43.10 (22.3)**	27.50 (21.2)**	39.76 (20.6)**
Unobserved heterogeneity				
α_1	2.90 (9.3)**		2.69 (7.9)**	
α_2	0.58 (1.4)		-0.63 (1.1)	
α_3	2.90 (9.3)**		2.61 (8.0)**	
α_4	-2.74 (1.3)		-0.27 (0.6)	
α_5	$-\infty$ (–)		-3.15 (2.3)**	
α_6	-0.98 (1.6)		-0.07 (0.2)	
α_7	1.56 (4.5)**		0.97 (2.5)**	
α_8	0.41 (1.0)		-1.43 (1.8)*	
α_9	0.72 (1.8)*		0.78 (2.1)**	
α_{10}	-0.70 (1.1)		-0.30 (0.6)	
α_{11}	-1.04 (1.9)*		-2.07 (2.7)**	
-Loglikelihood	8216.5		8674.0	

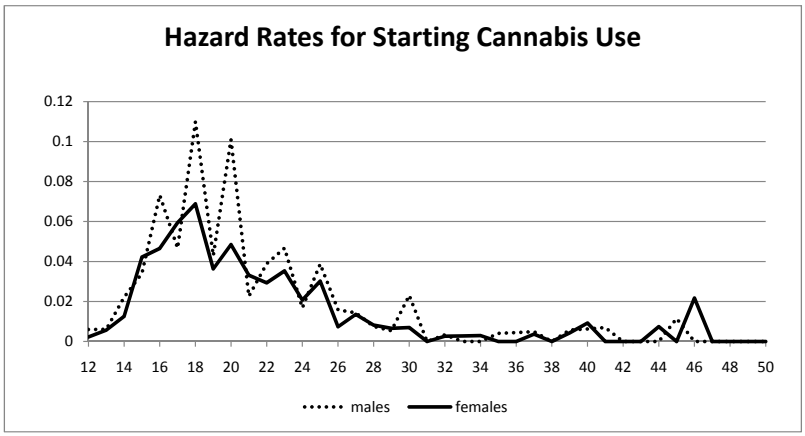
Distribution of unobserved heterogeneity

Mental health	Good	Good	Bad	Bad	
Physical health	Good	Bad	Good	Bad	Total
Men					
Cannabis use type 1	37.3	0.1	9.8	1.0	48.2
Cannabis use type 2	3.6	0.0	3.1	0.7	7.4
Cannabis use type 3	37.3	0.8	4.2	2.1	44.4
Total	78.2	0.9	17.1	3.8	100.0
Women					
Cannabis use type 1	39.3	2.0	7.0	2.0	50.3
Cannabis use type 2	1.4	0.1	0.6	0.3	2.4
Cannabis use type 3	36.3	2.5	5.8	2.7	47.3
Total	77.0	4.6	13.4	5.0	100.0

Note: Absolute t-statistics in parentheses; a ** (*) indicates significance at a 95% (90%) level. The cannabis starting rate contains 17 age categories (12-15, annually from 16-30 and 30+ years), the cannabis quit rate contains 4 duration dependence intervals (1, 2, 3-10, 10+ years).

Figure 1: **Hazard for Starting and Quitting Cannabis Use; women and men**

a. Uptake



b. Quitting

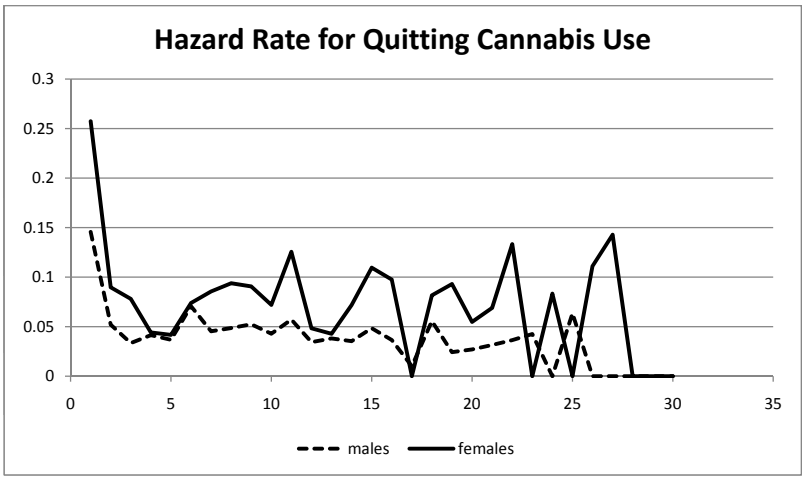
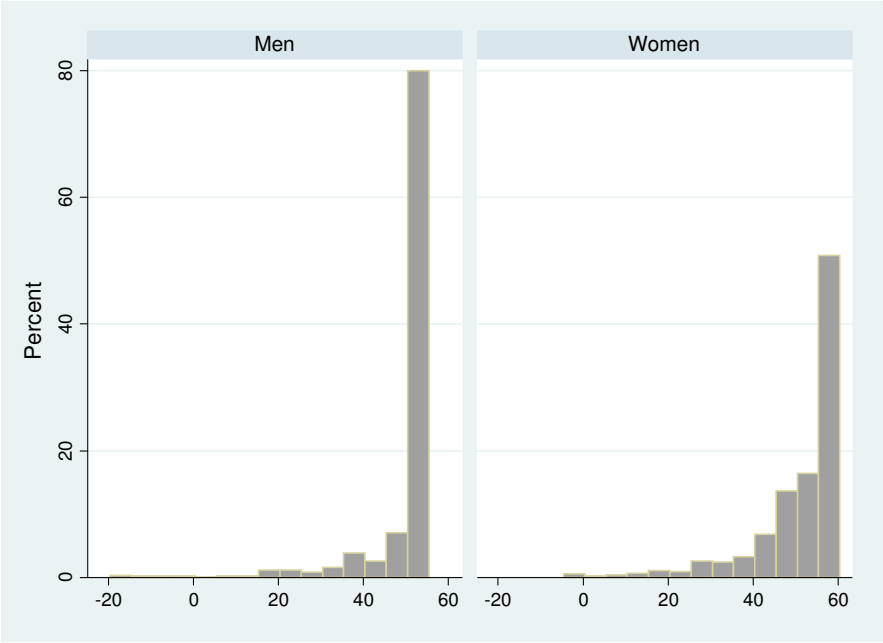


Figure 2: **Distributions of physical and mental health; women and men**

a. Physical health



b. Mental health