Alcohol Myopia and Risk Taking

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Abstract

The aim of this paper is to develop a model that explains how the consumption of some additive substances affects an individual's choice between risky alternatives. We do this by assuming that some additives substances, specifically alcohol, increase individual's present bias. As individuals that consume alcohol show greater preference for the present and less for the future, they would find risky choices with rewards in the present and costs in the future more attractive. Theferore, an individual that wouldn´t have accepted a lottery may do so after consuming alcohol and he regret his decision after the alcohol in his blood is eliminated. We analyze the effect of two taxes in discouraging a risky activity: a tax on the consumption of alcohol and a tax (or penalty) if the future costs of the lottery are realized. (JEL D11, D60, D81, D91)

Keywords: habit-formation, risk taking, alcohol consumption.

1. Introduction

Addictions are normally associated with irrational behavior, as the consumption of addictive substances is cyclical or explosive; their consumption negatively affects the health of individuals and is related to self-destructive and anti-social behavior such as violence, crime and unsafe sex.

Most economists have focused on how the consumption patterns of the users of addictive substances can be congruent with rational behavior. For example, in their seminal article, Becker and Murphy (1988) showed this to be true in the case of the explosive consumption patterns of addictive substances by assuming that such consumption accumulates a "stock of capital consumption" that increases the utility from consuming them. Similarly, Dockner and Feichtinger (1993) showed that the cyclical consumption patterns associated with addictive substances can be congruent with rational behavior by assuming that such consumption accumulates not one, but two stocks of capital consumption, for example an addictive stock and a satiating stock.

Other economists have analyzed the consumption of addictive substances by assuming that individuals are not entirely rational, their having time-inconsistent preferences. In these models, taxing addictive substances can increase individuals' welfare. Koszegi and Gruber (2002) analyze cigarette addiction when individuals have present-bias preferences. They show that taxes should be higher in order to include the "internalities" that individuals impose upon themselves. Gruber and Mullainathan (2002) use surveys on self-reported happiness to measure welfare, and conclude that individuals who are predicted to be smokers are happier when taxes on cigarettes are higher. However, with only a few exceptions,[1] economists have ignored the question of the apparently risky behavior that is associated with drug and alcohol use. When individuals are under the influence of drugs and alcohol they sometimes alter their behavior, often by choosing risky options they regret when sober. These decisions generally maximize their short-term utility, but are detrimental to their long-term well-being.

[1] For a review of the evidence of the effect of alcohol regulation on crime, see Carpenter and Dobkin (2010).

The aim of this paper is to develop a model that explains how the consumption of some addictive substances affects an individual's choice between risky alternatives. We do this by assuming that some addictive substances, specifically alcohol, increase individuals' present bias. Models of present bias assume that an individual has a preference for the present that creates time inconsistency (see O'Donoghue and Rabin 1999). Our paper extends the idea of present bias, allowing individuals to endogenize their bias for the present via alcohol consumption. To the best of our knowledge, this approach has not been used before in economic literature. From a public policy perspective, this approach provides important recommendations as to the best way to discourage crime and the imprudent behavior of individuals under the influence of drugs and alcohol.

Our model is founded on the psychological theory of "alcohol myopia". This theory states that alcohol consumption affects individuals' behavior by limiting their ability to perceive more salient cues, that is, those that are more visible and closest in time.

As individuals that consume alcohol show greater preference for the present and less for the future, they would find risky choices with rewards in the present and costs in the future more attractive. This could explain the apparent increase in risky behavior of individuals under the influence of alcohol, since the rewards associated with many lotteries are in the present, whilst their costs are in the future.

Numerous psychological studies support the theory of alcohol myopia, and have shown that individuals are more likely to engage in risky behavior when intoxicated with alcohol. For example, Davis et al. (2007) find that individuals that are intoxicated with alcohol are more attentive to impelling cues such as sexual arousal, and less so to inhibitory cues, such as sexual risks.

However, if alcohol consumption increases the importance of more immediate cues and reduces that of less immediate ones, as alcohol myopia assumes, then the consumption of alcohol can also increase prudent behavior if the associated risks are in the present and rewards in the future. MacDonald et al. (2000) show that in sexual situations alcohol-intoxicated individuals reported more prudent intentions than sober ones when strong inhibiting cues were present. For expositional purposes, we will refer to alcohol only when modeling alcohol myopia. However, our model is equally applicable to the consumption of other addictive substances linked to risky behavior.

We introduce our model of alcohol myopia in Section 2 by assuming that as individuals consume alcohol, their present bias increases, that is, they give more importance to the present and less to the future. This could be interpreted as a decrease in individuals' rationality, their being less aware of the future consequences of their actions.

In Section 3, we apply our model to analyze the risk-taking behavior of an individual that has consumed alcohol. We work with a two-period model, although we include a third period where individuals don't take any decision, but can receive the payment of a lottery taken in the second period. We analyze the effect of two taxes to discourage a risky activity that the government wants to discourage: a tax on the consumption of alcohol and a tax (or penalty) if the future costs of the lottery are realized.

In Section 4, we discuss a number of extensions and conclude.

2. Model

In this section, we define an inter-temporal utility function for an individual with alcohol myopia, leaving the analysis of the risk-taking behavior for the next section.

We extend the utility function of inter-temporal consumption with present bias used by O'Donoghue and Rabin (2003). Their utility function is given by the following equation:

$$U^t(u_t, u_{t+1}, ..., u_T) = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau$$

where u_t is the instantaneous utility of period t, δ is the standard discount factor and β represents the present bias (a preference for immediate gratification.)

In order to represent alcohol myopia, we assume that an individual that has consumed alcohol has a present bias that depends on the amount of alcohol that is accumulated in his blood. This term increases the discount of the future as the amount of alcohol in the blood increases. Our extended inter-temporal utility function is given by the following definition.

Definition 1: The perceived utility function for an individual that has alcohol myopia is given by the following equation:

$$U^t(u_t, u_{t+1}, ..., u_T) = u_t + \beta\left(A^t\right)\sum_{\tau=t+1}^{T}\delta^{\tau-t}u_\tau$$

where A^t is the level of alcohol in the blood in period t and is given by $A^t = \sum_{i=t-w}^{t} a_i$, where a_i is the amount of alcohol consumed in period i and w is the number of periods that the alcohol remains in the blood after its consumption. In order to represent that higher consumption of alcohol decreases the attention to the future, we assume that $\beta'\left(A^t\right) < 0$.

Although it would be more realistic to consider that the amount of alcohol that has accumulated in the blood affects an individual's immediate utility as a result of the pharmacological effect it has, for simplicity, we assume that alcohol affects the immediate utility, u_t, only through its present consumption.

Although the outcomes of a lottery are normally analyzed assuming payoffs are paid in the present, many lotteries have outcomes whose payoffs are paid at different periods of time. For example, a lottery might be to have unsafe sex, with one of the possible outcomes being that of catching a sexually- transmitted disease, the health effects of which are suffered in the future. In the remainder of this article, we will use lotteries over outcomes the payoffs of which may be occurring at different times. To make the lotteries comparable, we have to discount the utility of the payoffs that occur in the future. In this case, the preference over the lotteries will depend on the present bias of the individuals.

3. Alcohol consumption and Risk Taking

In this section, we apply our model to analyze the risk-taking behavior of those individuals that consume alcohol. We work with a simple case comprising two periods. In the first, an individual has to choose how much alcohol to consume, and in the second, he has to choose from a set of lotteries ($\mathcal{L}$). We include a third period, which serves no purpose other than to allow for the possibility that the payoffs of the lotteries chosen in the second period are paid in the future. In the second and third periods, we assume the individual does not consume alcohol and that his utility is given only by the outcomes of the lottery chosen in the second period.

The vector of consumption in the first period includes two goods: alcohol (a) and the numeraire (y) with the price of the numeraire being one dollar.[2] We assume that the alcohol consumed in the first period remains in the blood during the second, that is, $w = 1$ and $A^2 = a$. We make the usual assumptions for the instantaneous utility function $u_1(a, y)$: $u_{1a}(a, y) > 0$, $u_{1y}(a, y) > 0$, $u_{1aa}(a, y) < 0$ and $u_{1yy}(a, y) < 0$. We assume that the utility derived from the consumption of alcohol is bounded: $u_1(a, y) - u_1(0, y) \leq \overline{X}$ for any a and any y. We make this assumption as there is a physical limitation in the quantity of alcohol an individual can consume in one period. This contrast to our view of the expected utility of some lotteries as the payoffs of some of their outcomes can be very large or very small, as it is the case of unprotected sex and crime.

For simplicity, we assume that $\delta = 1$. We assume that individuals have von Newmann-Morgenstern utility functions. Note that according to Definition 1 the expected utility of a lottery that has outcomes paid in the future changes with the amount of alcohol in the blood, as the amount of blood increases the present bias; therefore, an individual that would not have accepted a lottery may do so after consuming alcohol. If this is the case, he may regret his decision after the alcohol in his blood is eliminated.

In the second period, individual's perceived utility from a lottery L is the expected utility of the outcomes for periods two and three, discounted for the present bias given by the amount of alcohol that the individual consumed in period one. I will call this expected utility as $U^2(a, L)$:

$$U^2(a, L) = \sum_{k=1}^{K} p_k(u(y_{2k}) + \beta\,(a)\,u(y_{3k}))$$

[2] Given that the desicion between consuming alcohol and the numeraire are made only in the first period, we will write them without any subscript indicating time.

where p_k is the probability of outcome k occurring and y_{tk} is the payoffs when outcome k occurs at time t. For simplicity we assume that the payoff of the lottery is given in the numeraire (y). In order to be consistent with the instantaneous utility of the first period we could allow the payoffs of the lotteries to be also in alcohol; however, this would complicate the model unnecessarily. The utility from the outcomes can be negative, as we want to represent lotteries that have a cost in some of their outcomes.

For clarity, we will write the utility evaluated in the first period as the sum of the instantaneous utility of the first period plus the expected utility from the lottery in the second. As the individual has not consumed alcohol in the first period he perceives the following utility: $U^1 = u_1 + U^2(0, L)$.

In order to solve the model, we apply the solution concept defined by O'Donoghue and Rabin (1999) to our two-period model. This concept—the "perception-perfect strategy"—is one in which an individual chooses his optimal action in every period based on his preferences for the period and his perception of his future behavior. Following O'Donoghue and Rabin (1999), we analyze the extreme cases where individuals are naïve or sophisticated and compare these with standard consumers that have no present bias and whom we will refer to as temporal-consistent agents (TC). As is standard, we regard naïve agents (naifs) as those that do not realize that their present bias changes, in this case due to alcohol consumption, while sophisticated agents (sophisticates) are those individuals that are fully aware of how their present bias changes with alcohol consumption.

We define the perception-perfect strategy for the three types of agents we are going to analyze. For a TC agent, the present bias is not affected by the amount of alcohol in his blood; therefore, in the first period he consumes the amount of alcohol that maximizes his instant utility.

Definition 2: a perception-perfect strategy for TCs is a strategy (a^{TC}, y^{TC}, L^{TC}), that satisfies:

$u_1(a^{TC}, y^{TC}) \geq u_1(a, y)$ and $U^2(0, L^{TC}) \geq U^2(0, L)$ for all a and y that satisfy $p_a \cdot a + y \leq m$ and $L \in \mathcal{L}$.

Although a naif's present bias is affected by his consumption of alcohol, he is unaware of this and behaves like a TC, consuming the amount of alcohol that maximizes his utility for the first period, without taking into consideration the fact that his behavior in the second period may change. However, once in the second period, his present bias changes and he chooses the lottery with the highest expected utility from the perspective of his alcohol present bias.

Definition 3: a perception-perfect strategy for naifs is a strategy (a^n, y^n, L^n), that satisfies:

$u_1(a^n, y^n) \geq u_1(a, y)$ and $U^2(a^n, L^n) \geq U^2(a^n, L)$ for all a and y that satisfy $p_a \cdot a + y \leq m$ and $L \in \mathcal{L}$.

Sophisticates are aware that their present bias in the second period is affected by their consumption of alcohol in the first period, and in the first period they consume the amount of alcohol that maximizes the sum of their utility in all periods.

Definition 4: a perception-perfect strategy for sophisticates is a strategy (a^S, L^S), that satisfies:

$U^1(a^S, y^S, L^S) \geq U^1(a, y, L^S)$ subject to $L^S \in \underset{L \in \mathcal{L}}{\arg\max} U^2(a, L)$ for all a and y that satisfy $p_a \cdot a + y \leq m$.

In order to guarantee the existence of a perception-perfect strategy, we assume that if an individual is indifferent between both lotteries, he chooses the one he would have chosen had he not consumed alcohol.

3.1 A Numerical Example

In this section we develop an numerical example to illustrate how the consumption of alcohol affects the risk taking of an individual and how, if he anticipates this, he will decrease his consumption of alcohol in order to avoid taking a lottery he does not want to take. We assume that the instantaneous utility function in the first period is $u_1(a, y) = a^{1/2} + y$, the income in the first period is two dollars and the price of alcohol is one. We assume that the alcohol present bias is given by the following equation: $\beta(a) = 1/(1 + a)$. We work with a simple example of two lotteries, the first with two outcomes whose payoffs are paid in both the second and third periods, and a second that has only one outcome. For simplicity, we give the payoffs already in utility values.

The first lottery gives a utility of 1 for sure in the second period, however, in the third period it gives a utility of -3 with probability of 1/2 and 0 with probability of 1/2.

The second lottery gives a utility of 0 for sure in both periods.

From the perspective of a TC, the second lottery is preferred to the first, given that its expected utility is 0, against -0.5 for the first lottery.

The perception-perfect strategy for a naif is to consume one unit of alcohol in the first period and then choose the first lottery in the second. A naif would maximize his instantaneous utility in the first period by dividing his income equally between alcohol and the numeraire, and have an amount of alcohol in the blood of one in the second period. With this amount of alcohol, his present bias in the second period would be one half and he would choose the first lottery (the risky lottery with future costs), given that this lottery's expected value has now increased for him to 0.25, and the second lottery's expected value continues to be zero.

The perception-perfect strategy for a sophisticate is to consume 1/2 of a unit of alcohol in the first period and to choose the first lottery in the second. A sophisticate would anticipate that his consumption of alcohol in the first period would increase his present bias in the second. He knows that if he drinks more than 1/2 of a unit of alcohol he would take the first and risky lottery. Given that he loses more by taking the risky lottery than he gains by consuming alcohol, he would limit his consumption of alcohol to just 1/2, enough to not take the risky lottery in the second period.

3.2 Welfare

Welfare comparisons are problematic, given that the utility function varies with the consumption of alcohol. Following O'Donoghue and Rabin (1999), we measure welfare using a fictitious period 0 that represents the long-term perspective by weighting all periods equally (without a present bias): $U^0(a, y, L) \equiv u_1(a, y) + U^2(0, L)$. Using this fictitious period 0, we measure the welfare loss as the difference in utility from any deviation with respect to the optimal solution, which is given by the perception-perfect strategy for a TC agent. For example, the welfare loss for a naif is given by $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^n, y^n, L^n)$.

In the following proposition we show that the welfare losses caused by alcohol are limited by sophistication. As the example above shows, a sophisticate would anticipate that his consumption of alcohol may affect his valuation of lotteries in the second period, and would limit his consumption of alcohol if the expected losses associated with the consumption of alcohol are higher than the utility from consuming it. This would limit the welfare losses for a sophisticate to the highest utility he can get from consuming alcohol: $\overline{X}$. However, for a naif, the welfare losses can be as high as the expected utilities of the lotteries involved.

Proposition 1: (1) For any set of lotteries the welfare loss caused by the consumption of alcohol for the sophisticates: $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^S, y^S, L^S)$, is bounded by $\overline{X}$; and (2) for a naif, we can find a set of lotteries for which the welfare loss caused by the consumption of alcohol: $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^n, y^n, L^n)$, is higher than any constant C.

All proofs are in the Appendix.

Proposition 1 suggests that the government should focus on policies that benefit naifs, since the welfare losses for the latter can be much higher than those for sophisticates.

In the following section we analyze two types of taxes in order to discourage a risky activity. The first one is a tax on the consumption of alcohol and the second one is a tax on the future outcomes of the risky lotteries.

3.3 Taxes

As we mentioned earlier, individuals that have consumed alcohol may choose risky activities only to regret them when sober. These are lotteries with rewards in the present and costs in the future with a welfare loss from the point of view of TC agents. The welfare loss of some of these lotteries is so high that governments try to discourage them, as it is with unsafe sex, driving under the influence of alcohol or crime.

In this section we analyze the effects of two types of taxes that try to discourage an undesirable lottery. The first tax is a tax on the price of alcohol (T_a), that is paid in period one and the second tax is a tax paid if the future costs of the lotteries are realized in period three ($T_{\mathcal{L}}$). The reason for assuming that the tax on the lottery is paid in period three as opposed to period two is that we believe that the government normally finds out if an individual as engaged in a risky activity only when some of the future costs of the lottery are realized and because the penalties the goverment can impose are paid in the future, as it is jail time for a crime. For simplicity we assume that there is only one lottery and individuals have to choose to take it or not.

The following proposition shows that a tax on the price of alcohol reduces the welfare for a sophisticate, while a tax on the future costs of a lottery with negative expected utility from the point of view of a TC agent, increases the welfare of a sophisticate. The reason for this is that a sophisticate is able to correctly predict his self control problems and limits his amount of alcohol consumption in the first period, even without a tax. A tax on the price of alcohol only increases the price he has to pay to consume alcohol. However, a tax on the future costs of a lottery with negative expected utility from the perspective of a TC will reduce the attractiveness of the lottery. Anticipating this, he may be able to increase his consumption of alcohol in the first period knowing that he won't engage in a risky and now less atractive activity.

Proposition 2: (1) A tax on alcohol weakly decreases welfare for a sophisticate and this welfare loss is lower than $\overline{X}$; and (2) a tax on the future costs of lotteries which have negative expected utility from the point of view of a TC agent, weakly increases the social welfare for the sophisticate, and this gain in social welfare is lower than $\overline{X}$.

In contrast to sophisticates, naifs can benefit from a tax on the price of alcohol. Naifs drink the amount of alcohol that maximizes their instantaneous utility without realizing that their risk choices are going to be affected by their alcohol consumption. When the cost of these risky activities is too high, tax on the future costs may not be enough to discourage these activities, but a tax on alcohol may do it.

Proposition 3 shows that any tax on alcohol has a welfare loss of at most $\overline{X}$ for naifs. However, the welfare gains from a tax on alcohol may be very high, as taxes on alcohol reduces the consumption of alcohol and may discourage naifs from taking lotteries with very high welfare losses.

Proposition 3: (1) The welfare loss for a naif from a tax on alcohol is bounded by $\overline{X}$; and (2) the welfare gain for a naif from a tax on alcohol is not bounded by any constant.

Our analysis suggests that a tax on alcohol is desirable compared to a tax on the future outcomes of the lotteries that the government want to discourage. Although taxing alcohol may harm sophisticates, the welfare gains for naifs can be much higher than the harm for sophisticates.

4. Conclusions

In this article we have developed a model of alcohol myopia that explains some of the apparently irrational risky behavior that is associated with addictive substances by assuming that these increase individuals' present bias.

However, certain aspects of our analysis should be treated with caution.

Firstly, as we saw in the introduction, the psychological evidence shows that alcohol myopia not only increases an individual's attention to cues that are in the present, but also increases his attention to visible cues. By not including this aspect in our model, we are providing only a partial explanation of alcohol myopia, and omitting a number of elements that could result in better policy advice.

Secondly, we are not considering the habit-formation aspect of alcohol consumption as is usually the case in the literature on addictive substances. However, we do not regard this as a fundamental flaw of our model, since habit-formation occurs over a period of time that is longer than that normally involved in an isolated case of alcohol consumption, which is the case in the scope of our article.

Thirdly, we have assumed that alcohol myopia affects the bias towards the present (the β from the present-bias model.) However, alcohol myopia could be modeled by assuming that the consumption of alcohol affects the discount factor (δ) in the standard exponential discount model. In our three-period model, this distinction makes no difference; however, in a model with more periods this difference may make very distinct predictions. Nevertheless, we are not yet able to assume either of these is correct, since the psychological evidence on alcohol myopia does not provide any information on whether it affects present bias or the discount factor.

There are a number of future extensions that can be made. First, a model with more periods would allow us to analyze certain aspects that we have not been able to consider in our three-period model, such as the "sophistication effect" introduced by O'Donoghue and Rabin (1999). This effect refers to when sophisticates are aware of their future self-control problems and react by exacerbating them. In our model, the sophistication effect would be that sophisticates anticipate that they will consume alcohol in the future, and so conclude that there is no case for them to limit their alcohol consumption in the present. Once we consider this effect, it may prove to be the case that sophisticates sometimes consume more alcohol than naifs.

Finally, we can extend our analysis to how individuals use the consumption of addictive substances to diminish the anxiety associated with the anticipation of future risks.

Appendix

Proposition 1: (1) For any set of lotteries the welfare loss caused by the consumption of alcohol for the sophisticates: $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^S, y^S, L^S)$, is bounded by $\overline{X}$; and (2) for a naif, we can find a set of lotteries for which the welfare loss caused by the consumption of alcohol: $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^n, y^n, L^n)$, is higher than any constant K.

Proof of Proposition 1

(1) Note that in the first period a sophisticate has always the option of consuming zero amount of alcohol, in which case he would face the same maximization problem as a TC agent in the second period and therefore he would choose the same lottery. His welfare loss with respect to a TC agent would come from the difference in utility from not consuming alcohol in the first period, which is bounded by $\overline{X}$. Because the sophisticate has always this option, he would never choose a higher amount of alcohol that gives him a lower overall utility.

(2) for a naif, we can find a set of lotteries for which the welfare loss caused by the consumption of alcohol: $U^0(a^{TC}, y^{TC}, L^{TC}) - U^0(a^n, y^n, L^n)$, is higher than any constant C.

(2) We prove it with an example. Because we assume that the instantaneous utility function is continous and unbounded, we can find a lottery that pays any payoff. Suppose that there are two lotteries, lottery one, L_1, that pays a utility of $\beta(a^n) \cdot (2C+1)/(1-\beta(a^n))$ for sure in the second period and zero in the third period and a second lottery, L_2, that pays a utility zero in the second period and a utility of $(2C+1)/(1-\beta(a^n))$ for sure in the third period. In the first period the naif does not realize that his consumption of alcohol affects his decision in the second period and consume the amount of alcohol that maximizes his instantaneous utility for that period: a^n. In the second period, the naif, after consuming a^n units of alcohol in the first period chooses lottery L_1. The welfare loss for the naif for taking lottery L_1 instead of L_2 is $2C$.

Proposition 2: (1) A tax on alcohol weakly decreases welfare for a sophisticate and this welfare loss is weakly lower than $\overline{X}$; and (2) a tax on the future costs of lotteries with negative expected utility from the point of view of a TC weakly increases the social welfare for the sophisticate, and this gain in social welfare is weakly lower than $\overline{X}$.

Proof of Proposition 2

1) Let's call $(a^{TaS}, y^{TaS}, L^{TaS})$ as the optimal amount of alcohol, numeraire and lottery for a sophisticate when there is a tax Ta on alcohol. Note that when there is no tax on alcohol the sophisticate has always the choice of consuming the same amount of alcohol, and the same lottery with a higher amount of the numeraire: $(a^{TaS}, y^{TaS} + Ta \cdot a, L^{TaS})$. Because the sophisticate has always this option, he has a weakly higher utility when there is no tax on alcohol.

(2) The sophisticate has always the option of drinking no alcohol in the first period. Because the welfare loss of this option is bounded by $\overline{X}$, he can always choose this option and avoid any welfare loss higher than $\overline{X}$ from a tax on alcohol.

Proposition 3: (1) The welfare loss for a naif from a tax on alcohol is bounded by $\overline{X}$; and (2) the welfare gain for a naif from a tax on alcohol is not bounded by any constant.

Proof of Proposition 3

We probe it by showing that a tax on alcohol reduces the welfare in the first period at most in $\overline{X}$ and show that it may increase the welfare of the lottery choosen in the second period, as individuals that consume less alcohol choose lotteries that have a higher utility from the point of view of the TC agents.

First period. A naif consumes the amount of alcohol that maximizes his utility in the first period. This amount of alcohol is given by the following first order conditions: $u'(a^n) = p_a$ when there is no tax and $u'(a^{Tan}) = p_a + T_a$ when there is a tax T_a on the price of alcohol. Because $u(a)$ is a decreasing function on a, $a^n \geq a^{Tan}$.

In the first period, as the tax on alcohol moves the naif from his optimal consumption of alcohol, his utility decreases. However, he always has he option of not consuming alcohol and not paying any tax, in which case his utility decreases in at most $\overline{X}$. Because the naif has always this option, he cannot do worst than this.

Second period. Now we show that a tax on alcohol weakly increases the welfare from the lottery choosen en the second period.

Let's call x_i as the expected utility of all the payoffs of lottery i paid in the second period (as seen in the second period) and z_i as the expected utility of all the payoffs of lottery i paid in the third period (as seen in the third period). If we call lottery L_a as the lottery choosen by a naif after a consumption of alcohol a in period one, then we have: $x_a + \beta(a) z_a \geq x_i + \beta(a) z_i$ (1) for any $i \in \mathcal{L}$. If, after the imposition of tax T_a, the naif consumes the amount of alcohol $a^{Tan} \leq a^n$ in the first period and chooses a lottery L_{Tan} different than L_a in the second period we have: $x_{Tan} + \beta\left(a^{Tan}\right) z_{Tan} \geq x_a + \beta\left(a^{Tan}\right) z_a$ (2). By adding inequalities (1) and (2) we get that $z_{Tan} \geq z_a$ and therefore we know that $\beta\left(a^{Tan}\right) z_{Tan} \geq \beta\left(a^{Tan}\right) z_a$. If we add this last inequality to inequality (1) we get that $x_{Tan} + z_{Tan} \geq x_a + z_a$ and therefore the welfare from the lottery choosen when there is a tax on alcohol is weakly higher as compared with the case where there isn't one.

(2) We probe it with an example. Suppose that there is only one lottery, one that pays $C \cdot \beta(a^{T_{an}})$ for sure in the first period and $-C$ for sure in the third period. If a naif consumes a positive amount of alcohol, he would take the lottery if there is no tax on alcohol, but he wouldn't take it if there is a tax on alcohol Ta. Therefore the tax gives a naif a welfare gain of $C \cdot \beta(a^{T_{an}} - 1)$. Because this is true for any $C > 0$ and

any tax T_a the welfare gain of a tax on alcohol is not bounded by any constant.

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