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**IS HEAVY DRINKING ALWAYS PROFITABLE FOR ALCOHOL INDUSTRY?
AN EPIDEMIC FRAMEWORK FOR ALCOHOL CONSUMPTION**

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Abstract

This article aims to provide a better understanding of the impact of heavy drinkers on the alcohol industry's profitability. At first glance, heavy drinking appears to improve alcohol's sales leading to an increase of profit. However, heavy drinking also involves fatal injuries and constitutes a shortfall for the industry. In this paper, we explore coexistence of these two forces through an epidemic model of alcohol use distinguishing 'light' and 'heavy' drinkers ('LH' model). We find that there exists a level of alcohol consumption beyond which heavy drinkers represent a loss of profit for the alcohol industry. We calibrate our model with U.S. data for 2011 and we estimate that this threshold should be between 10.22 and 10.80 drinks per heavy drinking occasion. The implication of our result is twofold: the alcohol industry should set up more effective actions against the heaviest consumers, and consequently genuine collaborations with public authorities could exist for this fringe of population.

1. INTRODUCTION

Alcohol, tobacco and other drugs (e.g. cocaine, heroin) are specific goods in the sense that these substances are addictive, and involve health, social and economic costs (Anderson and Baumberg, 2006; WHO, 2014). Among them, alcohol consumption is ranked the fifth leading cause of death and disability and accounted for 5.9% of global mortality in 2012 (WHO, 2014). More generally, the social cost of alcohol to the European Union (E.U.) is €125bn in 2003, equivalent to 1.3% of GDP (Anderson and Baumberg, 2006). In response to these alarming figures, health authorities implement prevention actions in order to reduce alcohol consumption, especially for harmful drinkers – that is people who are risking their health or doing themselves potentially lethal damages. In parallel, alcohol industry sets up Responsible Drinking Programs (RDPs), promoting responsible and moderate alcohol consumption. However, scholars often point an existing conflict of interest between alcohol industry and public health because a large part of alcohol industry's sales comes from harmful drinkers (Baumberg, 2009). Indeed, RDPs are often used to promote new products, or are part of a public relations strategy to reduce criticism and potentially forestall government regulations, rather than to prevent alcohol excessive use (Pantani *et al.*, 2012; Smith *et al.*, 2014; Esser *et al.*, 2016). Consequently, RDPs are often ineffective (Casswell *et al.*, 2016) and alcohol industry devotes very little effort to assess the impact of these actions (Pantani *et al.*, 2012; Esser *et al.*, 2016). In this article we argue that the alcohol industry should take into account more seriously the fight against harmful drinkers because it may be in its best interests.

In order to apprehend the spread of drug use in a given population, scholars turned to epidemic models to capture the co-evolution between light users ('L') and heavy users ('H') (Behrens *et al.*, 1999). Like an infectious disease, drug use largely depends on the prevalence of light and heavy users among the population. These models (hereafter 'LH' models) describe two groups of users (L and H) evolving according to three kinds of flows: the initiation flow representing new consumers, the escalation rate depicting the rate at which light users become heavy ones, and the exit rate capturing the share of users who stop using drugs. These epidemic models are mainly used in the case of cocaine (Behrens *et al.*, 1999; Caulkins *et al.*, 2010) or tobacco (Massin, 2012), and allow to highlight the existence of feedbacks generated by consumers themselves. First, light users generate a positive feedback on initiation because new consumers typically look for social integration. Second, heavy users yield negative feedback on initiation due to the bad publicity provided by 'damaged' drug users. All these flows (initiation, escalation and exit) shape 'LH' models.

If this framework seems correctly fitted with tobacco and cocaine's consumptions, it fails to depict the spread of alcohol uses. Compared to other drugs, two original key features can be drawn for the alcohol case: i) the high severity of short-term risks related to heavy consumption and ii) the social attractiveness of heavy drinkers. First, alcohol mortality burden can be divided into short-term deaths, resulting from a single consumption episode, and long-term deaths, arising from patterns of alcohol consumption (e.g. cancers, neuropsychiatric diseases, cardiovascular diseases). Short-term deaths mainly comprise intentional (e.g. self-inflicted injuries, homicides) and unintentional (e.g. motor vehicle collisions, poisonings, falls) injuries. For people aged 15-64 living in the E.U. in 2004, both intentional and unintentional injuries represent 32% of alcohol-attributable deaths (Rehm *et al.*, 2012). Heavy drinking is the critical feature in determining the risk of fatal injury (Li *et al.*, 1994). More precisely, heavy drinking corresponds to 'binge drinking' which can be defined as consuming 60+ grams of pure alcohol per day for men (the equivalent of at least 5 standard drinks of 12 g pure alcohol) and 40+ grams for women (WHO, 2014). Consequently, short-term deaths are much more widespread than in cocaine or tobacco's cases where mortality mainly results from long-term consumption. Second, contrary to heavy users in traditional 'LH' models, heavy drinkers may generate a positive feedback on the escalation rate. Indeed, especially for young people, binge drinking may be socially valorized and considered as a status symbol (Walters *et al.*, 2013). This point differs from other drugs where heavy users always have a deterrent effect on initiation (Massin, 2012). As a result, there is a need for an adjusted epidemic framework to provide a better understanding of the binge drinking phenomenon.

In this article we propose a modified 'LH' model corresponding more accurately to alcohol use. Our model contains three major changes with respect to the literature. First, we modify the temporal horizon of the model in the sense that our main line of interest is the impact of short-term risks associated with heavy drinking. As a result, we provide a two-period 'LH' model. Second, apart from pathological cases, heavy drinking requires an occasion (e.g. a specific day, friends' reunions).

Outside this occasion heavy drinkers consume moderate doses of alcohol. Therefore, we consider that each period can be split into binge-drinking episodes and ‘daily’ moderate consumption. Third, we integrate an endogenous escalation rate accounting for the social attractiveness of heavy drinkers.

Following Massin (2012) we implement the ‘LH’ framework with an offer side, in our case ‘alcohol industry’. In accordance with standard microeconomic analysis, we consider a maximizing-profit agent and we analyze the impact of heavy consumption on its profit. This integration allows us to study if heavy drinking is always profitable for the alcohol industry. Starting from the point that alcohol industry is interested in maximizing its profit, heavy drinkers have an ambivalent impact. On the one hand, because “industry is driven by the need to sell as much as it possibly can”,¹ heavy drinking increases immediate profit. In fact, heavy drinkers represent 50% of sales of the alcohol industry in high income countries, 63% for middle income countries (Casswell *et al.*, 2016). Also, the 20% heaviest drinkers consume 90% of total alcohol in Hungary, 73% in U.S., 63% in England, and 50% in France (OECD, 2015b). On the other hand, due to inherent risks of fatal injuries, and because “killing the customer is not good for business” (Earl, 2005, p. 148), heavy drinkers diminish future profits through a loss of consumers.

By using a modified LH model, we find that beyond a threshold of alcohol consumption, the risk of fatal injuries may outweigh the benefits of the alcohol industry. Then, pursuant to the U.S. *Behavioral Risk Factor Surveillance System* (BRFSS) data for the year 2011, we estimate this threshold may be between 10.22 and 10.80 drinks (or 143.08 – 151.2 grams of pure alcohol) per heavy drinking occasion. Our article can be seen as a modest theoretical contribution on why alcohol industry has an interest to genuinely combat heaviest consumptions.

The paper proceeds as follows. Our theoretical model is presented in Section 2. In Section 3, we calibrate our model with U.S. data and we conclude in Section 4.

2. A TWO-PERIOD ‘LH’ MODEL

In order to focus on short-term risks associated with alcohol consumption, we use a two-period ‘LH’ model. A different way of seeing things would be to say that our model considers myopic agents abstracting for long-term considerations.

2.1. General description of the model

‘LH’ models typically consider a given population differentiated into two groups: light drinkers (L) and heavy ones (H). This population evolves between period 1 and period 2 as depicted in Figure 1.

¹ The Guardian, 22 January 2016, “Problem drinkers account for most of alcohol industry’s sales, figures reveal”. Link: <https://www.theguardian.com/society/2016/jan/22/problem-drinkers-alcohol-industry-most-sales-figures-reveal> (accessed March 15, 2017).

Figure 1. Diagram flow for the two-period LH model

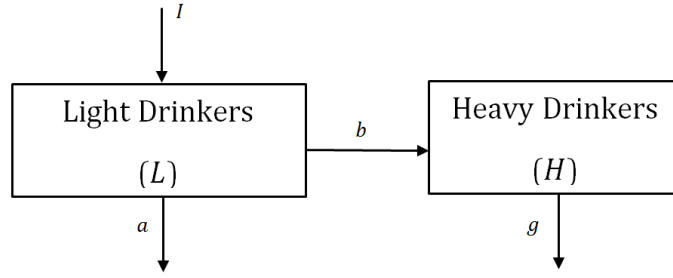


Figure 1 distinguishes three kinds of flows. First, the initiation, I , represents the new (light) consumers at the end of the first period. For the sake of clarity, we assume that the number of new light consumers is not influenced by short-term risks and is considered as exogenous. Second, the escalation parameter, b , captures the flow of light drinkers who become heavy ones. This flow corresponds to a desire of social interactions considering the more or less appealing nature of alcohol (Mubayi and Greenwood, 2013). Following Behrens *et al.* (1999), we use the Markov assumption stating that flows from heavy to light drinkers are indistinguishable from those from light to heavy drinkers. Third, the exit parameters, a and g , measure the number of drinkers who stop consuming, because of death or ceasing use (e.g. pregnancy). Their value hinge upon individual short-term risks related to alcohol consumption. Flows are summarized in the following system:

$$\begin{cases} I = i_1 \\ a = a_1 \beta^L L_1 \\ b = b_1 \left(\frac{H_1}{L_1 + H_1} \right) L_1 \\ g = g_1 \beta^H H_1 \end{cases} \quad (1)$$

Where i_1 is a positive parameter capturing the number of new light consumers at the end of the first period ($i_1 \geq 0$), β^j ($j = \{L, H\}$) is the probability of death for a j -drinker, a_1 and g_1 are parameters measuring the impact of the individual risk. In particular for $a_1 = g_1 = 1$ the only reason for stopping alcohol use is death. On stark contrast, for all values higher than one, a share of drinkers quits drinking as a precaution, typically because they fear for their lives. Last, b_1 measures the weight attached to the desire of social interactions which positively depends on the share of heavy drinkers in the total population, $H_1/(H_1 + L_1)$. It should be noticed that b_1 may be either positive – if heavy drinking is socially valorized – or negative – if, for example, heavy drinkers are composed of marginalized people. This corresponds to the distinction between ‘social drinkers’ and ‘problem drinkers’ provided by Manthey *et al.* (2008).

Considering Figure 1 and (1), the evolution of the number of drinkers between period 1 and period 2 is defined by the following equations:

$$\begin{cases} \Delta L = I + \left[-a_1\beta^L - b_1 \left(\frac{H_1}{L_1 + H_1} \right) \right] L_1 \\ \Delta H = -g_1\beta^H H_1 + b_1 \left(\frac{H_1}{L_1 + H_1} \right) L_1 \end{cases} \quad (2)$$

2.2. Alcohol consumptions and short-term risks related

Short-term risks associated with alcohol are non-uniformly distributed in a period and are mostly concentrated in binge drinking episodes (Li *et al.*, 1994). As a result, we divide each period in a fixed share θ of binge drinking episodes depending on cultural and social factors ($0 \leq \theta \leq 1$). In the rest of the period, $(1 - \theta)$, there is no special occasion and drinkers have a ‘daily’ moderate consumption. During a period, light drinkers always have the same (low) level of alcohol consumption, \underline{q} . On stark contrast, heavy drinkers change their consumption from \underline{q} during ‘daily’ moderate consumption to \bar{q} during binge drinking episodes ($\bar{q} > \underline{q}$). As a result, for each period $t, t = \{1, 2\}$, the total level of alcohol consumption is defined as follows:

$$Q_t = L_t \underline{q} + H_t \left(\theta \bar{q} + (1 - \theta) \underline{q} \right) \quad (3)$$

However, heavy drinkers (\bar{q}) have a negative external effect in the sense that they generate risks of fatal injuries for both type of drinkers (H and L). Let ρ be the global risk of fatal injuries related to excessive consumption during ‘festive’ episodes at the end of the first period. Following Borges *et al.* (2006) and Rehm *et al.* (2012), we consider an exponential relation between the global risk of fatal injuries and the level of heavy consumption such as:

$$\rho = \lambda e^{\bar{q}} \quad (4)$$

Where λ is a positive parameter. This risk can be decomposed as the weighted sum of individual risks borne by each kind of drinkers: $\rho = L_1\beta^L + H_1\beta^H$, where β^j is the probability of death for a j -drinker, $j = \{H, L\}$. Let RR be the relative risk for a heavy drinker compared to a light one ($RR = \beta^H/\beta^L$). We can deduce from (3) the following two relations:

$$\beta^L = \frac{\lambda e^{\bar{q}}}{L_1 + H_1 RR} \quad (5)$$

$$\beta^H = \frac{RR \lambda e^{\bar{q}}}{L_1 + H_1 RR} \quad (6)$$

2.3. The behavior of the alcohol industry

Following Massin (2012) we consider a profit-maximizing producer, the ‘alcohol industry’, whose profit is depicted by:

$$\pi = \sum_{t=1}^2 \frac{(p-c)Q_t}{(1+\delta)^{t-1}} \quad (7)$$

Where p and c are exogenous and respectively correspond to the price and the cost of one ‘unit’ of alcohol, and δ is the discounted rate in our discrete two-period ‘LH’ model. The exogeneity of p and c finds its justification in two elements: i) the price of alcohol is often fixed by the regulator and ii) our temporal horizon is the short-term, thus assuming stable production costs seem quite reasonable.

This paper aims to question the nature of the link between heavy drinking and profit. In particular heavy drinkers constitute a shortfall for the alcohol industry if $\partial\pi/\partial\bar{q} < 0$. According to equation (7), it would involve:

$$(p-c) \frac{\partial Q_1}{\partial \bar{q}} < -\frac{1}{1+\delta} \left(\frac{\partial Q_2}{\partial \bar{q}} \right) (p-c) \quad (8)$$

Inequality (8) means that an increase in the level of heavy drinking is costly for the alcohol industry if gains realized during the first period – due to its increase – are inferior to actualized losses related to the decrease of alcohol sales in period two – due to higher short-term risks. Using (2), (3), (5) and (6), we can rearrange (8) as follows:

$$H_1\theta < -\frac{1}{1+\delta} \left[\theta \left(\frac{b_1 H_1 L_1}{H_1 + L_1} + H_1 - \frac{g_1 RR \lambda e^{\bar{q}} H_1}{L_1 + H_1 RR} \right) - \frac{\lambda e^{\bar{q}} \left(a_1 L_1 \underline{q} + g_1 RR H_1 \left(\theta \bar{q} + (1-\theta) \underline{q} \right) \right)}{L_1 + H_1 RR} \right] \quad (8')$$

We face a computational difficulty related to the use of the exponential relation between the global risk of fatal injuries, ρ , and \bar{q} . In order to isolate \bar{q} on the left-hand side, we use the ‘Lambert W function’, noted $W(\cdot)$, where $W(\cdot)$ is the inverse function $f(W) = We^W$. It should be noticed that because $\bar{q} \geq 0$, $W(\cdot)$ is a real number, $W' > 0$ and $W'' < 0$. In order to stay tractable and without loss of generality, we assume a unitary population at period 1 such as $L_1 + H_1 = 1$. We deduce from (8') the following threshold:

$$\bar{q} > W \left(\frac{(L_1 + RR H_1)(b_1 L_1 + (2 + \delta))}{\lambda g_1 RR} e^{1 + \frac{a_1 \underline{q} L_1 + (1-\theta) RR H_1 \underline{q}}{H_1 \theta g_1 RR}} \right) - \frac{\underline{q}(1-\theta)}{\theta} - \frac{a_1 L_1 \underline{q}}{H_1 g_1 \theta RR} - 1 \quad (9)$$

Proposition: In a two-period ‘LH’ model addressing alcohol use, there is always a threshold of heavy drinking beyond which heavy drinkers represent a loss of profit for the alcohol industry. This threshold is given by (9).

Proof. We know that the level of heavy drinking is a positive number such as $\bar{q} \in \mathbb{R}_+$ and, by definition of the ‘Lambert W function’, $W(0) = 0$, and $W' > 0$. As a result, $\forall \lambda, g_1, RR, \theta, H_1 > 0$, $W(\cdot)$ is a finite number and it is always possible to pick a value of \bar{q} such as (9) holds.

The proposition states that, from a theoretical perspective, there always exists a threshold beyond which heavy drinking damages the profit of the alcohol industry. The third section proposes to estimate the value of this threshold for the 2011 U.S. case.

3. CALIBRATION WITH 2011 UNITED STATES DATA

We use 2011 U.S. data to calibrate the value of the parameters of our model. Levels of alcohol consumption came from the 2011 *Behavioral Risk Factor Surveillance System* (BRFSS). The BRFSS is a state-based random-digit-dial telephone survey of people aged ≥ 18 years, which is conducted monthly in all states, the District of Columbia, and three U.S. territories. BRFSS collects self-reported data on health conditions and risk behaviors. Binge drinking was defined as consuming ≥ 5 (men) or ≥ 4 (women) drinks per occasion. Data were weighted to be representative of state populations². Using the 2011 BRFSS, Kanny *et al.* (2013) stated that binge drinkers represent 18.4% of the U.S. population. Binge drinkers reported 4.2 occasions of binge drinking by month, with an average of 7.7 drinks by binge drinking episode. It should be noted that for the U.S. one standard drink is equal to 14 grams of pure alcohol. In order to shape our model to the available data, let the ‘unit’ of alcohol be a drink and the period be a year. According to the findings of the study conducted by Latino-Martel *et al.* (2011) in some developed countries (UK, Australia, Denmark, France, *etc.*), we define ‘daily’ moderate consumption as 2.5 drinks per day. Finally, we approximate the discount rate by the 2011 U.S. inflation rate (2.962%).

In 2011, the percentage of fatal injuries in the U.S. was 0.06%, and according to Guérin *et al.* (2013) the percentage of injuries attributable to alcohol consumption reaches 21.82%. The probability of dying from a fatal injury caused by alcohol per year is 0.01% and 0.095% per binge drinking episode. By doing so, we assume that fatal injuries caused by alcohol are only related to ‘festive’ episodes, but both heavy drinkers and moderate ones have a probability of fatal injury of β^B and β^M , respectively. Following the study conducted by Borges *et al.* (2006) on several countries (Canada, Sweden, New Zealand, *etc.*), we consider that the relative risk between a consumption higher than 6 drinks and a consumption around 2-3 drinks equals 2.59 ($\beta^B/\beta^M = 10.1/3.9$). Using equations (4) and (5), we get $\beta^L = 0.0007$ and $\beta^H = 0.0019$. We did not find documented values for a_1 , g_1 and b_1 . As a result, we consider the most basic case in which $a_1 = g_1 = 1$ (exit flows consist entirely of deaths) and $b_1 = 0$ (heavy drinking is neither attractive nor repulsive). All the values of the parameters are summarized in Table 1³.

² Extensive details about the BRFSS and its methods are available at www.cdc.gov/brfss (accessed March 01, 2017).

³ Appendix A provides details concerning the value of the parameters described in Table 1.

Table 1. Parameters of the model for the case of the United States in 2011

Parameter	Value	Description
H_1	0.184 [0.181, 0.186]	Number of heavy drinkers at period 1*
L_1	0.816 [0.814, 0.819]	Number of light drinkers at period 1*
θ	0.138 [0.133, 0.14]	BD episodes per period *
\bar{q}	7.7 [7.6, 7.7]	Level of heavy consumption during binge drinking *
q	2.5 [2, 3]	'Daily' moderate consumption †
ρ	0.00095 [0.00090, 0.001]	Probability of fatal injury during a BD episode §
λ	0.00000043 [0.00000041, 0.00000045]	Risk parameter §
β^H	0.0019 [0.0018, 0.00201]	Risk of fatal injuries borne by binge drinkers §
β^L	0.0007 [0.00069, 0.00078]	Risk of fatal injuries borne by light drinkers §
a_1	1 [1, 1.1]	Negative impact of light drinker's risk ¶
g_1	1 [1, 1.1]	Negative impact of heavy drinker's risk ¶
b_1	0 [-0.05, 0.05]	Transition parameter ¶

* Ranges of values are 95% confidence interval (Kanny *et al.*, 2013).

† Ranges of values are defined by Latino-Martel *et al.* (2011).

§ The lower bounds and the higher bounds are defined considering the minimum and maximum of fatal injury rates during the period 2009-2013 calculated with data of the *Centers for Disease Control and Prevention*.

¶ We choose the fluctuating range such as the amplitude reaches 0.1.

We use a Monte Carlo-like approach in order to test the sensitivity of our result considering the ranges of values of the parameters used. We randomly and simultaneously simulated all parameters 10,000 times to obtain a consistent fluctuating range for the threshold highlighted in (9). According to our model calibrated with U.S. data, the threshold is 10.6 drinks (or 148 grams of pure alcohol) fluctuating into 10.22 – 10.80 drinks (or 143.08 – 151.2 grams of pure alcohol). This threshold is higher than the average number of drinks (7.7 drinks) consumed by binge drinkers during 'festive' episodes in the U.S. in 2011. However, this figure disregards the variance of the average number of drinks. In fact, the intensity of binge drinking varies largely across socioeconomic data (Kanny *et al.*, 2013). A salient illustration is provided by Dawson *et al.* (2010). With a representative population sample of U.S. drinkers, they show that, according to the type of disorder, people subject to alcohol use disorder report an average number of drinks included in a range between 9.4 and 15.4 per 'festive' episodes. In the 2011 BRFSS, 3% of the drinking population consumed more than 10 drinks during a binge drinking episode, with an average of 15.86 drinks. According to our model these drinkers would represent a loss of profit for the U.S. alcohol industry.

Finally, it should be noticed that data from the BRFSS are self-reported and thus suffer from underreport, especially for binge drinking (Kanny *et al.*, 2013; WHO, 2014). This is due to recall bias, social desirability response bias, and nonresponse bias (Stockwell *et al.*, 2004). These biases probably imply a level of \bar{q} higher than 7.7 and a lower threshold as defined in (9). Consequently, results exhibited here are likely underestimated.

4. CONCLUSION

In this article we argue that, due to the short-term risks of fatal injuries, heavy drinkers may represent a loss of profit for the alcohol industry. We use a two-period 'LH' model and we find that

there always exists a threshold of alcohol consumption during festive episodes beyond which heavy drinkers represent a shortfall for the alcohol industry. Regarding the U.S. case in 2011, the threshold estimated equals 10.6 drinks (or 148 grams of pure alcohol), fluctuating into 10.22 – 10.80 drinks (143.08 – 151.2 grams of pure alcohol) per heavy drinking occasion. Then, in order to maximize profits, alcohol industry would have an interest to limit alcohol consumption of heavy drinkers exceeding this threshold.

In our opinion, our results have two main implications. First of all, alcohol industry should take into account more seriously that a portion of heavy drinkers are ‘bad for business’ and should set up more effective actions to face this loss of profit. However, as pointed by Esser *et al.* (2016, p. 711, brackets are ours): “the alcohol industry did not report evaluation for nearly two third (63%) of its actions [to reduce drink driving from 1982 to May 2015]. Among the reported evaluations, none were rigorous [...]”. This lack of meticulousness shows that heavy drinking is currently not considered as a real issue for the industry. Yet, our results suggest that it should be the case. The second implication regards collaborations between public health and alcohol industry. We find that tackling (highly) excessive drinking through Public-Private collaboration may be a ‘win-win’ strategy, as suggested by the OECD (2015a) report. Nonetheless, it should be noted that our results also indicate that for all drinkers consuming less than (9), the alcohol industry has interest to increase their level of alcohol use until the threshold. In this case, “the conflict of interest is such the alcohol industry cannot afford to be [public authorities’] friend” (Caswell *et al.* 2016, p. 663, brackets are ours). Consequently, a ‘win-win’ collaboration may be reachable only for the heaviest drinkers.

Finally, this article can be characterized as a modest theoretical expansion of works conducted by Behrens *et al.* (1999), Caulkins *et al.* (2010), and Massin (2012) for the case of alcohol use. Further extensions of this work may be envisaged in future research. First, the temporal horizon of the model may be extended ($t > 2$) to capture long term-risks associated to alcohol use (e.g. cancers or cardiovascular diseases) and cohort-related effects. By doing so, heavy consumptions would represent a higher shortfall for the alcohol industry in the sense that the global risk (ρ) increases. Therefore, by extending the temporal horizon of the model, we would find that alcohol industry should be more prone to implement effective actions to fight against heavy drinking. Second, a “treatment” stage may be implemented to account for people willing to stop consumption. Third, it would be interesting to distinguish for various age groups and other countries in order to study the impact of different patterns of drinking. For example, social drinking is a key feature of college drinking ($b_1 \gg 0$) but seems less relevant for other populations (probably negative b_1). In the same vein, the threshold defined in (9) is likely to be different between high income countries (low θ) and middle income countries (high θ) (Caswell *et al.*, 2016), but also within high income countries, for example between Southern Europe (e.g. France, Italy) where binge drinking is not a common practice (low θ) and Northern Europe (e.g. U.K., Sweden, Latvia) (high θ) (OECD, 2015b).

APPENDIX A. Details concerning the value of the parameters described in Table 1

Parameters $H_1, L_1, \theta, \bar{q}, q, RR$ and ρ are directly picked in previous works or studies as mentioned in Table 1.

Concerning parameters associated with short-term risks (λ, β^H and β^L):

- Following equation (4), we have $0.00095 = \lambda e^{7.7}$ and thus $\lambda \approx 0.00000043$.
- Following equation (6),
$$\beta^H = 2.59 \times 0.00000043 \times e^{7.7} / (0.816 + 0.184 \times 2.59) \approx 0.0019.$$
- Following equation (5), $\beta^L = 0.00000043 \times e^{7.7} / (0.816 + 0.184 \times 2.59) \approx 0.00073$.

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