Optimal alcohol taxation: Simulation results for Estonia

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Abstract

The aim of this paper is to empirically estimate the optimal level of alcohol taxes for Estonia on externality as well as fiscal grounds. For this purpose, a static general-equilibrium model with a representative agent was used. Simulation results showed that raising alcohol taxes a certain amount is warranted. However, if one were to use conservative parameter values, this result is undermined. With an eye towards future research, more reliable estimates for several parameters are required in order to increase the policy relevance of the model.

Keywords: alcohol, externalities, optimal tax
JEL classification: H21, H23

1. Introduction

Until 2008, the Estonian government implemented a rather liberal tax policy concerning alcohol. As a consequence, prices of alcoholic beverages fell constantly relative to the average overall price level. At the same time, Estonia experienced an increase in alcohol consumption (Estonian Institute of Economic Research, 2010a) to approximately 12 liters of pure alcohol per capita in 2008, and struggled with extremely high alcohol-related mortality rates (WHO, 2011). In 2008 and in 2010, however, tax rates were raised fairly sharply. Rates on most alcoholic beverages were raised almost 50% during this period. One reason for this policy change was the government’s aim to rely more on indirect taxation. The aims to decrease alcohol-related harm and achieve positive fiscal effects were also considerations. The latter applies especially to the last tax increase in 2010, which was imposed mainly because the government needed to minimize a fiscal deficit caused by the world-wide economic downturn.

This hectic train of events posed the question as to what the appropriate alcohol policy should actually be. Previously, no single study has been conducted to address this issue in Estonia. The main concern of Estonian researchers has been quantification of alcohol-related morbidity and mortality (Kaasik et al., 2007; Lai et al., 2003) as well as estimation of the social costs of alcohol (Saar, 2009). Additionally, one study compared different alcohol control strategies in regard to the way that they apply to the health care sector (Lai et al., 2007). Although these studies have shown that alcohol places a substantial burden on society and that alcohol taxation policy may be one of the most cost-effective intervention strategies, the optimal alcohol taxation issue has not been considered. This paper, aimed at addressing that matter, is the first attempt to generate empirical estimates for an optimal level of alcohol taxation in Estonia.

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Prior literature has usually addressed the optimal alcohol taxation problem in a partial equilibrium setting, in order to deal with inefficiency in alcohol markets caused by negative externalities. In these papers, the classic solution to the externality problem, first proposed by Pigou (1920), has been applied. In that approach, optimal alcohol taxation concerns internalizing external costs attributed to excessive drinking. This is carried out by balancing the deadweight loss of taxation due to distorted consumption choices of moderate drinkers against benefits from reduction of external costs caused by abusive drinkers (e.g. see Kenkel, 1996; Pogue and Sgontz, 1989). However, while the partial equilibrium approach completely ignores fiscal issues, fiscal considerations are of high importance in the Estonian context. For example, alcohol excise tax revenues represented approximately 4% of total tax revenues to the central government budget in 2009, even exceeding revenues from personal income tax. Therefore, it would be quite important for Estonia to arrive at an optimal level of alcohol taxation that would be appropriate for both revenue-raising and externality-corrective purposes. Pigouvian taxation alone fails to accomplish that.

Until the middle of the 20th century, revenue-raising taxation and externality-corrective taxation were analyzed separately in the literature. Pigouvian taxation was designed to address only externalities, while revenues collected under these taxes were assumed to be returned in a lump-sum fashion. Revenue-raising taxation had dealt with the question of how to raise public revenues with minimized deadweight loss of taxation, while the existence of externalities was ignored. The general-equilibrium approach, which would integrate these two strands into a single framework, was introduced by Sandmo (1975), and has been further developed mainly in environmental policy literature (Goulder et al., 1996; Schwartz and Repetto, 2000; Williams, 2003; Caffet, 2007). This approach suggests in essence that the optimal tax rate on externality-generating commodities may differ considerably from Pigouvian tax on fiscal grounds.

To the author’s best knowledge, only Parry et al. (2009) have considered both externality and fiscal rationales simultaneously for obtaining optimal levels of alcohol taxation and resulting welfare gains in the United States. Compared with models applied in environmental policy literature, Parry et al. take a broader range of revenue uses into account, since excessive drinking may result in economic costs not only to the health care sector, but also to the criminal justice system. They also include drunk driving as well as pecuniary and non-pecuniary penalties for incidents of drunk driving. In their model, the effects of raising alcohol taxes are assumed to immediately spill into changes in other areas of government policy, such as labor taxation, medical spending or government transfers, while also accounting at the same time for behavioral responses of individuals. The latter concern drinking, drunk driving, and labor supply decisions. By decomposing optimal tax into different components and estimating them empirically, the main conclusion of the authors was that the fiscal component of an optimal alcohol tax may be as large, or even larger, than the externality-correcting Pigouvian component.

This paper applies an almost identical model to obtain an optimal alcohol tax for Estonia. However, compared with analysis conducted by Parry et al. (2009), neither taxes on individual beverages nor overall welfare effects are estimated. At the same time, the model has been expanded upon, primarily in four ways. Firstly, alcohol purchases by tourists represent a considerable proportion of total alcohol sales in Estonia. Unlike tax revenues from local
taxpayers, which are simply transfers within a society, tax revenues from tourists could be treated as benefits, because they reflect an additional “windfall” contribution to the welfare of the community. These revenues can be used to provide public goods without the locals having to incur any costs (Gooroochurn and Sinclair, 2003). Therefore, this paper includes this effect in the optimal tax formula as well. Although - in addition to the alcohol market - tourists could also have a considerable effect on other sectors such as food services, accommodation, and transportation, this paper only considers excise tax revenue from alcohol purchases by tourists.

Secondly, it is assumed that raising tax on alcohol increases resource costs to government. Parry et al. (2009) only considered this kind of cost when a penalty rate is charged. Tax increases may however require even greater increases in administrative costs, since the black market tends to expand as price levels go up on the legal market. Therefore, deriving the optimal tax on alcohol, it is assumed that government can use more resources to deal with the possible expansion of the illegal alcohol market.

Thirdly, this paper allows public spending to interact with labor supply. For example, using alcohol tax revenue to increase public medical expenditure may raise the quality of health care services and as a result, labor supply incentives for individuals could go up. For this reason, an efficiency gain under the scenario described may be derived from two sources. First is the potential efficiency gain that comes from public spending itself. This arises when households place more value on the public good than on the money used to provide it. Secondly, if the supply of labor increases, deadweight loss in the labor market caused by labor taxes is reduced. This paper takes into account both of these effects. In fact, compared with the revenue-neutral case, examination of tax policy involving adjustment of public spending could have higher policy relevance because reduction of labor taxes, required to keep the budget balanced, may be politically unfeasible. In Estonia, for instance, this would mean a change in the overall system of social security funding, since part of the revenue from labor taxes is earmarked for social security expenditure.

The fourth expansion arises from estimates presented by Saar (2009), who indicated that public drinking misdemeanors and criminal offenses against persons account for more than half of the alcohol-related costs borne by the criminal justice system in Estonia. Consequently, in addition to drunk driving, public drinking and offenses against persons are also incorporated in the model as externalities. As regards public drinking, three different kinds of activity prohibited in Estonia are considered. Firstly, the Alcohol Act allows drinking alcohol in public only if permitted by the local government, or in places where retail sale for public consumption takes place. Secondly, the same law prohibits being under the influence of alcohol in a public place if this offends human dignity or the sense of morality. Thirdly, the Traffic Act applies specific pecuniary penalties for violation of traffic regulations by pedestrians who are under the influence of alcohol. In this paper, a public drinking variable that involves all of these acts is included for two reasons. To begin with, prosecuting public drinking misdemeanors places a substantial economic burden on the criminal justice system. In addition, a drunken individual may seriously harm other individuals as well as himself or herself when in a public place, such as on the road. Although Estonian laws do not prohibit drunken pedestrians being in traffic, this paper assumes that the risk of causing traffic accidents is the main negative externality of public drinking.
The paper is structured as follows: section 2 presents the model and derives an optimal alcohol policy formula, while section 3 estimates parameter values. Section 4 simulates the formula and discusses the results. Section 5 draws conclusions.

2. Deriving an optimal policy formula

2.1 The model

In this section, a static one-period general-equilibrium model with a representative agent is laid out. The structure of the model and variable notations closely follow Parry et al. (2009). However, since there are several important extensions, some new variables are included that are more specifically discussed below. The basic assumptions have not been changed, such as that regarding the agent’s ability to internalize the future costs of addiction. In the same manner, it is assumed that efficiency alone determines the optimality of policy, and that the fiscal system is financed only through labor tax, alcohol tax and pecuniary penalties. It is assumed that the agent, representing an aggregation of all households, maximizes continuous and quasi-concave utility function:

\[ U = U(A^0, c, l, d, n, p, \tau_D d, \tau_P p, h) \]  
\[ H = f(A^0, d, n, p, \bar{d}, \bar{n}, \bar{p}, r^M) \]  

In utility function (1), all variables are expressed as per capita, and a bar denotes variables exogenous to the agent. The agent’s utility is an increasing function in all variables except, \( \tau_D d \), \( \tau_P p \) and \( H \). The latter is an increasing function in all its arguments except \( r^M \).

The agent can freely choose the level of legal alcohol consumption \( A^0 \), consumption of non-alcoholic goods \( C \), leisure \( l \), drunk driving \( D \), public drinking \( N \) and offenses against persons \( P \). The agent’s choice to take a number of drunk driving trips or commit offenses against persons entails expected penalties equal to \( \tau_D D \) and \( \tau_P P \), respectively. Both, \( \tau_D \) and \( \tau_P \) denote non-pecuniary penalties per unlawful act. These penalties can be interpreted as the product of probability of being convicted per act and penalty per act.

Health risks \( H \) capture the risk of becoming ill, as well as the risk of being injured, disabled or killed. This is a quasi-concave function of crimes and misdemeanors committed by agents themselves and by others (variables with bar). Health risks are also affected by alcohol drinking directly, by causing internal illnesses, and by government expenditure level per one medical case \( r^M \). The latter is assumed to determine the quality of medical services, which are assumed to be free for individuals. Therefore higher quality of medical services improves chances for recovery and alleviates health risks.

There are no pure profits in the production side of the economy. Producer prices are fixed and firms pay a gross wage of that is equal to the value marginal product of labor. The effective labor supply \( W \) is the product of labor supply \( L \) and \( w \). Changes in \( H \) are assumed to affect labor productivity so that \( \frac{\partial W}{\partial H} < 0 \). In addition, auto insurance companies charge households a lump-sum premium \( k \) to cover the costs of auto repair \( C_D \) and \( C_N \). Auto repair
costs are expressed per one drunk driving trip and per one public drinking incident, respectively. To earn zero profit, companies adjust $K$ so that $K = c_D D + c_N N$.

Maximizing the utility agent faces the following budget and time constraints:

$$(1 - t_L)wL = (p_A + t_A)A^D + p_c C + t_N N + t_D D + K_D$$

$$T(H) = L + l$$

In (2) $t_A$ is tax rate on alcohol, $t_L$ is tax rate on labor, $t_D$ and $t_N$ are pecuniary penalties on drunk driving and public drinking, while $p_A$ is the producer price of alcohol. $T$ is time endowment, divided between labor and leisure, and is a decreasing function in health risks. The latter means that as alcohol-related health risks are higher, the time available to agents shortens due to being disabled or dying prematurely.

The consumer’s maximization problem yields the following first-order conditions:

$$\frac{u_A}{\lambda} = p_A + t_A + mpc \cdot H_A, \quad \frac{u_D}{\lambda} = t_D + \tau_D + mpc \cdot H_D$$

$$\frac{u_N}{\lambda} = t_N + mpc \cdot H_N, \quad \frac{u_P}{\lambda} = mpc \cdot H_P + \tau_P, \quad \frac{l}{\lambda} = (1 - t_L)w$$

$$mpc = -\left[\frac{u_H}{\lambda} + (1 - t_L)(wT_H + W_H)\right]$$

In (4) it is normalized, so that $-\frac{u_A}{\lambda} = -\frac{u_D}{\lambda} = 1$. In addition, $\lambda$ is marginal utility of income and $mpc$ denotes the marginal private cost of health risks. The latter consists of direct disutility from suffering $\frac{u_H}{\lambda}$, the value of reduced life expectancy $(1 - t_L)wT_H$, and lost wages from lower productivity $(1 - t_L)W_H$. It is seen from (4) that the agent increases alcohol consumption to the point where the marginal benefit received from the last drinking unit is equal to the tax-inclusive alcohol price and marginal private health cost. Similarly, misdemeanors and criminal offenses are committed until expected marginal benefit equals expected government penalties and marginal private health cost. Individuals also equate marginal benefit from leisure with net wage. (4a) and (4b) essentially show that the agent is assumed to be rational and possesses perfect information regarding the consequences of drinking. This means that in addition to the tax-inclusive market price she or he pays for alcohol, the agent also internalizes expected penalties as well as internal morbidity and mortality costs arising from alcohol consumption, drunk driving, public drinking and offenses. As a result, these variables do not appear in the Pigouvian component of the optimal tax formula below, which includes only external effects borne by the agent.

The government faces the following budget constraint:

$$r^M M + (r^D - t_D)D + (r^N - t_N)N + r^P P = (t_A - r^A)(A^D + A^P) + t_L W$$

$$M = f(A^D, P, D, N)$$

The right side of the equation (5) indicates that government receives revenues from two different sources. The government first gets revenues from alcohol taxation, less administrative cost per liter of pure alcohol $r^A$. Legal alcohol purchases are divided between consumption
by local drinkers $A^D$ and purchases by tourists $A^T$. The government also collects labor taxes. Total revenue is used for three purposes. First, government finances public medical expenditures $r^M M$, where $M$ is the number of medical cases, i.e. it is the number of medical conditions that an agent has, including only such conditions that government finances treatment of. Medical cases are defined by the function that increases in all its arguments. Secondly, government finances the criminal justice system, which includes costs of proceedings in cases of drunk driving $r^D D$ and public drinking $r^N N$, less pecuniary penalties, as well as proceedings costs in cases involving offenses against persons $r^P P$. In optimizing alcohol policy, externalities borne by foreign agents are ignored, while possible losses or gains to local agents arising from public use of tax revenues derived from alcohol purchases by tourists are taken into account.

In the model described above, increasing the alcohol tax brings several welfare effects. Before the optimal level of alcohol tax is obtained formally, the effects of alcohol taxation are followed intuitively in Figure 1. It is shown that increasing the tax reduces alcohol consumption, which in turn curbs drunk driving, public drinking, and offenses against persons. Accordingly, these effects improve the health of individuals by preventing a number of injuries and fatalities. A decrease in excessive alcohol consumption also has a direct effect on the health of individuals by lessening the incidence of internal illnesses. Negative health effects which would have been caused to other people by drinkers and are prevented due to increased taxes, termed as reduced health externalities in Figure 1, are regarded as the efficiency gain from reduced external costs. It must also be noted that resulting cost savings to the fiscal and auto insurance systems are included in the total efficiency gain, denoted as reduced fiscal and insurance externalities in Figure 1.

Figure 1: Welfare effects of alcohol taxation
A second type of welfare gain arises from reduced preexisting tax distortions in the labor market. Specifically, reduction in drinking is expected to decrease leisure demand and consequently increase labor supply. In addition, preexisting tax distortions in the labor market are also reduced through the fiscal system. This arises due to the assumption that the government keeps its budget balanced by adjusting either labor taxes or public spending. Specifically, an increase in tax revenues from alcohol tax and cost savings to the health care and criminal justice systems allows reduction of labor taxes, increasing labor supply even more. The arrow running from the labor market to the fiscal system reflects the fact that any change in labor supply affects revenues from labor taxes and also affects the public budget.

Alternatively, if - instead of cutting labor taxes – the improved budget position is used to increase public spending, efficiency gains may arise from such spending. This efficiency gain could be amplified if public spending interacts with labor supply choices by increasing labor supply. There is of course the possibility that these revenues might be used wastefully, in which case efficiency gain would fail to arise from this channel. Finally, there is an arrow running from “better health” to “labor market”. This denotes the fact that people’s better health increases their productivity. As a consequence, their wage as well as the time they are available for work increases, resulting in an additional efficiency gain, identified as on-the-job-productivity.

2.2 Optimal tax policy

This section derives optimal alcohol policy formulas. Throughout the optimization, it is assumed that government aims to maximize the utility of the agent by finding the optimal level of \( t_L \), given the level of \( t_D \), \( v_N \), \( \tau_D \) and \( \tau_P \). At the same time, the government must keep its budget balanced. To do that, it can change the tax rate on labor \( t_L \) or resource cost per medical case \( r^M \). Optimal policy formulas for both alternatives are derived.

Differentiating the indirect utility function with respect to \( t_A \), allowing changes in \( t_L \) or \( r^M \) to keep the government budget balanced, equating the resulting equation with zero and solving for \( t_A \), gives the following optimal tax formula (see derivation in Appendix 4):

\[
t_A^* = PV^A + RR^A + FB^A - TI^A + PR^A
\]

where

\[
PV^A = g^A + \frac{\eta_{DA}}{\eta_{AA}} (c_D + mpc \cdot H_D) + \frac{\eta_{NA}}{\eta_{AA}} (c_N + mpc \cdot H_N) + \frac{\eta_{PA}}{\eta_{AA}} mpc \cdot H_P + \tau_A^A \frac{p_A + t_A}{\eta_{AA}}
\]

\[
RR^A = [(1 + \mu_A) (\mu_i + MEG_i) - \mu_i] \left[ (1 - r_A^A) \frac{p_A + t_A}{\eta_{AA}} - t_A + g^A \right].
\]

\[
FB^A = (1 + \mu_A) (1 + MEG_i) \left[ (1 - r_A^A) \frac{A^F p_A + t_A}{A^B (-\eta_{AA})} - (t_A - r_A^A) \frac{\eta_{EA}}{A^B \eta_{AA}} \right].
\]

\[
TI^A = (1 + \mu_A) (1 + MEG_i) \frac{t_L (p_A + t_A) (\eta_{AA} + \mu_i)}{(1 - t_L) (-\eta_{AA})},
\]

\[
PR^A = (1 + \mu_A) (1 + MEG_i) t_L (-W_H H_A d), \quad (i = t_L, r^M)
\]
It is seen from (6a) that the optimal tax on alcohol contains five components. $P\lambda$ is the Pigouvian tax that captures the externalities that alcohol abusers impose on others, less marginal resource costs required to administer alcohol taxes. More specifically, marginal external costs $g^t$ are borne by third parties through the fiscal system. These costs, formally decomposed in Appendix 4, are divided into three different categories. First are costs to the health care system due to alcohol consumption, drunk driving and public drinking, expressed as resource cost per medical case $r^\mu$, multiplied by marginal medical case of alcohol consumption, marginal medical case of drunk driving and marginal medical case of public drinking, respectively. Second are costs to the criminal justice system expressed as resource cost per incident of drunk driving $r^\sigma$, public drinking $r^\pi$ and offense $r^\rho$, less pecuniary penalty. Third are costs that have to be borne by the government in order to collect alcohol tax $r^\iota$, expressed per liter of pure alcohol.

The Pigouvian component also includes the marginal private health cost $mpc \cdot H_p$, that individuals must face due to others’ drunk driving, others’ offenses and others’ public drinking, respectively. Property damage due to traffic accidents $C_d$ and $C_n$ are expressed per drunk driving trip and per public drinking incident, respectively. This shows up in the agent’s budget in terms of higher insurance premiums charged by auto insurance companies. Almost each term in $P\lambda$ is multiplied by either $\frac{D_{nda}}{\eta_{aa}} \cdot \frac{N_{nda}}{\eta_{aa}}$ or $\frac{P_{nda}}{\eta_{aa}}$ in order to express them in terms of per unit reduction in alcohol consumption. Only marginal medical cost of alcohol consumption and administrative costs per liter of pure alcohol are expressed simply as $r^\lambda M^\lambda_d$ and $r^\lambda$, since both are already in the appropriate form.

The second component of optimal tax is the revenue-recycling effect, denoted as $T\lambda$. This captures changes in both tax revenues and alcohol-related public expenditure induced by alcohol tax. To be more specific, the first two terms of this component reflect marginal tax revenue, net of the marginal administrative cost of alcohol tax, and are expressed per unit reduction in alcohol consumption (by domestic agents). The third term reflects savings in expenditure by the criminal justice system and health care system. As regards the role of price responsiveness of locals’ alcohol consumption: the lower it is, the greater the tax revenue from alcohol taxation as well as the overall revenue-recycling effect.

The third component $T\iota$ is the tax-interaction effect that - together with the revenue-recycling effect - forms the fiscal component. This arises from change in labor supply induced by raising the alcohol price relative to leisure. When alcohol and leisure are complements or weak substitutes, the alcohol tax increases the labor supply, and the tax-interaction effect is positive. Under weak substitutability, labor supply increases because the income effect that is also caused by the rise in alcohol tax more than offsets the substitution effect. Formally, labor supply increases as long as $\eta_{\lambda L} < 0$ or $0 < \eta_{\lambda L} < |\eta_{\lambda L}|$. If alcohol and leisure were strong substitutes, raising the alcohol tax would decrease alcohol consumption as well as labor supply and labor tax revenue. In this case, the tax interaction component would obviously be negative.

Fourth is the productivity effect $P\iota$, expressed per unit reduction in alcohol consumption. This arises since taxing alcohol reduces drinking overall, to include public drinking, drunk driving and alcohol-related crimes. As a result, consequences of these activities such as internal diseases and external harm inflicted on others are also decreased. This means that
individuals have better health and longer life spans. Both have a positive effect on effective labor supply.

Finally, there is the additional component reflecting changes in tax revenues from alcohol purchases by tourists, termed as foreign benefit effect $FBA$. This is expressed per unit change in alcohol consumption by local drinkers, net of administrative costs of alcohol tax. Although the foreign benefit effect has characteristics similar to the revenue-recycling effect, since in both cases revenues are recycled either to reduce labor tax or to increase public spending, there is one important difference. While marginal tax revenue from drinking by locals does not improve efficiency per se, marginal tax revenue from tourists does. More specifically, the former simply shifts resources within society from households to government, while the latter directly reflects an addition to the community’s welfare that is complemented by a possible efficiency gain from use of these revenues.

Multipliers in front of each component except Pigouvian tax account for efficiency gain achieved either by reducing labor taxes or increasing medical expenditure. It should be noted that $\mu_L$ in (6) is the dummy variable that integrates tax policies with labor tax and public spending adjustments in one equation. For this purpose, $\mu_{r, M} = 1$ and $\mu_{tL} = 0$. In case of $i = t_L$, the multiplier in front of the revenue-recycling component simplifies to $1 + MEG_{ul}$. The multipliers of the following components simplify to $\mu_{r, M}$ is the marginal efficiency gain from reducing labor tax, defined as the marginal deadweight loss of labor tax per marginal tax revenue (defined formally in Appendix 4). Deadweight loss is expressed as the product of the wedge between the gross wage and net wage $tL$ and reduction in labor supply $\frac{\partial L}{\partial tL}$. Therefore: when alcohol policy enables a reduction in labor tax, efficiency gain can be achieved in terms of reduced deadweight loss.

When public spending is increased – instead of cutting labor taxes – i.e. $i = r^M$, tax policy with a public spending adjustment is implemented, meaning that marginal tax revenue and savings in alcohol-related public expenditure are used to increase $r^M$. As a result, the revenue-recycling effect comprises the multiplier $[(1 + \alpha)(1 + MEG_{r, M}) - 1]$, and tax-interaction, productivity and foreign benefit components comprise $[(1 + \alpha)(1 + MEG_{r, M})]$. $MEG_{r, M}$ is the marginal efficiency gain from marginal medical expenditures, and $\alpha$ is the multiplier effect of government medical expenditure (both defined formally in Appendix 4). The former reflects the value of one additional euro to the agent, spent on medical services, per medical case, minus one euro. This effect arises from changes in the labor supply caused by change in medical expenditure. As regards the latter, the numerator of the first term in $\alpha$ expresses increase in government medical expenditure due to marginal increase in $r^M$. This is obtained by differentiating $r^M M$ with respect to $r^M$. The same term is included in the denominator, except that an additional term, denoted by $wt_L \frac{\partial L}{\partial r^M}$ is added. The latter, while reflecting marginal labor tax revenue, arises from change in labor supply as labor supply decisions are affected by changes in the level of $r^M$. Therefore, $\alpha$ basically indicates that increasing $r^M$ by one euro requires resources of less than one euro. The reason is that this kind of spending policy returns part of the resources through an increase in labor tax revenue after it has increased labor supply. It should be also noted that as it is reasonable to assume that $M > wt_L \frac{\partial L}{\partial r^M} > 0$, it is also obtained that $0 < \alpha < 1$. 
3. Parameterization of the model

In this section, parameter values and their derivation are described. All values were estimated for 2009 if not stated otherwise. Three different values were applied to most parameters to obtain the mid, low (conservative) and high (non-conservative) estimates. Low is interpreted here as parameter value that - compared with mid value - decreases optimal tax. In contrast, computations based on high values reflect the upper limit of tax rates. To find upper and lower limits, a ±30% variation is allowed, so that parameter values under mid estimates were multiplied by 1.3 and 0.7, respectively.

As regards elasticities, a somewhat different logic was followed. Specifically, while the range was chosen based on evidence in the literature, high price responsiveness was assumed in order to obtain low estimates for optimal policy and vice versa, regardless of their influence on the optimal level of taxation. Although higher price responsiveness of violence, for instance, contrary to higher alcohol demand elasticity, suggests need for imposition of higher tax on alcohol, it is reasonable to assume that under high alcohol demand responsiveness the same would apply to crime and misdemeanors as well. Therefore, under low optimal tax estimates, all elasticities are assumed to be at the upper range.

**The alcohol market and labor tax**

The current tax rate $t_A=9.4$ EUR was estimated by dividing revenue from alcohol tax (Statistics Estonia, 2011a) by the quantity of alcohol sales (measured in liters of pure alcohol). Producer price of alcohol $p_A=7.8$ EUR is the tax-exclusive market price per one liter of pure alcohol. The tax-inclusive market price was found by dividing the retail turnover of the alcoholic beverages market by alcohol sales in liters of pure alcohol. Initial alcohol consumption $A_D=9.6$ measures total consumption of pure alcohol (excluding illegal alcohol) and $A_F=3.26$ measures sales to tourists, both expressed in liters of pure alcohol per Estonian. Data pertaining to the alcohol market including turnover, alcohol sales, alcohol consumption and purchases by tourists were obtained from the Estonian Institute of Economic Research (2010a) which compiles regular alcohol market overviews in Estonia.

In 2008, the implicit tax rate on labor was 33.7% in Estonia (Eurostat, 2011a). During the recession in 2009, when real GDP decreased by more than one tenth, the government carried out some policy changes concerning income tax and employment insurance tax to achieve its fiscal goals. As a result, the tax rate on labor was probably somewhat higher than in the preceding year. Therefore, in this paper $t_L=0.35$ is applied.

**Misdemeanors and crimes**

Data about registered misdemeanors were drawn from the Estonian Police and Border Guard Board, and data about registered crimes were drawn from the Ministry of Justice through personal communication. Deriving empirical estimates about the total number of drunk driving and public drinking incidents, it was assumed that 5% of all incidents are registered. In the case of serious crime, a detection rate of 90% was applied. This means...
that $D=191\,520$ and that $N=382\,580$ was obtained by multiplying the registered number of drunk driving and public drinking incidents by 20, and was obtained by multiplying the registered number of crimes by 1.11.

This was estimated that $t_D=28.8$ EUR and $t_N=9.6$ EUR. Both represent half of the maximum penalty rate that can be charged in Estonia on the basis of the Traffic Act and Alcohol Act, divided by the number of unlawful acts committed. To be more specific, $t_D$ is the penalty rate per drunk driving trip and $t_N$ is the penalty rate per public drinking incident.

Cost parameters regarding auto repair due to drunk driving $C_D=70.6$ EUR and public drinking $C_N=11.8$ EUR were estimated based on data from Statistics Estonia (2011b). More specifically, alcohol-related motor third party liability insurance gross claims, attributed equally to drunk drivers and public drinkers, were divided by the number of drunk driving trips and public drinking incidents, respectively. Association with alcohol was created through an alcohol attributed factor that is equal to 0.42, the same that was used by Saar (2009).

**Marginal effects**

Appendix 1 comprises values for parameters that reflect marginal effects of drinking, drunk driving, public drinking and offenses. To obtain figures for marginal medical cases, medical cases attributed to alcohol were first found, using the total number of medical cases registered by the Estonian Health Insurance Fund and attributable factors analogous to Saar (2009). Secondly, alcohol-related medical cases were divided into four categories – traffic injuries caused by drunk drivers, traffic injuries caused by pedestrians, injuries related to offenses, and medical cases related to internal diseases. In the case of traffic accidents, it was assumed that three fourths of alcohol-related traffic injuries were caused by drunk drivers and one fourth by pedestrians. Medical cases in the fourth category were considered to be the consequence of drinking alcohol. The third step was to subtract the number of medical cases that will be canceled out due to premature mortality. Based on data obtained from the Estonian Health Insurance Fund (2011) it was estimated that in 2009 there were 2.6 medical cases per inhabitant in Estonia. Therefore, in essence, each death reduces the burden to the health care sector by eliminating the costs of treating these 2.6 medical cases. This means that the final number of medical cases in each category is expected to reflect the number of medical cases that can be attributed to alcohol, net of medical cases prevented by the use of alcohol. The fourth step was to divide the number of alcohol related medical cases in each category by the total number of respective alcohol-related acts. For example, in case of $M_D$ the number of medical cases in the fourth category was divided by the amount of alcohol consumed by Estonians in 2009, including alcohol bought from the black market (0.6 liters of pure alcohol per capita). Therefore, the estimated value for $M_D=0.007$ applies to both legal and illegal alcohol, as it is assumed that there is no difference between legal and illegal alcohol regarding generation of externalities. To estimate $M_D$, $M_N$, $M_P$, the number of alcohol-related medical cases of drunk driving, public drinking and offenses were divided by the total number of drunk driving trips, incidents of public drinking, and offenses, respectively.

In essence, this kind of derivation method to derive marginal medical cases means that marginal and average values are assumed to be equal. However: it is reasonable to assume in practice that
as alcohol consumption, drunk driving or the number of crimes committed increase, marginal alcohol-related externality also increases. In such a case, this assumption underestimates marginal effects and yields conservative estimates for Pigouvian as well revenue-recycling components.

There is another block of parameters in Appendix 1 comprising marginal on-the-job-productivity costs and marginal private costs, both borne by individuals through marginal health risks. Based on 2006 data, Saar (2009) has estimated productivity costs due to the lower state of health of alcohol abusers to be EUR 13.52 million, and productivity costs due to disability costs that arise from lost workdays attributed to alcohol to be EUR 7.41 million. Accordingly, total workplace productivity cost is estimated as EUR 20.93 million and productivity costs per liter of pure alcohol $W_H H_D = 1.63$.

As defined hereinbefore, marginal private costs that enter the Pigouvian component comprise direct disutility from suffering, the value of reduced life-expectancy, and lost wages from lower productivity. All three components must be estimated in order to obtain $H_D$, $mpc \cdot H_R$ and $mpc \cdot H_P$, - separately for all three parameters. Starting with the latter component, according to Saar (2009), offenses against persons and traffic accidents account for 4.6% and 7.4% of disability costs, respectively. Therefore, total workplace productivity costs due to the agent’s drunk driving are estimated to be EUR 0.55 million and EUR 0.34 million, due to offenses. As concerns offenses, all costs were considered as external. In the case of workplace productivity costs due to the agent’s drunk driving, however, it was assumed that three fourths of traffic-related external health costs attributed to alcohol were caused by motor-vehicle drivers, one third of which are assumed to be external. This means that two third of alcohol-related traffic accidents caused by drivers were assumed to have been caused by the victims themselves. For example, a drunk driver may have driven off the road or crashed into a tree. Values for $W_H H_D$ and $W_H H_P$ were obtained by dividing external productivity costs respectively by the number of drunk driving trips and offenses committed. Although one fourth of traffic-related health costs were assumed to be caused by pedestrians, all of them were considered as internal (meaning that $W_H H_N = 0$).

While disutility from suffering was excluded, the monetary value of reduced life expectancy was obtained from Saar (2009). He has estimated that productivity losses due to alcohol-related premature mortality ranged from EUR 142 million to EUR 247 million in 2006. Dividing the lower value by alcohol-related deaths in the same year produces a figure of EUR 0.56 million. This was chosen to reflect the value of life. To find the reduced value of life expectancy due to offenses, the value of lost life was multiplied by the number of alcohol-related homicides, and the resulting value was divided by the total number of alcohol-related assaults. Finally, to obtain $mpc \cdot H_P = 8442$ EUR, the sum of monetary values of reduced life expectancy and lost wages per alcohol-related assault was multiplied by $(1-t)$). $mpc \cdot H_P$ was derived analogously, with the caveat that just as in the case of lost wages, only one third of fatalities were considered as externalities. It is assumed that in all accidents caused by pedestrians, only pedestrians themselves are injured or killed, so that $mpc \cdot H_N = 0$.

**Government resource costs**

Appendix 2 is comprised of variables indicating resource cost to government. As regards costs to the criminal justice and health care systems, estimates were derived analogously to
Saar (2009), applying the same alcohol-attributable factors to the costs incurred in 2009. In the case of the criminal justice system, costs to the Police Board, the Courts of the first and second instance, the Prosecutor’s Office and Prisons were included. Required data were obtained through personal communication with the Estonian Police and Border Guard Board and the Estonian Ministry of Justice, and from statistics published by the Estonian Ministry of Justice (2010a, 2010b). In short, operating costs per alcohol-related activity (expressed as proceedings initiated or crimes registered etc.) engaged in by these institutions were computed in order to estimate resource costs attributed to alcohol. It was also assumed that in Police Board proceedings, one criminal offense requires 20% more resources than processing a misdemeanor. To obtain court costs, initiated proceedings were weighted by the duration of different types of proceedings to differentiate between misdemeanors and criminal offenses. Otherwise it was assumed that all activities entail proportionally equal costs within an institution. Average cost to the health care system per medical case was estimated based on data about total costs by different alcohol-related diseases. Data were obtained from the Estonian Health Insurance Fund through personal communication.

Resource costs for the Tax and Customs Board in respect of alcohol taxation were found by taking the share of total operating costs of the Tax Board proportional to the ratio of alcohol tax revenues to total tax revenue, and dividing this by alcohol sales in liters of pure alcohol. In the last row of Appendix 2, marginal costs due to the increase in tax rate are presented. Although administrative costs of alcohol taxation were estimated to represent only 0.05% of alcohol tax revenue, a marginal cost figure $\tau^A_t = 0.1$ was applied in the present study. Basically, this means that by increasing the tax rate by one euro, the Tax Board increases its expenditure by 10 cent per each liter of pure alcohol sold on the market. This highly conservative value was applied to take into account possible expansion of the black market, because as the tax rate goes up, the more resources the government may require for monitoring.

**Elasticities and marginal efficiency gain**

Elasticities used to derive the optimal tax level are presented in Appendix 3. Analogously to Parry et al. (2009) a range from -0.4 to -1.0 was chosen for price elasticity of alcohol demand by locals. Recently this choice has been supported by a review conducted by Elder et al. (2010). Price elasticity of alcohol purchases by tourists was held constant, while it was allowed to vary from -0.4 to -2.0 in sensitivity analysis. There is empirical evidence that the quantity of criminal offenses or misdemeanors committed is responsive to alcohol price (Elder et al., 2010; Wagenaar et al., 2010). In this paper, the elasticity of both misdemeanors and criminal offenses is suggested to lie within the same range as alcohol consumption. Elasticity of drinking with respect to price of leisure was drawn from West and Parry (2009), who indicated an interval from -0.12 to 0.08. In this study, the interval is widened somewhat and $\eta^L_t = -0.1$ is used as the mid estimate.

There is a vast body of literature estimating labor supply elasticity. The majority of these reports have found it to be inelastic (Evers, et al. 2008). Recently, Staehr (2008) has applied Estonian data to estimate labor participation elasticity and arrives at 0.6. This study applies 0.2 to get conservative estimates for optimal alcohol policies. The latter gives an outcome of $MEG_{a.e} = 0.12$. There is, to the author’s knowledge, no scientific evidence that would help
to estimate $\alpha$ and $MEG_{M}$, 0.1 was suggested as the mid estimate for both parameters. However, lower values are examined under sensitivity analysis.

4. Simulation

Baseline results

Table 1 presents simulation results. As shown, the mid estimate suggests that the optimal tax rate per liter of pure alcohol is EUR 13.1 with a labor tax adjustment and EUR 15.9 with a public spending adjustment. Both patently exceed the current tax rate. However, the optimal policy is rather sensitive to changes in parameter values. Low estimates represent two thirds and high estimates more than 500% of the current tax rate. It may be surprising to find that the Pigouvian component is negative under high estimates. The reason is that under this scenario, a low elasticity of alcohol demand was applied that considerably increased the marginal administrative cost, with the latter expressed per unit of decreased consumption of alcohol. In other words, at the same time that the amount of traffic in alcohol monitored by the Tax and Customs Board does not change appreciably, administrative costs per liter of pure alcohol do increase. The consequence is that the marginal increase in administrative costs exceeds marginal external costs, producing a negative Pigouvian effect. Examining the structure of the Pigouvian component, it appears that regardless of the scenario, more than half of it is attributable to property damage due to traffic accidents and external costs borne by the fiscal system.

It is easy to see that the great variability in the optimal tax under the alternative scenarios is mostly caused by the high level of sensitivity of the fiscal and foreign components. The variability is caused mainly by differences in price elasticities of alcohol demand on the part of locals (from -0.4 to -1) applied to derive low, mid and high estimates. This causes tax revenues from alcohol purchases by locals to vary, also causing variation in the revenue-recycling component. It should be noted here that alcohol-related cost savings represent only 2% to 10% of the revenue recycling component under alternative scenarios, while the remaining part is formed by alcohol tax revenues.

Table 1. Optimal alcohol tax (EUR per liter of pure alcohol)

<table>
<thead>
<tr>
<th>Components of optimal alcohol tax</th>
<th>With labor tax adjustment</th>
<th>With public spending adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td>Pigouvian</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Revenue-recycling</td>
<td>0.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Tax-interaction</td>
<td>0</td>
<td>3.6</td>
</tr>
<tr>
<td>Productivity</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>Foreign benefit</td>
<td>2.9</td>
<td>5.3</td>
</tr>
<tr>
<td>Total</td>
<td>5.5</td>
<td>13.1</td>
</tr>
<tr>
<td>Current</td>
<td>9.4</td>
<td>9.4</td>
</tr>
</tbody>
</table>
As regards the tax-interaction component, it disappears completely under the low estimate. The reason for this is that under the given parameter values, the substitution effect between alcohol and leisure that decreases the labor supply is offset by the income effect from the higher alcohol price that, to the contrary, increases labor supply. Under high estimates, the tax-interaction effect is inflated, so that it alone represents more than half of the total optimal tax rate, and together with the revenue-recycling effect, they represent more than 75% of it. Tax revenues from alcohol purchases by tourists captured by the foreign benefit component play an important role under all three scenarios. Although the elasticity of the tourist alcohol demand was held constant, variation in the price responsiveness of the locals and in the overall level of the tax rate causes the foreign benefit effect to range from EUR 2.9 to EUR 12.4.

In Figure 2, changes in the optimal tax under mid estimates with respect to different elasticities are more closely observed. In the panel on the left, optimal tax is decomposed into two parts. The first is the Pigouvian tax and the second is the sum of revenue-recycling, tax-interaction, foreign benefit and productivity effects. As was already inferred above, under inelastic demand, Pigouvian tax represents only a marginal part of the tax rate. Similarly to the high estimate presented in Table 1, it is negative when price elasticity is lower than -0.5. However, the remaining part more than offsets this negativity and almost triples the tax, compared with the current tax rate. Although the role of other than Pigouvian rationale for alcohol taxation is sharply diminished under elastic alcohol demand, it still stays greater than Pigouvian tax.

**Figure 2: Sensitivity with respect to elasticities**

Note: PV is the Pigouvian component, Remaining is optimal tax less the Pigouvian component, Current is prevailing average tax rate, FBE is foreign benefit component, and Total denotes optimal tax including all components.

The range from -0.4 to -2.0 was chosen to illustrate the sensitivity of alcohol tax with respect to changes in the price elasticity of tourist alcohol demand. Under inelastic demand,
the foreign benefit rationale for alcohol taxes alone may exceed the current rate and represents more than half of the simulated optimal tax rate. It is also interesting to note that under the mid estimate, tourist price elasticity must be more than -1.8 for the foreign benefit component to become negative. Cancelling out the foreign benefit effect, however, would bring the optimal level below the currently prevailing rate.

Sensitivity of the optimal tax rate with respect to the marginal administrative cost of alcohol tax can be followed in the left-hand panel of Figure 3. It illustrates that just as was described above, the optimal tax rate is especially sensitive under low alcohol demand elasticity. More precisely, it becomes more than six times higher when the increase in the tax rate does not require additional resources for tax administration, compared with the case when a one unit increase in the tax rate requires an additional 40 cents per one liter of pure alcohol (i.e. $r^d_A = 0.4$). As regards the optimal tax rate under higher demand elasticity, variation is much smaller. The overall level of optimal tax, however, tends to be lower than the current rate from the point where a one unit increase in tax rate requires an additional 10 cents per one liter of pure alcohol for tax administration. Finally, it appears that the role of elasticity disappears under high marginal administrative cost, as in this case simulated optimal taxes are almost equal under all three elasticities. In any event, the main point here is that optimal policy is strongly affected by government capability to operate the tax system effectively when the tax rate is raised. As Figure 3 suggests, with zero marginal cost, optimal policy would involve raising the current tax rate even under unit-elastic alcohol demand. In contrast, with high costs, this is not true even under inelastic demand.

Figure 3. Sensitivity with respect to cost parameters

Note: Elast is price elasticity of locals’ alcohol demand, Current is the prevailing average tax rate, alpha denotes the multiplier effect arising from interaction of public spending with the labor market.
While allowing increases in administrative costs per liter of pure alcohol improves the ability of the government to deal with the potential expansion of the illegal alcohol market, in practice the latter cannot be eradicated completely. This poses the question of whether and how the results would change if agents were to partially replace legal alcohol with black market alcohol. If that were to happen, the illegal market would probably induce three kinds of adjustments to have to be made in regard to the model used in this paper. All of these factors suggest a need to reduce the optimal tax. First of all, expansion of the illegal market would mean higher price elasticity of legal alcohol demand, as there would be a good substitute commodity available in terms of tax-free alcohol. Secondly, under conditions of an expanded illegal alcohol market, there would be no decrease in total alcohol consumption as we observe in the legal alcohol market. As a consequence, the government could find it difficult to achieve savings in respect of alcohol-related costs (denoted by $g^d$ in the optimal tax formula) because misdemeanors, felonies and health effects would now partially be caused by consumption of illegal alcohol. The same applies to the productivity effect. Finally, if reduction in total alcohol consumption is hindered, it would probably have the same effect on labor supply incentives. This means that the tax-interaction effect would be smaller. To put all of this together in a nutshell, in a highly conservative way: applying price elastic alcohol demand and totally inelastic alcohol demand with respect to the price of leisure, without changing other relevant elasticities regarding drunk driving, public drinking and offenses, and cancelling out the productivity effect, only the high estimate with the public spending adjustment would exceed the currently implemented average tax rate on alcohol.

Whether an improved budget position is used to reduce labor tax or to increase public spending makes a substantial difference only for high estimates (see Table 1). As the only difference between these two policies concerns marginal efficiency gain parameters, this result was expected. In this paper, marginal efficiency gain was suggested to be higher with labor supply adjustment (0.12), and a marginal efficiency gain from public spending (0.1) was assumed to be amplified by interactions with labor supply. As a result, a higher optimal tax was obtained under the policy with public spending adjustment. This multiplier effect was especially large under high parameter values, resulting in an optimal tax 50% higher than would have been the case under labor tax adjustments (EUR 52.3 and EUR 33.5, respectively).

A solid basis of information was not available for estimating the values of \( MEG_M \) and \( \alpha \). They do however play a decisive role in inflating the tax rate to an extremely high level under high parameter values. As is shown in the right-hand panel of Figure 3, if public medical spending affects the labor supply incentive so that \( \alpha = 0.1 \), efficiency gains from alcohol tax are substantially amplified, and as a consequence, the optimal tax rate under high parameter values rises from EUR 30 to above EUR 50. Even without experiencing the multiplier effect \( (\alpha = 0) \), an increase in \( MEG_M \) may cause a considerable increase in the optimal level. It was also revealed that under high parameter values, even an inefficient spending program under which households obtain less utility than the program costs them \( (MEG_M < 0) \), does not eliminate the rationale to increase the current tax rate. Further analysis showed that this does not apply under mid estimates. For example, if \( MEG_M = -0.05 \) (meaning that the revenue-recycling effect is negative) and \( \alpha = 0 \), optimal tax is estimated to equal EUR 8.7.
Comparison between Estonia and the US

An almost identical model has been used to obtain optimal levels of alcohol taxes and drunk driver penalties for the USA. The results of both studies regarding optimal taxation with labor tax adjustment are compared in Figure 4. Although fluctuations in the exchange rate between the euro and the dollar complicate this comparison somewhat, it can be said that the overall optimal tax in the US has been estimated to be higher than in Estonia. In reality, however, the Estonian tax rate is more than twice as high as the rate implemented in the US (EUR 9.4 and EUR 4.5, respectively). More specifically, Parry et al. (2009) have estimated that optimal tax on alcohol with labor tax adjustment ranges from EUR 18 to EUR 161 per liter of alcohol under alternative scenarios (using an exchange rate of 1 USD = 0.76 EUR, i.e. from USD 88 to USD 803 per gallon of alcohol), while the prevailing rate in practice is EUR 4.5. The estimate for the US depicted in Figure 4 - named here arbitrarily as mid-range - assumes that the own-price elasticity of alcohol demand is -0.7, alcohol/leisure cross-price elasticity is zero, and productivity effect is calculated on the basis of the most conservative estimates. For Estonia, optimal tax with labor tax adjustment is estimated to range from 6 EUR to EUR 34 under low and high parameter values, while the mid estimate is depicted in Figure 4.

Figure 4. Estimated optimal alcohol taxes in Estonia and the USA

As for the structures of optimal tax rates under mid-range simulation results in both countries, it appears that in contrast to the Estonian case, the total tax rate in the US is formed almost equally by Pigouvian and fiscal components. Although, unlike the model used for the USA, the Pigouvian component in the Estonian case also includes effects from public drinking and offenses against persons, it is less than one fifth of the level in the US and represents a considerably lower proportion of the total tax rate as well. In addition to differences in core data that are determined by the extent of alcohol externalities in both countries, as well
as by methods used to monetize these externalities, one obvious reason behind this result arises from the considerable gap between income levels in the two countries. Estonian GDP per capita represents less than half of US GDP per capita (Eurostat, 2011b). This means that in absolute terms, the cost of alcohol-related public spending allocated to the criminal justice system, for instance, is substantially higher in the US. The same applies to most of the other monetary variables. For instance, value of life - an input-providing Pigouvian component - was assumed to be EUR 0.56 million in this paper. Parry et al. (2009) used a much higher value of EUR 3.04 million (or USD 4 million). Last but not least, Pigouvian tax in the Estonian case compared with the USA is also reduced, due to administrative costs that were ignored by Parry et al. (2009).

Productivity effects that are probably underestimated in both cases only play a marginal role in affecting the overall level of alcohol tax. For example, Parry et al. (2009) also obtained a considerably higher value for this component, amounting to EUR 16. In the Estonian case, estimates regarding productivity losses due to alcohol misuse presented by Saar (2009) were used as input data. This, however, only includes the decrease in the wage rate of alcoholics and the monetary value of lost workdays due to temporary alcohol-related illnesses, and not some other factors. For instance, due to a lack of data, unemployment caused by alcohol abuse was not included.

Both papers have shown that the fiscal component exceeds Pigouvian rates under a number of plausible parameter combinations. This holds true under mid-range estimates as well. Figure 3 also demonstrates the substantial difference in absolute levels of fiscal components between the two countries. One reason why the fiscal effect is much greater in the US has to do with the fact that alcohol prices are lower in Estonia. More specifically, under different price levels, while assuming identical price elasticities of demand, a one-unit increase in alcohol price reduces alcohol consumption more in the country with lower prices. Therefore, as the fiscal component of optimal alcohol tax is expressed as per unit reduction in alcohol consumption, the tax rate proves to be lower in the country with lower prices. In addition, the higher tax rate also affects labor supply more intensely, increasing the tax-interaction component in the US, when compared with Estonia. Another reason for the difference concerns the level of pre-existing labor taxes. The higher these are, the more welfare gain there is to receive when taxes are reduced. In this paper, the pre-existing tax rate on labor was assumed to be 0.35 compared with 0.4 applied by Parry et al. (2009), which causes an additional divergence between the results.

5. Final comments

This study has revealed a set of empirical estimates for alcohol policy in Estonia, considering both externalities as well as fiscal aspects. Simulation results moderately support the view that policy as currently implemented is not restrictive enough. Under several alternative combinations of parameter values, the socially optimal tax rate on alcohol patently exceeds the rate implemented in practice. In addition, under tax policy with adjustments for public spending, the optimal alcohol tax could be substantially inflated, due to the amplifying effect of interaction between public spending and labor supply.
On the other hand, optimal tax was also shown to fall below the current rate when low values were applied to parameters with a high degree of uncertainty. This applies especially to marginal administrative costs and price elasticity of alcohol demand as concerns tourists. The latter was revealed to have a remarkable role in determining optimal policy. The importance of accuracy of parameter values becomes especially important under low price elasticity of locals’ alcohol demand, since in this case optimal policy varies the most.

Similarly to Parry et al. (2009), this paper has shown that accounting for fiscal considerations strongly affects the optimal level of alcohol taxation. Compared with earlier papers, which applied a partial equilibrium approach and captured only the Pigouvian component, the range within which optimal tax could lie becomes much wider. For instance, Pogue and Sgontz’s (1989) estimates regarding average optimal tax rate ranged from USD 20 to USD 314 per gallon of pure alcohol. In their analysis, arriving at the precise value of the tax depended on making an assumption concerning the share of internal cost that drinkers fail to internalize. Parry et al., while holding the Pigouvian component constant at USD 72 per gallon of alcohol, disclosed the range from USD 90 to USD 799, regardless of the fact that actual average tax on alcohol was estimated to remain below USD 25 in both papers. Compared with Parry et al., this paper has extended the role of fiscal consideration mainly in two ways. Firstly, it was demonstrated that considering alcohol as a commodity heavily consumed by tourists further strengthens revenue-raising rationale for an excise tax on alcohol. Secondly, the optimal taxation level could also be reduced if tax increases require more administrative costs. Fiscal effects can therefore move the optimal tax in both directions, resulting in additional uncertainty regarding appropriate alcohol policy.

In interpreting the results of this paper, one must be aware that the model does not consider several relevant effects that could substantially affect the optimal level of alcohol taxation. The impact of potential expansion of illegal alcohol consumption was discussed above. It needs to be noted, however, that this paper does not explore the precise influence of the black market in depth, but future research on the topic is warranted. In addition, there are also legal channels that can be used to avoid paying higher taxes. For example, according to the Estonian Institute of Economic Research (2010b), 6-12% of drinkers produce alcoholic beverages such as wine and beer at home. In addition, just like Finns who purchase alcohol in Estonia, Estonians buy a certain amount of alcohol from abroad. This applies especially to people living in the northeastern region bordered by Russia. Both home production as well as border trade probably reduce optimal alcohol taxes, as has been theoretically discussed by Aronsson and Sjögren (2010).

It must also be acknowledged that the tax rates obtained in this paper are based on tangible economic costs attributed to alcohol. In other words, intangible costs such as pain or psychological suffering have not been considered. For instance, when one drives drunk and causes a traffic accident in which a victim is injured, only fiscal health care costs and productivity losses due to temporary disability were considered, in order to derive optimal tax. Psychological stress and its impact on the relatives of victims were not considered. Alcohol-related domestic violence is also a well-known social problem which often remains hidden and is therefore difficult to capture. What this means is that increases in alcohol taxes certainly entail substantial social benefits that are difficult to estimate in monetary terms. Finally, it must be stressed that the results of this paper should be treated cautiously, as many
empirically estimated parameters are based on very rough approximations or have rather weak scientific foundations. Therefore, with an eye towards future research, a more solid base is required for several parameter values in order to improve the policy relevance of the results. In addition, the model could be extended by capturing additional alcohol-related externalities not considered in this paper, including property damage and productivity losses attributable to fires.

**Appendix 1. Estimates of marginal effects**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marginal medical case of alcohol consumption, $M_a$</td>
<td>0.005</td>
<td>0.007</td>
<td>0.009</td>
</tr>
<tr>
<td>Marginal medical case of offense against persons, $M_o$</td>
<td>2.211</td>
<td>3.158</td>
<td>4.105</td>
</tr>
<tr>
<td>Marginal medical case of drunk driving, $M_d$</td>
<td>0.016</td>
<td>0.022</td>
<td>0.029</td>
</tr>
<tr>
<td>Marginal medical case of misdemeanor, $M_N$</td>
<td>0.003</td>
<td>0.004</td>
<td>0.005</td>
</tr>
<tr>
<td>Marginal on-the-job productivity of alcohol consumption (EUR), $W'_H H_a$</td>
<td>1.139</td>
<td>1.627</td>
<td>2.115</td>
</tr>
<tr>
<td>Marginal private cost of health risks per unit change in drunk driving (EUR), $mpc \cdot H_D$</td>
<td>16.517</td>
<td>23.595</td>
<td>30.674</td>
</tr>
<tr>
<td>Marginal private cost of health risks per unit change in misdemeanors (EUR), $mpc \cdot H_N$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Marginal private cost of health risks per unit change in offenses against persons (EUR), $mpc \cdot H_{\bar{p}}$</td>
<td>5909.722</td>
<td>8442.459</td>
<td>10975.200</td>
</tr>
</tbody>
</table>
### Appendix 2. Estimates of government resource costs

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average costs to criminal justice system per offense against persons (in euros), $r^p$</td>
<td>2916.61</td>
<td>4166.59</td>
<td>5416.57</td>
</tr>
<tr>
<td>Average costs to criminal justice system per drunk driving incident (in euros), $r^D$</td>
<td>25.01</td>
<td>35.72</td>
<td>46.44</td>
</tr>
<tr>
<td>Average costs to criminal justice system per public drinking incident (in euros), $r^V$</td>
<td>10.82</td>
<td>15.46</td>
<td>20.09</td>
</tr>
<tr>
<td>Average cost to Tax and Customs Board per liter of pure alcohol (in euros), $r^t$</td>
<td>0.06</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>Average cost to health care system per medical case (in euros), $r^h$</td>
<td>76.96</td>
<td>109.94</td>
<td>142.92</td>
</tr>
<tr>
<td>Marginal administrative cost of alcohol tax, $r^t_A$</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

### Appendix 3. Applied elasticities

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
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</thead>
<tbody>
<tr>
<td>Drinking with respect to alcohol price, $\eta_{AA}$</td>
<td>-1.0</td>
<td>-0.7</td>
<td>-0.4</td>
</tr>
<tr>
<td>Alcohol purchases by tourists with respect to alcohol price, $\eta_{FA}$</td>
<td>-0.7</td>
<td>-0.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>Drunk driving, public drinking or offenses against persons with respect to alcohol price, or $\eta_{DA}$, $\eta_{NA}$ or $\eta_{PA}$</td>
<td>-1.0</td>
<td>-0.7</td>
<td>-0.4</td>
</tr>
<tr>
<td>Drinking with respect to price of leisure (compensated), $\eta_{AL}$</td>
<td>0.1</td>
<td>-0.1</td>
<td>-0.2</td>
</tr>
<tr>
<td>Labor supply with respect to income, $\eta_{LI}$</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Labor supply with respect to wage rate, $\eta_{LL}$</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Appendix 4. Derivation of optimal policy formulas

Deriving equation (6) with \( i = t_L \)

From (1), (2) and (3) agents solve the following maximization problem:

\[
V(t_A, t_L, r^M, D, N, P) = \text{Max } U(.) + \lambda[(1 - t_L)wL - K - (p_A + t_A)A^D - C - t_D D - t_N N]
\]

(A.1)

Totally differentiating (A.1) with respect to \( t_A \), substituting total derivative of government budget constraint (5) in (A.1) and assuming that \( K = c_D D + c_N N \) due to zero profits of auto insurance companies gives:

\[
\frac{1}{\lambda} \frac{dV}{dt_A} = (PV^A - t_A) \left( -\frac{dA^D}{dt_A} \right) - r_{t_A} A^D + MEG_{t_A} \frac{dM}{A^D} + t_L \frac{dW}{dt_A} + \left( 1 - r_{t_A} \right) A^F + (t_A - r^A) \frac{dA^F}{dt_A}
\]

(A.2)

In (A.2) \( PV^A \) is defined in (6b). Labor supply effects from (1), (2), (3) and (4) are defined:

\[
\frac{dW}{dt_A} = \frac{\partial W}{\partial H} \frac{dH}{dt_A} + w \frac{\partial \ell}{\partial t_A} + \frac{\partial L}{\partial \ell} \frac{d\ell}{dt_A} + w \frac{\partial L}{\partial r^M} \frac{dr^M}{dt_A}
\]

(A.3)

Differentiating government budget constraint (5) with respect to \( t_A \), allowing \( t_L \) to vary while holding \( r^M \) fixed, and substituting in (A.3) and solving for \( \frac{dt_l}{dt_A} \) gives:

\[
\frac{dt_l}{dt_A} = \frac{(1 - r_{t_A})(A^D + A^F) + t_A \left[ \frac{dA^D}{dt_A} + \frac{dA^F}{dt_A} \right] - r_{t_A} A^D + t_A \frac{dA^A}{dt_A} + t_L \left( \frac{dW}{dt_L} \frac{dH}{dt_A} + w \frac{\partial L}{\partial r^M} \frac{dr^M}{dt_A} \right)}{w(l + t_L \frac{dt_l}{dt_A})}
\]

(A.4)

where \( g^A \) is defined:

\[
g^A = r^M M_A + (r^M D + r^D - t_D) \frac{\partial \eta_{DA}}{\partial \eta_{AA}} + (r^M N + r^N - t_N) \frac{\partial \eta_{NA}}{\partial \eta_{AA}} + (r^M P + r^P) \frac{\partial \eta_{PA}}{\partial \eta_{AA}} + r^A
\]

(A.5)

Substituting (A.3) and (A.4) into (A.2) gives:

\[
\frac{1}{\lambda} \frac{dV}{dt_A} = (PV^A - t_A) \left( -\frac{dA^D}{dt_A} \right) + MEG_{t_A} \left[ \left( 1 - r_{t_A} \right) A^D + t_A \frac{dA^D}{dt_A} - g^A \frac{dA}{dt_A} \right] + \left( 1 + MEG_{t_A} \right) \left[ (1 - r_{t_A}) A^F + (t_A - r^A) \frac{dA^F}{dt_A} \right] + (1 + MEG_{t_A}) W t_L \frac{\partial L}{\partial \eta_{AA}} + (1 + MEG_{t_A}) t_L \frac{dW}{dt_L} \frac{dH}{dt_A}
\]

(A.6)
Where marginal efficiency gain from reduction in labor taxes is defined

\[ MEG_{t_L} = - \frac{t_{LL} \frac{\partial L}{\partial t_L}}{L + t_{LL} \frac{\partial L}{\partial t_L}} = \frac{t_{LL}}{1-t_{LL}} \eta_{LL} \cdot \eta_{LL} \] (A.7)

From Slutsky equations:

\[ \frac{\partial L}{\partial t_A} = \frac{\partial L}{\partial t_A} - \frac{\partial L}{\partial t_{LL}} A^D \cdot \frac{\partial L}{\partial (1-t_{LL})} - \frac{\partial L}{\partial t_L} w_L \] (A.8)

Slutsky symmetry property yields:

\[ \frac{\partial L}{\partial t_A} = - \frac{\partial A^{Dc}}{\partial [(1-t_{LL})w]} \] (A9)

Substituting (A.8) and (A.9) into (A.6), equating the resulting equation to zero and solving for \( t_A \) yields optimal tax formula (6) with \( i = t_L \), where elasticities are defined as follows:

\[ \eta^c_{AA} = \frac{\partial A^D}{\partial (1-t_{LL})w} \cdot \frac{(1-t_{LL})w}{A}; \eta_{LL} = \frac{\partial L}{\partial t_{LL}} \frac{(1-t_{LL})w}{L}; \eta_{AA} = \frac{\partial A^D}{\partial t_A} \frac{(p_A + t_A)}{A}, \eta_{LL} = \frac{\partial L}{\partial [(1-t_{LL})w]} \frac{(1-t_{LL})w}{L} \] (A.10)

**Deriving equation (6) with \( i = r^M \)**

Differentiating government budget constraint (5) with respect to \( t_A \), holding \( t_L \) fixed and allowing \( r^M \) to vary, substituting in (A.3) and solving for \( \frac{dt^M}{dt_A} \) gives:

\[ \frac{dt^M}{dt_A} = - \frac{(1-r_{AA}^M)(A^D + A^F) + t_A(A^D + A^F) - r_{AA}^M \frac{dt^F}{dt_A} - g^A \frac{dt_A}{dt_A} + t_L \frac{\partial w}{\partial t_{LL}} + t_L \frac{\partial h}{\partial t_A} + \frac{\partial w}{\partial t_{LL}} + \frac{\partial h}{\partial t_A}}{M - wt_{LL} \frac{\partial t^M}{\partial t_A}} \] (A.11)

Substituting (A.3) and (A.11) into (A.2), after some manipulation, the following equation is obtained:

\[ \frac{1}{\lambda} \frac{dv}{dt_A} = (P V^A - t_A) \left( - \frac{dt_A}{dt_A} \right) + \left[ (1 + MEG_{r,M})(1 + \alpha) - 1 \right] \left[ (1 - r_{AA}^M)A^D + t_A \frac{dt_A}{dt_A} - g^A \frac{dt_A}{dt_A} \right] + \\
(1 + MEG_{r,M})(1 + \alpha) \left[ (1 - r_{AA}^M)A^F + (t_A - r^A) \frac{dt_A}{dt_A} + wt_{LL} \frac{\partial L}{\partial t_{LL}} + t_L \frac{\partial w}{\partial t_A} + \frac{\partial w}{\partial t_{LL}} + \frac{\partial h}{\partial t_A} \right] \] (A.12)

In (A.11) \( MEG_{r,M} \) and \( \alpha \) are defined

\[ MEG_{r,M} = - \frac{1}{M} mp c \cdot H_{r,M} - 1, \alpha = \frac{M}{M - wt_{LL} \frac{\partial t^M}{\partial t_A}} - 1 \] (A.13)

To obtain (6) with \( i = r^M \), a derivation process analogous to deriving (6) with \( i = t_L \) is followed.
References


