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Social Costs and Benefits of Czech Beer Industry - Optimal Taxation

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature. This thesis was not used to obtain another academic degree.

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Prague, May 14, 2014

Signature

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Abstract

This thesis analyzes the Czech brewing industry by describing its structure, recent development, and social and economic impacts on the society as a whole. The aim is to empirically estimate the optimal level of beer tax, which would balance both social costs and benefits of beer production. For this purpose, we use a model determined by both externality corrections and fiscal considerations as the tax increase is assumed to immediately change other governmental policies such as labor taxation or medical expenditures. The results of our analysis show that under most of the sets of parameters, the current tax rate on beer is under its optimal level and that the fiscal component has a significant impact on the optimal level of tax.

Keywords	Alcohol, Beer, Brewing industry, The Czech Republic, Elasticity, Modelling, Price, Social costs, Tax

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Abstrakt

Tato práce se zabývá analýzou pivovarnictví v České republice, podrobně popisuje strukturu průmyslu včetně jeho nedávného vývoje a zkoumá sociální a ekonomický vliv pití piva na celou společnost. Cílem je empiricky odhadnout optimální úroveň zdanění piva, která by vyrovnávala společenské náklady a zisky plynoucí z jeho produkce. Za tímto účelem je použit model, který kromě vyrovnání těchto externality zohledňuje také rozvahy o fiskální politice, protože předpokládané zvýšení daní ovlivní i jiné oblasti vládní politiky jako jsou výdaje za zdravotnictví a daň z příjmu. Výsledky analýzy pro většinu souborů parametrů ukazují, že současná úroveň zdanění piva je pod svojí optimální úrovní a že fiskální složka významně ovlivňuje výslednou úroveň daně.

Klíčová slova	Alkohol, Celospolečenské náklady, Daň, Česká republika, Elasticita, Modelování, Pivo, Pivovarnictví

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Acronyms

CBMA Czech Beer and Malt Association

CZK Czech koruna

CSO Czech Statistical Office

EUROSTAT European Statistical Office

EU European Union

GDP Gross Domestic Product

l liter

RIBM Research Institute of Brewing and Malting, Plc.

USA United States of America

Chapter 1

Introduction

Czech brewing has a long history and tradition. Beer has always been an important part of the Czech culture having a very special position among other commodities, which can be illustrated by the fact that Czech Republic has the highest beer consumption per capita in the world. Excessive beer production and exports together with tourists coming to our country to taste "the famous Czech beer" contribute to the Czech economy with a considerable amount of money, however, beer consumption is also connected with social costs including health problems, loss of labor productivity and drunk driving. Public policy's target should therefore be at least equilibration of these positive and negative effects. Taxation of beer seems to be an appropriate means of reducing social costs of beer consumption. This thesis presents an empirical estimate of optimal level of tax on beer for the Czech Republic, accounting for both externalities and how policies interact with the broader fiscal system.

For the description of Czech and world beer production and its recent development, we use the latest statistical data from Research Institute of Brewing and Malting and Czech Statistical Office. Various institutions and organizations such as World Health Organization or Institute of Alcohol studies in London focus on studying the negative effects of alcohol consumption on society. In this paper we work mainly with findings of Anderson and Baumberg (2006) who describe both tangible and intangible costs of alcohol created by the society. The relationship between smoking and beer consumption has been subject of many studies, e. g. Decker and Schwartz (2000), Tauchmann et al. (2006) and Cameron and Williams (2001) concluding that cigarettes and beer are complements, which further increase the harms of beer consumption. Among the

most recent studies of beer production benefits we should mention the report of Brewers of Europe by Berkhout et al. (2013), analyzing the contribution of beer industry to European economy.

Previous literature examining the appropriate level of alcohol taxes focuses mainly on measuring externalities. The most recent Czech study by Janda and Mikolasek (2011) is an example of such a study, proposing beer prices that would maximize the welfare of Czech society using similar approach as Pogue and Sgontz (1989). In contrast to Parry et al. (2009) who has considered both externality and fiscal rationales simultaneously. According to their findings, the fiscal component of the optimal alcohol tax may even exceed the externality-correcting component, strengthening the need for higher alcohol taxes. This paper applies an almost identical model, however neither optimal tax with increased public spending nor drunk-driving penalties are estimated. We came to similar conclusions to Parry et al. (2009): under most sets of parameters, beer taxes should slightly increase and the fiscal component of the optimal tax is positive and quantitatively important.

The thesis is structured as follows. Chapter 2 gives a general introduction to the topic by taking a look at Czech beer statistics in the world context and describing the structure, characteristics and recent development of the brewing industry. In Chapter 3, social costs and benefits of beer production are discussed in detail, the main result being the need of balancing both of these effects by appropriate tax rate. In the following chapter, Chapter 4, two different theoretical models for calculation of the optimal alcohol tax are be presented, using an analogy to methods developed by Parry et al. (2009) and Pogue and Sgontz (1989). In Chapter 5, first of these models is being parametrized using Czech data and a set of parameters. Chapter 6 presents the results of our simulation and compares them with previous literature, namely the second model earlier described. The closing chapter, Chapter 7, contains a summary of the study and suggestions for future work.

Chapter 2

Structure and Concentration of Czech Beer Industry

2.1 Statistics and Comparison in World Context

Beer is undoubtedly a worldwide spread beverage. In 2012, world's beer production exceeded 190 million kiloliters, which makes it one of the most popular drinks. Brewing is traditionally connected with particular regions, namely a plenty of European countries - Ireland, Great Britain, Denmark, Belgium, the Netherlands and especially the countries of Central Europe - Germany, Austria, Slovakia and least but not last the Czech Republic, however times are changing. Today the largest beer-producing region in the world is Asia. Top 10 of the biggest beer producers surprisingly mainly consists of countries which are historically less associated with brewing, though their beer production exceeds many countries listed above – mentioning for example China, the world leader in both beer production and consumption. Another interesting example is Brazil, which have experienced a production growth in many sectors, including brewing industry. For the list of biggest beer producers and consumers see Table 2.1 and Table 2.2.

Table 2.1: World Leaders in Beer Production

Global Beer Production by Country in 2012			
	Country	**Production volume (kl)**	**Production share in the Global Market**
1	China	44 348 100	23.3%
2	USA	22 952 295	12%
3	Brazil	13 400 000	7%
4	Russia	9 740 000	5.1%
5	Germany	9 461 800	5%
6	Mexico	8 250 000	4.3%
7	Japan	5 590 845	2.9%
8	UK	4 204 900	2.2%
9	Poland	3 780 000	2 %
10	Spain	3 300 000	1.7%
...	...	...	...
24	Czech Republic	1 861 100	1%
	World total	190 700 940	100%

Source: http://www.kirinholdings.co.jp

Table 2.2: World Leaders in Beer Consumption

Global Consumption by Country in 2012			
	Country	**Volume Consumed (kl)**	**Share in the Global Market**
1	China	44 201 000	23.6%
2	USA	24 186 000	12.9%
3	Brazil	12 800 000	6.8%
4	Russia	10 560 000	5.6%
5	Germany	8 630 000	4.6%
6	Mexico	6 890 000	3.7%
7	Japan	5 547 000	3%
8	UK	4 319 000	2.3%
9	Poland	3 790 000	2%
10	Spain	3 220 000	1.7%
...	...	...	...
21	Czech Republic	1 905 000	1%
	World total	187 363 000	100%

Source: http://www.kirinholdings.co.jp

Regardless the fact that total beer production of the Czech Republic of 1.8611 million kiloliters and consumption of 1.905 million kiloliters did not make it even to the Top 20 of world biggest producers (which is actually not so sur-

prising given by the small size of the country), Czech position in the ranking in production and consumption compared to the population is much better. With 148.6 liters of beer consumed per capita in 2012, the Czech Republic led all other nations in per capita beer consumption for the 20th consecutive year (see Table 2.3). According to Berkhout et al. (2013), Czech beer production is alongside Estonia proportionately the largest in the EU .

Table 2.3: World Leaders in Beer Consumption Per Capita

Per Capita Beer Consumption by Country in 2012		
	Country	**Volume consumed (liters)**
1	Czech Republic	148.6
2	Austria	107.8
3	Germany	106.1
4	Estonia	102.4
5	Poland	98.5
6	Ireland	98.3
7	Croatia	85.9
8	Venezuela	85.5
9	Finland	84.2
10	Romania	83.2

Source: http://www.kirinholdings.co.jp

2.2 Overall Structure

First, let us divide breweries into two groups according to their ownership structure. It is important to distinguish between breweries and brewing companies. The latTer term indicates a group of breweries possessed by the same owner. An example might be Czech largest, world-famous brewing company Plzeňský Prazdroj, owned by a British brewing company SABMiller, associating three large breweries - Plzeň (Prazdroj, Gambrinus), Radegast Nošovice and Velké Popovice Kozel. The second largest brewing company is Pivovary Staropramen, which is also in ownership of foreign brewing company named Molson Coors. Altogether there were five brewing companies associating 18 breweries on the Czech market in 2012, producing 15 101 961 hl of beer per year in total.

The brewing yearbook of RIMB states that there were 28 independent breweries in the country in 2012, in which Budějovický Budvar was the largest.

Together their yearly production was 3 486 086 hl, which corresponds only to a quarter of brewing companies production. Micro-breweries are not included in this category, we will talk about them later. Despite the fact that volume of production of four smallest independent breweries have already met the definition of a micro-brewery, we include them in this category too, similarly to Frantík (2013).

The second possible way of categorizing breweries is classification by to the volume of their production. Czech legislation recognizes only three types of breweries – "large"(with production over 200 000 hl per year), "small" and "micro", which seem insufficient. For the purpose of this thesis, we divide the brewing industry into five categories, listed in Table 2.4 below. In the following chapters, we will analyze each of these categories separately.

Table 2.4: Breweries Classification - Production

Group	**Volume of production**	**Number of breweries**
Very Large Breweries	Over 1 000 000 hl	4
Large Breweries	200 000 hl – 1 000 000 hl	4
Medium-sized breweries	100 000 hl – 200 000 hl	5
Small Breweries	10 000 hl – 100 000 hl	21
Micro-breweries	0 – 10 000 hl	177

Source: RIBM

The above mentioned classification takes into account the production of the whole companies (e.g. the production of Plzeňský Prazdroj's 4 plants counts as a production of one very large brewing company). Number of microbreweries fluctuates during the year, the specified number is valid to 12/31/2012. Altogether, including micro-breweries and dividing brewing companies into individual plants (e.g. Heineken ČR counts as three breweries – Krušovice, Starobrno, Velké Březno),there are 223 breweries in the country (without microbreweries only 46), which is above average in Europe. The similar number of breweries can be found in countries with a rich brewing tradition such as Belgium and the Netherlands (both having 165 breweries) and Austria with its 173 breweries. In the EU, the Czech Republic has the fifth largest number of breweries. European state with the most breweries is Germany (1337), followed by the United Kingdom (1113), France (503) and Italy (425). Most of the statistical

data comes from the report of Brewers of Europe written by Berkhout et al. (2013).

2.2.1 Very Large Breweries

This group consists of four market leaders – three brewing companies (Plzeňský Prazdroj, Pivovary Staropramen, Heineken ČR) and one brewery (Budějovický Budvar), although Pivovary Lobkowicz from the group of large breweries is really close to the one million hectoliters limit. Together they produce more than 75% of the entire production of the country's beer industry.

The absolute Czech market leader is the brewing company Plzeňský Prazdroj a.s., based in Pilsen - the city traditionally associated with beer. It includes three breweries, each of them producing a specific brand of beer. The biggest is Plzeň brewery, which manufactured 4 417 432 hl of beer in 2012 (RIBM, 2014). It includes two famous brands - the most popular Czech beer Gambrinus (http://www.sabmiller.com/) and the world's most famous Czech beer – Pilsner Urquell, the first Pilsner and the founder of this category of lager. Up to two thirds of all beer consumed in the world is Pilsner-style beer, inspired by the Czech original Pilsner (http://www.prazdroj.cz/). The second brewery is Radegast in Nošovice, beer from Moravia with the yearly production of 1 822 958 hl and the last is Kozel Velké Popovice with 1 537 290 hl manufactured per year. Besides the above mentioned brands, Prazdroj also produces low alcohol fruit beer Frisco and non-alcoholic beer Birell. Plzeňský Prazdroj is a member of SABMiller PLC., one of the largest brewers in the world with activities on six continents. Altogether it supplies Czech and foreign market with 7 777 680 hl of beer (RIBM, 2014).

Staropramen Brewery in Prague, a member of Molson Coors Brewing Company is with its 3 160 163 hl of beer per year the second biggest beer producer in a country. The company operates two breweries - Staropramen and Ostrava.

Another brewing company operating on the Czech market is Heineken - the world's third largest brewing group and the largest European producer of beer, owning three domestic breweries : Starobrno, Královský Pivovar Krušovice and Velké Březno. At present, Heineken Czech Republic is the third largest player

on the domestic beer market with 2012 year production of 2 436 626 hl.

The only independent brewery in this category is Budějovický Budvar. This national enterprise is strongly export-oriented: in 2013, it produced 1 424 000 hl of beer, of which almost half was exported abroad.

All of these beer producing companies have similar characteristics. They face stable demand and operate on the nationwide market, mainly due to supermarket chains that sell their products all over the country. Despite the changing economic conditions (e.g. years characterized by economic crisis and a decrease in consumption of beer) these breweries show long-term stability and very good economic results such as stable production growth, compensating increase in raw material and energy prices.

Table 2.5: The Largest Advertisers in the Czech Brewing Industry Segmentt

Money spent on advertising/million CZK		
Subject	**2012**	**2013**
Plzeňský Prazdroj	308.4	358.2
Pivovary Staropramen	138.3	226.7
Heineken ČR	217.5	156.4
Budějovický Budvar	80.0	100.4
Budějovický měšť. piv.	30.4	19.2
Rodinný pivovar Bernard	12.9	13.8
Pivovary Lobkowicz	6.6	8.5
Pivovar Svijany	0.5	4.5

Source: Admosphere

Other specific features of this group are promotions and advertising. To increase sales and income, big brewing companies run a wide range of promotion activities - from traditional commercials on TV or in magazines to promotion of musical events and festivals and various sponsorship programs. Gambrinus is, for example, an official partner of Czech football – the Czech Football Association Cup even has the name of the brand in its title. The money these very large breweries spend on marketing and advertisement increase every year (with the exception of Heineken, which has, on the contrary decreased its expenses). As seen in Table 2.5, spending on marketing of all breweries from this group differs significantly from smaller breweries.

Every brewing company from the group of very large breweries has its dominant brand that occupies more than a half of the entire production. Therefore, a typical feature for the beer production of these companies is homogenization.

2.2.2 Large Breweries

In 2007, there were 11 breweries belonging to this group. Since then, the number has dropped to less than a half, mainly due to the fact that some large breweries (Krušovice, Starobrno etc.) have become a part of brewing companies with a total production over 1 million hl per year. In 2012, the group of large breweries consisted of two brewing companies and two independent breweries with quite different characteristics. While the biggest one – Pivovary Lobkowitz with its seven plants (Vysoký Chlumec, Platan Protivín, Klášter, Rychář, Uherský Brod, Jihlava and Černá Hora) and production of 970,000 hl per year is expected to exceed 1 million boundary in the following years, the production of the smallest one – Bernard, Humpolec (212 874 hl/year in 2012) is just above the lower limit of this group. Another two breweries included in this category are Pivovary Moravskoslezské Přerov, producing 757 492 hl per year in their three plants (Holba, Zubr, Litovel) and Svijany, which brewed 595 363 hl of beer in 2012. Altogether, these four large breweries account for 13.5% of Czech beer production.

Large breweries are heterogeneous even in the rate of their production growth. While the production of both individual breweries has grown (Svijany around 2.2% and Bernard even over 6% in 2013), the production of both brewing companies has undergone a yearly decline of approximately 2%.

2.2.3 Medium Breweries

The market position of breweries with production between 100 and 200 thousand hectoliters is not easy. The overall share of beer produced in medium breweries declined sharply in the last 20 years: from 17.1% in 1994 to 3.3% in 2012. They are constantly being pushed out from the nationwide market by the very large breweries, whose target is to leave only minor breweries with local importance. And while there were 21 medium-sized breweries operating on the Czech market in 1994, in 2012 the number declined to three.
For that reason, many breweries from this category had either increased their

production and became one of the leaders or lowered their production and got out of sight of the market leaders. Some of them have even completely ceased their activity. Several breweries, as in the case of large breweries, became a part of bigger brewing companies. Until 2010, the production of most of the medium-sized breweries had been declining at an average rate of 2% per year.

In 2013, another two breweries – Krakonoš and Městský pivovar v Poličce managed to overcome a barrelage threshold of 100 hl per year, so the number of medium breweries increased to five in 2013. Simultaneously, all 5 medium breweries have undergone a production growth. Pivovar Nymburk has experienced the biggest one – between 2012 and 2013 its production grew by 18%. In 2012, the contribution of medium sized breweries to the state budget via excise taxes was 83 874 000 Kč (RIBM, 2014).

2.2.4 Small Breweries

A typical feature for small breweries with barrelage below 100 hl is their focus on the regional market. Due to their size, their production is concentrated on one particular geographical area, usually centered around their plant. Their market strategies include product diversification - their production, in addition to classical lager beer, consists of various beer specialties such as fruit beer or beer with higher alcohol content. Thus, it is common for small breweries to produce more than one brand, usually around five. Another competitive advantage of local breweries is customer loyalty – local beer patriots often support their favorite brand and create a relatively stable demand.

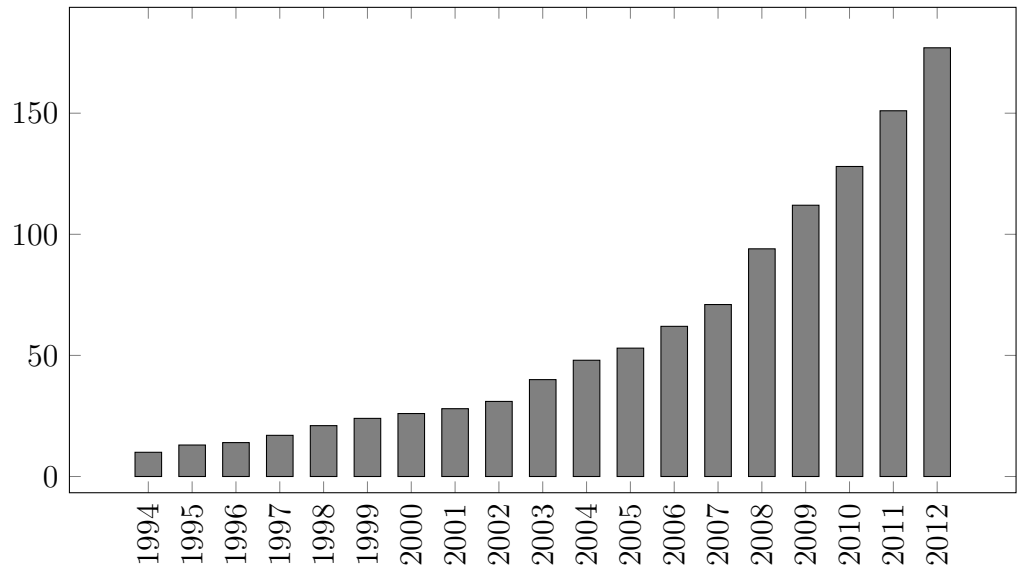
The overall share of beer produced in 21 breweries from this category is approximately 5%, contributing with and excise tax of 186 503 000 CZK. The production of the four smallest breweries in this category is below the line of 10 000 hl per year, which would made them micro-breweries, however, according to RIBM, they belong to this group due to some characteristics of their production.

2.2.5 Micro-breweries

Micro-breweries have played a role on the Czech market during the entire history with an exception of communist regime, when they almost disappeared.

The oldest and only micro-brewery that survived centuries of diverse political regimes is Pivovar U Fleků, founded in 1499. The first boom of micro-breweries occurred after the Velvet Revolution in the 1990's when the trend of micro-breweries was imported from the USA. The second boom arrived in 2004 as the beginning of an era of annual increases in the number of enterprises, which continues until today. In 1994, there were only 10 micro-breweries in country, in 2000, their number had risen to 26 and continued growing, so there were 48 breweries in 2004 and 71 in 2007. At the end of 2012, the number of micro breweries reached 177 (for the development of the number of micro-breweries see Figure 2.1). The annual growth of number of micro-breweries is stable with an approximate yearly increase of 20 breweries. Though the Czech beer market has been already saturated for many years, the number of micro-breweries is expected to rise until it reaches its equilibrium value of 250-300 breweries (prediction of Czech-Moravian Confederation of Microbreweries).

Figure 2.1: Development of Number of Micro-breweries



Source: RIBM

Typical Czech microbrewery is often a part of pub or restaurant. They are usually located in smaller towns and villages, preferably close to some tourist attraction, because tourists are (in addition to local patriots) an important part of micro-breweries' customer base. To attract more customers, micro-breweries usually offer attractions such as the brewery tours and beer tasting.

It is clear that micro-breweries operate on regional markets. They mostly produce draft beer which is then sold in their own restaurants or possibly sell barrels to several other restaurants. Beer is bottled or even exported only exceptionally. Advertising is focused regionally (for example beer festivals), but companies mostly rely on good brand reputation. Similarly to the group of small breweries, the product portfolio consists mainly of beer specialties such as strong beer, flavored beer, top fermented beer and especially not pasteurized beer, which stores beer's characteristic taste and is cheaper to produce, but lasts fresh for a shorter period of time.

Undisputed disadvantage of micro-breweries is seasonality of their sales. On the other hand, rivalry and competition among micro-breweries is not so strong, as each of them operates in their own region. The higher cost of beer production and lower productivity of micro-breweries is offset by the fact that they can afford selling their beer at a higher price (thanks to higher beer quality and manual production). In addition, the government favors them with lower excise tax – while large breweries pay 32 CZK/hl, micro-breweries pay twice less, 16 CZK/hl. Despite their growing number, micro-breweries produce only 1% of the total beer production of the country. In 2012, they paid 22 296 000 CZK on excise tax.

2.3 Recent Development

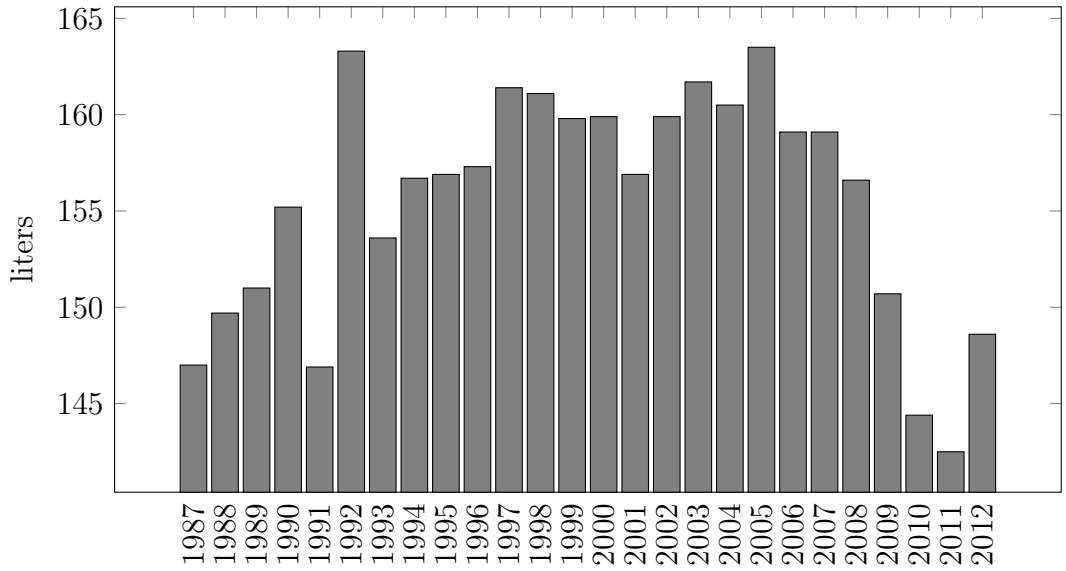
During the past two decades, the production of an average brewery has experienced an annual growth (Table 2.6). The size of the brewery with a maximum efficiency of production appears to be much higher than the current average. Increasing share of beer production was manufactured in large enterprises, which indicates industry shift to higher concentration.

Table 2.6: Development of Average Production per Brewery

Average production per brewery	
1990	270413 hl/year
2000	325902 hl/year
2010	375756 hl/year
2012	404088 hl/year

Source: RIBM

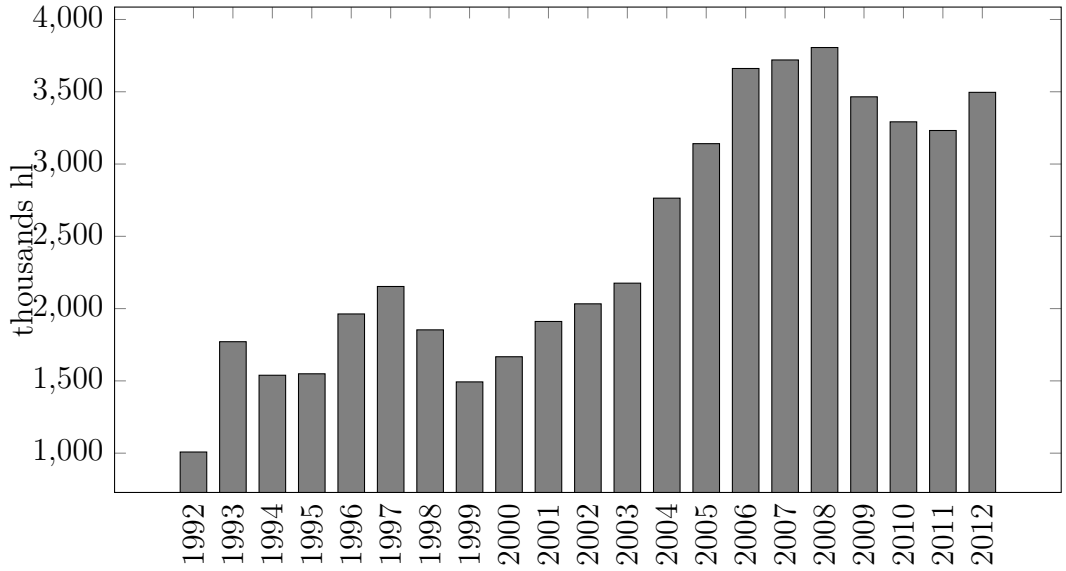
Figure 2.2: Beer Consumption Per Capita in the Czech Republic



Source: Czech Statistical Office

Consumption per capita has been, unlike the average brewery size, quite stable during the last 20 years (see Figure 2.2). It climbed its maximum in 1997 when it reached the value of 161.6 l. Minimum of 144 liters was reached in 2010 as a consequence of economic crisis, which was accompanied by a general decrease in consumption. Since then, the consumption slowly increased again. Constant consumption indicates that the Czech beer market has already been saturated for many years and the only way for our breweries to grow is either expanding abroad or eliminating competition by acquiring other breweries in the industry or pushing them out of the market.

Figure 2.3: Beer Exports of the Czech Republic



Source: Czech Statistical Office, 2014

As a result of the economic downturn caused by the crisis in 2008, the Czech Republic experienced a big increase in imports of low-cost beer, with a peak of 1.0 million hl of beer imported in 2010. Since then, the import has decreased by 50 percent to its current level of 0.5 million hl. In 2012, exports overcame an annual decrease, which lasted from 2009 and increased by 8% (see Figure 2.3) . Nevertheless, the current exports are still below the maximal exported volumes since 2008. In total, about 18.7% of beer made in the Czech Republic is being exported, while Budějovický Budvar exports the highest share of its production - almost a half. Most beer is exported to the EU countries - our neighbors Germany (approximately one third of the exported amount) and Slovakia, Sweden and the United Kingdom. From the remaining countries, the most exports go to Russia, the USA and Canada.

Table 2.7: Market Leaders

	Company	**2011**	**2012**
1	Sab Miller (Plezňský Prazdroj)	43.42%	41.59%
2	Molson Coors (Staropramen)	17.17%	16.88%
3	Heineken	13.52%	13.03%
4	Budějovický Budvar	7.49%	7.15%
5	Lobkowicz	5.51 %	5.19%
6	PMS Přerov	4.2%	4.05%
7	Svijany	4.14%	3.17%
8	Bernard	1.7%	1.14%
	others	3.37%	7.8%

Source: FORBES 2012 : Tržní podíly piovarnických skupin 2011, RIBM

Now we focus on an ownership structure. More than 85% of the market was captured by the seven biggest companies in 2011(see Table 2.7). This ratio decreased slightly in 2012, when it was approximately 84%. The industry has therefore a relatively high concentration, which can be demonstrated with 2012's Herfindal index of approximately 0.183 and Four-firm concentration ratio of 78.65%. In 2012, a slight downturn in the concentration occurred, which showed an increasing capability of smaller and micro-breweries to succeed.

Chapter 3

Beer and the Society

3.1 Czechs and their Relationship to Beer

An interesting probe into the opinion of Czech people on beer are results of a research project called The pub and beer in the Czech society run by Vinopal (2010). One of the most discussed issues in this report is a general public attitude to an amount of consumed beer by Czech people and weather we should be proud of this leadership. The results of this research have shown that the number of people that are proud of our leadership (43%) has grown since 2007 (37%) and the number of people who are ashamed of that fact has, on the contrary, decreased. This could be explained by the fact that people are glad that we have, at least, a world first in some sector of industry. Systematic educational campaign about beer benefits to the Czech economy and society also helps to improve the public attitude to brewing, as brewery sector is significantly export-oriented and the attractiveness of the Czech Republic as a touristic destination is reportedly driven by the fame of our beer as the second most mentioned thing, right after our historical monuments and cultural heritage. And while every Czech person drinks an average of 0.3l of beer a day, foreign tourists drink 2 beers a day. According to Brewers of Europe, Berkhout et al. (2013) the consumption of foreign tourists made 4% of total beer consumption in the country in 2012.

The report also mentions a slightly downward trend in the Czech beer consumption. Reasons of this decline might be a change to healthier lifestyle and a decrease of number of heavy-drinkers. Another socially favorable trend is therefore less beer consumed per person per night, but an increasing amount of

consumers. The proportion of people drinking beer reaches values around 90% for men and between 50 and 60% for women and does not differ significantly according to categories such as age, education or income, however the biggest beer consumers are men in older middle-age generation (45 and 59 years) who drink five liters of beer per week. Slightly lower volumes of sales include the youngest generation (18-29 years old).

Consumption of non-alcoholic beer is experiencing a long term significant increase, mainly due to incompatibility of alcohol-drinking with driving or working, improving quality of non-alcoholic beer and last but not least, the expanding number of places where non-alcoholic beer is available, whether bottled or draft. In 2010, 53% of men and 26% of women said that they automatically choose non-alcoholic beer if they can not drink the alcoholic one.

Another typical Czech tendency – drinking in pubs - has been changing as well. In 2013, sales of bottled beer exceeded sales of tap beer in restaurants and pubs for the first time. Czechs are beginning to reach the habits of their western neighbors – for example in Germany only one beer in five is sold in the pub or restaurant (http://www.pratelepiva.cz/). This change can be a sign of recession (beer in bottles is significantly cheaper) and the lack of time for hanging out in pubs – Czechs are saving money and time.

One of the well-known and generally accepted characteristics of the Czech beer drinker is its conservativeness. This refers to his little willingness to experiment with other kinds of brands, but also to other kinds of beer. Despite the dramatic onset of microbreweries in recent years, the consumer of 2010 prefers drinking one of the great Czech brewery's beers in 53% of cases and only 40% of interviewees prefer local beer. The selection of beer is for most consumers affected mainly by its taste (it was considered as an important factor for 70% of the interviewees), while advertising is regarded as a significant factor only by 10% of drinkers. The question is to what extent the consumer is willing to actually admit the impact of advertising on his choice of beer. The influence of prices when deciding which beer to buy slightly increases. Consumer response may be the shift in demand to lower-priced beers, mostly imported, which might be regarded as a threat for domestic beer industry. This is related to a question of confidence whether the brewing sector will continue successfully in the international arena and to what extent we have to worry about the Czech

beer. To that extent, a relatively optimistic long-term view of the public is encouraging (CSMB, 2010).

3.2 Social Costs of Beer Industry

Even though beer consumption in the Czech Republic is closely linked to culture, social interaction, fun and leisure and revenues from beer sales bring a considerable amount of money to the state treasury, drinking beer as well as any other alcoholic beverage (and especially alcohol abuse) entails many social costs. According to Anderson et al. (2012), alcohol is the third leading cause of diseases and premature mortality in Europe (after high blood pressure and tobacco, whose consumption is also linked to alcohol consumption, as explained later) as Europe is the region with the highest alcohol consumption in the world.

Medical and health issues connected with alcohol consumption can be divided into multiple groups. At first, there are various diseases and health complications happening directly to the alcohol consumer - both physical (cancers, liver and cardiovascular diseases) and psychical (alcohol addiction, Delirium tremens). Excessive alcohol consumption (which is related to risky sex behavior) also increases the risk of spreading of communicable diseases such as HIV/AIDS. Other examples are various intentional and unintentional injuries including suicides.

Alcohol abuse significantly decreases workplace productivity due to absence at work and reduction of effectiveness under the influence of alcohol. On the top, heavy drinkers often experience troubles with finding and maintaining a job. Additional tangible costs may arise from drunken driving and alcohol-originated criminality. Despite the fact that the Czech Republic has managed to reduce the number of alcohol–related deaths on roads in recent years, driving under the influence of alcohol is still very dangerous. The proportion of deaths due to alcohol in the Czech Republic in 2013 was 8.97% (very negative is that more than half of these accident were committed by a person with the content of alcohol in blood higher than 1.5 ‰when the risk of accident is 22 times higher than for sober people). The European Commission states even higher proportion - according to their estimates alcohol is involved in more than a quarter of deaths on European roads. (Ministry of Transport of the Czech Republic, 2014)

Beside the drinkers themselves, alcohol consumption harms other people as well. This does not concern only injuries from drunken driving accidents and street violence. Their surrounding suffers from divorces and domestic violence and even complete strangers are harmed thanks to using government resources for health care, unemployment and dealing with crimes connected with alcohol abuse. Following Anderson and Baumberg (2006), intangible cost of alcohol consumption (mainly to families) can even exceed the total sum of tangible costs.

3.2.1 Relation between Beer Drinking and Smoking

In connection with social cost of beer consumption it is worth mentioning the special relation between beer consumption and smoking. From my own experience there is a group of people who smoke only when they drink alcohol, especially beer. The issue of complementarity of alcohol and cigarettes has been discussed in many studies, although evaluation of this relation is extremely difficult.

Decker and Schwartz (2000) investigates cross-price effects in cigarette and alcohol consumption. An interesting finding has been reached. While increasing alcohol prices lowers the amount of both alcohol and cigarettes consumed (implying complementarity in consumption of these two goods), higher cigarette prices tend to decrease smoking but increase drinking. Therefore this study does not find enough evidence to prove whether cigarettes and alcohol are substitutes or complements, however, it proves that alcohol drinking may increase people's desire for cigarette. Complementarity of tobacco and alcohol was later demonstrated by Tauchmann et al. (2006) using alternative instrumental variables approach and German survey data.

In the Czech Republic, the third most commonly used drug after alcohol and tobacco is cannabis. Its use is widespread especially among young people – almost one fifth (18.5%) of people between the age of 15 and 34 smoke at least one cigarette of cannabis per year, which makes the young Czechs the biggest consumers of marijuana in Europe (Annual report of European Monitoring Centre for Drugs and Drug Addiction, 2014). Therefore a study by Cameron and Williams (2001) estimating the relationship among alcohol, tobacco and cannabis might be really interesting when studying the Czech market. The

results show some evidence for cannabis being a substitute for alcohol and a complement to cigarettes and also for complementarity of cigarettes and alcohol.

Based on the studies mentioned above, we assume beer and tobacco to be complements. Social costs of tobacco use are therefore tightly linked with beer consumption. This assumption even strengthens the need for raising taxation on beer. The issue of tobacco taxation is not an object of interest of this paper, however, the optimal level of tax on cigarettes could be estimated using similar methods to estimating the tax on alcohol, because both alcohol and tobacco are goods with negative externalities. Review of the current Czech cigarettes taxation policy can be found in Cnossen (2006).

3.3 Benefits of Beer Industry

Despite all of the social costs described in the previous section, the contribution made by beer to the Czech economy is considerable. In 2012, total consumer spending reached 79 279 million CZK and Value added to the production and sales of beer accounted for 27 450 million CZK (0.8% of nominal GDP of the Czech Republic). Note that this value consists not only of contribution of breweries themselves, but also contribution by supply, retail and hospitality sector, which even exceeds brewing companies direct effect. Czech government also benefits from beer industry by tax revenues. In 2012, revenues from excise duties, VAT and income-related contributions related to Czech beer production and sales reached approximately 28 506 million CZK, which is even more than back in 2008. Among other causes, this increase can be explained by two percent rise in the VAT rate since 2008. More than a half of this amount was accounted by revenues from VAT.

Besides the direct contribution to government revenues, we remark a significant impact of Czech beer sector on employment. Evaluating of this contribution in money terms would be really difficult, so this study uses only the number of jobs created for illustration. In 2012, the brewing industry directly employed approximately 7 000 people. This direct employment accounted only for 11% of the total beer-related employment of 63 100 jobs in various other sectors (38 200 jobs in the hospitality sector, 12 800 jobs in the supply sectors and 5 200 jobs in the retail sector). All the estimates described in the last two para-

graphs come from a report of Brewers of Europe by Berkhout et al. (2013). As we needed the prices in CZK, these estimates are multiplied by the exchange rate EUR/CZK for 12/31/2012 (25.14 Source : Czech National Bank).

Describing intangible benefits of the beer production seems to be much more difficult. One thing is for sure – besides the country's historical and natural heritage, famous "cheap Czech beer" and night life associated with it is one of the key tourist attractions of the Czech Republic, increasing country's incomes from tourism.

Pubs and beer drinking play an irreplaceable role in the Czech culture. While in other countries people spend their time in cafes or restaurants inviting their friends for coffee, Czech people meet their friends or business partners over a glass of beer in pubs. Beer-drinking is also typically connected with meeting new people and social moments such as parties and weddings.

Chapter 4

Modeling the Optimal Taxation

The empirical part of this paper focuses on estimation of optimal alcohol tax, using an analogy to a method developed by Pogue and Sgontz (1989) (in Model 2) and Parry et al. (2009) (in Model 1). Both models are at first theoretically described. Later, Model 1 is parametrized using values for the Czech Republic. Finally, estimated optimal taxes are compared to results of parametrization of Model 2 by Janda et al. (2010).

4.1 Literature Review

Prior literature, e.g. Manning et al. (1989) and Saffer and Chaloupka (1994) usually focuses on measuring various externalities such as cost of drunk driving and medical burden and estimating of Pigouvian, externality correcting tax. Kenkel (1996) concludes that alcohol taxation is not the only solution of problems connected with alcohol abuse and that stricter penalties for drunk driving together with higher public awareness of the health consequences of heavy drinking might significantly reduce social costs arising from alcohol consumption. Another study by Lyon and Schwab (1995) compares effect of alcohol taxation with respect to annual and lifetime revenues. Results of all these studies agree on the fact that current alcohol tax rate is below its optimal level.

Pogue and Sgontz (1989) as well as previous authors focus on measuring Pigouvian tax using partial-equilibrium approach, balancing DWL of taxation due to destored consumption choices of moderate drinking against benefits from reduction of externalities caused by abusive drinking. For this purpose, the population is divided into several groups according to the level their alco-

hol consumption/abuse. The result is either taxation near the present level or higher.

Parry et al. (2009) in contrast with prior literature including Pogue and Sgontz (1989) measures for both Pigouvian and fiscal rationales, presenting an analytical framework for assessing the optimal levels and welfare effects of alcohol taxes and drunk driver penalties, accounting for both externalities and how policies interact with the broader fiscal system. Optimal alcohol tax is decomposed into four different components - Pigouvian tax, Revenue-recycling tax, Tax-Interaction effect and Productivity effect. This approach was introduced earlier in the article of Sandmo (1975) who suggested that optimal level of tax on alcohol may differ considerably from Pigouvian tax on fiscal grounds. Empirical estimation shows that fiscal considerations can significantly strengthen the case for higher alcohol taxes as the fiscal component of the optimal alcohol tax may be as large as (or even exceed) the externality-correcting component. Unlike Pogue and Sgontz (1989) individual beverages have different taxation, varying in the fiscal component of tax. The results of analysis also suggest that optimal levels of alcohol taxes in the USA are much higher than their current level.

4.2 Model 1

First, we present the model whose structure is very similar to the one used in Parry et al. (2009). This static general - equilibrium model with representative agent assumes that agent's future costs of addiction are internal and not undervalued and that efficiency determines optimality of policy. Fiscal system is highly simplified - it is financed only through labor and alcohol taxes and pecuniary penalties. Regarding this, the fiscal component of the optimal alcohol tax in our analysis might be undervalued.

Preferences

Let us assume that the agent, representing an aggregation over all households in the real economy, has continuous, quasi-concave utility function:

$$U = U(A, D, \tau_D D, C, l, G^P, H) \tag{4.1}$$

$$H = H(A, D, \overline{D}, M) \tag{4.2}$$

In (4.1) all variables are expressed on a per capita basis and the bar label variable is exogenous to our agent. U is a function increasing in all arguments except $\tau_D D$ and H. Agent can arbitrarily choose the consumed level of alcohol A and non-alcoholic goods C, number of driving trips under the influence of alcohol D and leisure time l. τ_D denotes non-pecuniary penalties (e. g. license suspensions, jail) per drunk-driver trip. G^P is government spending on public goods and H health risks, further explained in the next paragraph.

Health risks H comprise risks of becoming ill, injured, disabled or killed due to heavy-drinking or alcohol-involved traffic incident. These risks are defined in (4.2) by the continuous, quasi-concave function, increasing in agent's own alcohol consumption, drunk driving, drunk driving committed by others $\overline{D}$ and decreasing in agent's consumption of medical services M, as this mitigates health risks and improves the chance of recovery.

Production

There are no pure profits on the production side of the economy because alcohol, general goods, medical and auto services are produced by competitive firms with constant returns to scale. Therefore, producer prices are fixed and firms pay a gross wage of w that is equal to the value of a marginal product of labor. Effective labor supply is defined as $W = wL$ where L is labor supply (time at work). Changes in H are assumed to have a negative impact on W ($\frac{\partial W}{\partial H} < 0$).

The government pays for fraction s of medical care costs, while the rest $1 - s$ is paid for by private insurance and auto-insurance companies that cover their costs through charging a variable payment amounting for the fraction υ_M of medical expenses charged by insurance companies or υ_D per drunk-driver trip charged by auto/insurance companies ($\upsilon_D < c_D$ where c_D is the expected cost of auto repair) and also a lump-sum premium to households of K_M (respectively K_D) . Insurance companies' profits are zero in equilibrium because υ_M and υ_D adjust and K_M and K_D are given.

Government

The government faces the following budget constraint:

$$G^P + G^T + sM = t_L W + t_A A + (t_D - r)D \tag{4.3}$$

The right side of the equation (4.3) describes three kinds of government spending - on public goods G^P, lump-sum transfer spending G^T and government medical expenditures. These expenses are financed by revenues, which are described on the left side. t_L, t_A and t_D denote, respectively, a proportional tax on labor income, a tax on alcohol consumption, and an expected fine per drunk-driver trip. $r = r(\upsilon_D, t_D)$ denotes resource costs expended by the government from implementing drunk driver penalties is increasing in both υ_D and t_D.

Agent optimization.

Agents face the following budget and time constraints:

$$\begin{gathered}(1 - t_L)W + G^T = (p_A + t_A)A + C + K_M + \upsilon_M M + K_D + \upsilon_D D + t_D D \\ T(H) = L + l\end{gathered} \tag{4.4}$$

In the first equation, net of tax labor income and the government transfer spending equal expenditures on alcohol (p_A is the producer price of alcohol), general consumption, lump-sum and variable costs paid to medical and auto insurance companies and drunk driver fines . T is available time divided between leisure and labor, a function decreasing in health risks H.

The consumer's maximalization problem yields the first order conditions:

$$\begin{array}{ll}\frac{U_A}{\lambda} = p_A + t_A + mpc\ H_A & \frac{U_D}{\lambda} = \upsilon_D + t_D + \tau_D + mpc\ H_D \\ -mpc\ H_M = \upsilon_M & \frac{U_l}{\lambda} = (1 - t_L)w\end{array} \tag{4.5}$$

In (4.5) we have normalized $-\frac{U_{\tau_D D}}{\lambda} = 1$, λ is the marginal utility of income and $mpc = -(U_H/\lambda + (1 - t_L)(wT_H + W_H))$ denotes the marginal private cost of health risks, which consists of direct disutility from suffering $-U_H/\lambda$, the value of lost time from incapacitation or premature mortality $-(1 - t_L)wT_H$ and forgone private earnings from lower workplace productivity $-(1 - t_L)W_H$.

It is seen from (4.5) that agents increase their alcohol consumption to the point where the marginal benefit received from the last drinking unit is equal to the tax-inclusive alcohol price and the own-health cost. Similarly driving under the influence of alcohol is committed until the marginal benefit from drunk driving equals the expected out-of-pocket expenses for auto crashes, (monetized) government penalties, and own health risks. Individuals also equate the marginal private benefit from medical care with the variable cost and the marginal benefit from leisure with the net wage.

In equilibrium, consumption and labor supply depend on the following reduced form functions:

$$y = (t_A, t_L, G^P, G^T, s - \upsilon_M, c_D - \upsilon_D); y = A, D, C, M, L \tag{4.6}$$

These functions only slightly differ from the demand/supply functions of the representative agent, because they account for feedback effects from changes in $\overline{M}$ and $\overline{D}$ on the equilibrium, lump-sum medical and auto premiums charged by insurance companies.

Marginal welfare effect from an increase in t_A

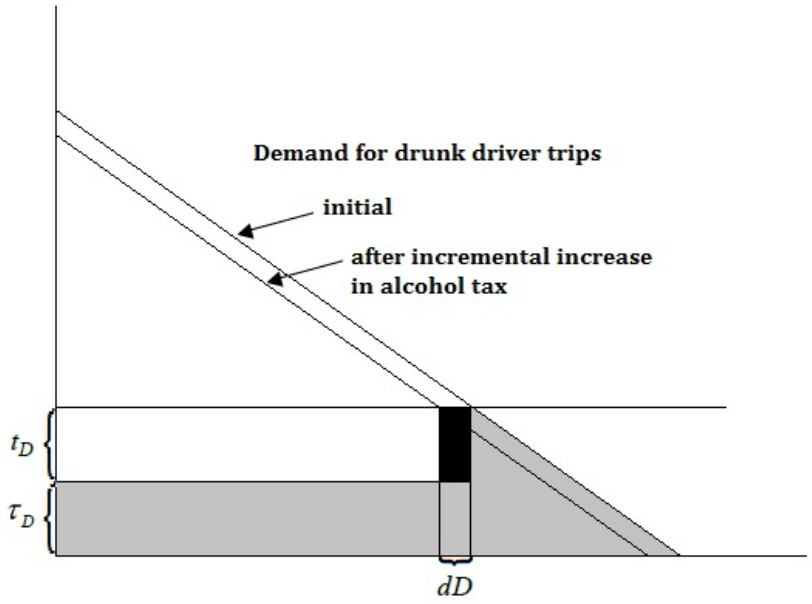
By totally differentiating the indirect utility function (see Appendix A for derivation and definition of elasticities), we obtain marginal welfare effect from an increase in t_A, accounting for any changes in t_L, G^T and G^P to maintain government budget balance.

$$\begin{gathered} (E^A - t^A)(-\tfrac{\partial A}{\partial t_A}) + t_L(\tfrac{\partial W}{\partial t_A}) + MEG_{G^P}(\tfrac{\partial G^P}{\partial t_A}) \\ E^A = (1 - \upsilon_M)M_A + E^D D\eta_{DA}/A\eta_{AA} \\ E^D = mpc\ H_{\overline{D}} + c_D - \upsilon_D + (1 - \upsilon_M)(M_D + M_{\overline{D}}) + r - t_D \end{gathered} \tag{4.7}$$

In these expressions $\eta_{AA} < 0$, $\eta_{DA} < 0$ are elasticities of alcohol consumption and drunk driving with respect to price of alcohol, $MEG_{G^P} = U_{G^P}/\lambda - 1$ denotes marginal efficiency gain/loss from spending on public goods and E^A stands for the marginal external cost of alcohol consumption. Finally E^D, denoting the external cost per drunk driver trip is gross of the non-pecuniary penalty τ_D, which implies that the optimal level of alcohol taxes will be independent of the level of non-pecuniary penalties. This is further explained

by Figure 4.1, which shows deadweight losses under the drunk driver demand curve from the drunk driver penalties $t_D + \tau_D$. Deadweight losses from drunk driver penalties include, in addition to the traditional Harberger triangle from the distortion of demand also the first-order utility loss from the non-pecuniary penalty (the rectangle $\tau_D D$), which is not compensated by a revenue to the government. If alcohol taxes increase, demand curve shifts to the right and subsequently deadweight loss increases by t_D per unit reduction in D (the black rectangle in Figure 4.1).

Figure 4.1: Deadweight Losses from Drunk Driver Penalties



Source: Based on figure by Parry et al. (2009)

Labor supply effects from 4.7 is defined as

$$\frac{\partial W}{\partial t_A} = \frac{\partial W}{\partial H}\frac{\partial H}{\partial t_A} + w\frac{\partial L}{\partial t_A} + w\frac{\partial L}{\partial t_A} + w(\frac{\partial L}{\partial t_L}\frac{\partial t_L}{\partial t_A} + \frac{\partial L}{\partial G^T}\frac{\partial G^T}{\partial t_A}) \tag{4.8}$$

By totally differentiating (4.6) we divide the change in effective labor supply into three components - the increase in workplace productivity due to the effect of lower alcohol consumption on reducing illness or road injuries, the labor supply effect of raising the price of alcohol relative to leisure and the effect of revenue recycling (leisure is a normal good, so if we use revenues to decrease t_L, labor supply increases and it decreases if we use it to increase G^T).

Optimal tax with revenue neutrality.
Through the optimization, it is assumed that the government's goal is to maximize the utility of agent by finding the optimal level of t_a, given the level of G^T and G^P and keeping the budget balanced when using all the revenues to reduce the labor tax t_l. From the first equation in (4.7) and (4.8) we calculate the optimal alcohol tax (see derivation in Appendix A):

$$\begin{gathered} t_A* = PV^A + RR^A - TI^A + PR^A \\ Where: \\ PV^A = E^A; \quad RR^A = MEGt_L \left\{ \frac{p_A+t_A}{(-\eta_{AA})} - t_A + g^A \right\} \\ TI^A = \frac{(1+MEGt_L)t_L(p_A+t_A)(\eta^C_{Al}+\eta_{LI})}{(1-t_L)(-\eta_{AA})}; \quad PR^A = (1 + \ MEGt_L)t_L(-W_H H_A) \end{gathered} \tag{4.9}$$

$$\begin{gathered} MEGt_L = \frac{-t_L \frac{\partial L}{\partial t_L}}{L+t_L \frac{\partial L}{\partial t_L}} = \frac{\frac{t_L}{1-t_L}\epsilon_{LL}}{1-\frac{t_L}{1-t_L}\epsilon_{LL}} \\ g^A = sM_A + \{s(M_D + M_{\overline{D}}) + (r - t_D)\} D\eta_{DA}/A\eta_{AA} \end{gathered} \tag{4.10}$$

η_{Al} denotes the elasticity of demand for alcohol with respect to the price of leisure (or household wage), $\epsilon LL > 0$ is the labor supply elasticity, $\eta_{LI} < 0$ is the income elasticity of labor supply and c denotes a compensated elasticity (all elasticities are defined in Appendix A). In equation (4.10), $MEG_{t_l} > 0$ is the efficiency gain from using a dollar of revenue to cut the labor tax.

It is seen from (4.9) that the optimal alcohol tax consists of four components - the marginal external cost of alcohol consumption E^A and three other components that arise from various fiscal interactions.

PV^A (or E^A) is the Pigouvian tax, the marginal external cost of alcohol (for the detailed formula, see 4.7). These costs are divided into two parts - first is the fraction of medical costs due to the health risks from alcohol consumption paid by third parties (government and insurance companies). The second component accounts for drunk-driver trip costs.

The first extra component is the revenue - recycling tax (RR^A), that captures changes in both tax revenues and alcohol-related public expenditure induced by alcohol tax. It is equal to MEG_{t_l} times marginal revenue to the government

from raising the alcohol tax, including indirect savings in government medical and resource expenditures g^A. Regarding the role of price elasticity of alcohol demand: the lower it is, the greater the tax revenue from alcohol taxation, as well as the revenue - recycling component.

The second extra component TI^A is the tax - interaction effect which arises from change in labor supply as the alcohol price rises relative to the price of leisure, multiplied by $1 + MEGt_L$ to account for the change in labor tax revenue. To maintain the government revenue balanced, t_L must be changed. When alcohol and leisure are complements (${\eta_{Al}}^C < 0$), the alcohol tax increases the labor supply and the tax - interaction effect is positive. It also includes the income effect from higher alcohol prices, which reduces labor supply because leisure is a normal good ($\eta LI < 0$). If alcohol and leisure were substitutes (${\eta_{Al}}^C > 0$), the alcohol tax would decrease both labor supply and labor tax revenue, which implies the negativity of the tax - interaction effect.
We assume that alcohol is a relative complement for leisure, otherwise there would be a downward adjustment to the optimal alcohol tax and therefore no need for higher alcohol taxes.

Finally, third component is productivity effect (PR^A), expressed in per unit reduction in alcohol consumption. Taxing alcohol reduces drinking and also drunk driving, resulting in better health of individuals and positive effect on effective labor supply. It equals the health-induced increase in productivity per unit reduction in alcohol $-W_H H_A = (\partial W/\partial H)(dH/dA)$ times the labor tax t_L, times $1 + MEGt_L$ to account for the change in labor tax revenue.

Taxation of individual beverages
Now, let us assume that:

$$\begin{gathered} A = A(A_{BE} + A_{WI} + A_{SP}) \\ E^{Ai} = E^A \quad H^{Ai} = H^A \end{gathered} \tag{4.11}$$

where A is a weakly quasi-concave function of individual beverages: beer (BE), wine (WI) and spirits (SP). The second equation indicates that marginal external costs E^{Ai} and productivity effects H^{Ai} per alcohol unit are the same across these beverages.

We calculate optimal taxes on these individual beverages as :

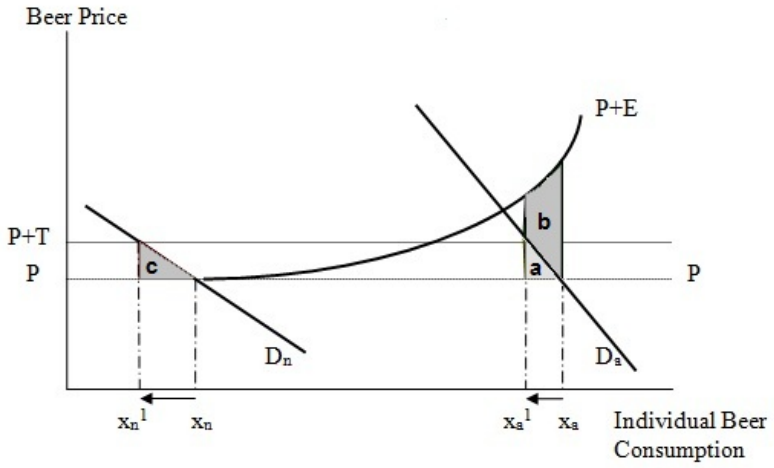
$$\widehat{t_i} = t_i * - \sum_{k \neq i} (t_k * - \widehat{t_k})(\frac{\eta_{ki} A_k}{\eta_{ii} A_i}) \tag{4.12}$$

where $i, k = BE, WI, SP$ and η_{ii} η_{ki} denote own and cross - price beverage elasticities. t_i* is the optimal tax in the absence of cross-price effects among beverages and is analogous to that in (4.9). Therefore if a beverage is more elastic and complementary to leisure, the optimal tax on it is likely to be higher.

4.3 Model 2

The second model we use is based on the one represented by Pogue and Sgontz (1989). We assume that the beer industry is a competitive industry where constant price P equals long run marginal cost and beer is a homogenous product. The basic model divides the entire population of N beer consumers into two groups - abusers N_A and non-abusers N_N, so that consumption by moderate drinkers results in no externality costs, whereas consumption by abusers does. These two groups of consumers also have different demand curves D_a and D_n, where demand of abusers is higher and perhaps less elastic. We define a function of marginal external abuse cost E, which is a positive function of beer consumption x, because marginal cost in the lower levels of consumption are negligible, but increase with higher alcohol consumption. Abstracting from the issue of different beverage types to illustrate, the problem of setting the optimal alcohol tax can be understood by considering Figure 4.2 .

Figure 4.2: Model with External Costs and Dead Weigh Losses



Source: Janda et al. (2010), based on figures by Pogue and Sgontz (1989)

In Figure 4.2, each non-abuser consumes x_n, imposing no external costs on society. On the other hand, extensive consumption of abusers x_a creates positive external costs to society. Optimal solution to this situation would be imposing tax only on the originators of the externality (it is, in fact, a case of Pigouvian tax), which is in reality quite difficult or rather impossible. Therefore, we impose unity tax T levied on all consumption and quantity consumed by both groups falls to ${x_a}^1$ and ${x_n}^1$ (unfortunately imposing this tax damages also the welfare non-abusers).

Welfare gain

We can calculate the welfare gain of the whole society as:

$$W = Na \int_{{x_a}^l}^{x_a} E(x)dx - \frac{1}{2}T(-\Delta x_a)Na - \frac{1}{2}T(-\Delta x_a)Na \tag{4.13}$$

This equation contains three components - the gain from lowering the external abuse costs (area a+b), the welfare loss of abusers (area b) and the welfare loss of non-abusers (area c). $\Delta x_i = {x_i}^1 - x_i, i = a, n$ denotes reduction in individual demand caused by the tax.

For simplification, we introduce $E*$, denoting the marginal external abuse cost averaged over the change in abusive consumption Δx_a. Let $X_a = x_a\ N_a$, $X_n = x_n\ N_n$ be the total alcohol consumption by whole abusers and non-

abusers group respectively.

Assuming that prices increase exactly by the amount of tax T, we calculate demand elasticities for both consumer groups as :

$$\epsilon_a = \frac{\frac{\Delta x_a}{x_a}}{\frac{T}{P}}; \qquad \epsilon_n = \frac{\frac{\Delta x_n}{x_n}}{\frac{T}{P}} \tag{4.14}$$

Substituting (4.14) in (4.13) gives the following simplified version of the model :

$$W = \frac{E * T(-\epsilon_a)X_a}{P} - \frac{T^2(-\epsilon_a)X_a}{2P} - \frac{T^2(-\epsilon_n)X_n}{2P} \tag{4.15}$$

Maximizing W

Maximizing (4.15) with respect to T brings us to the following first order condition:

$$\frac{\partial W}{\partial T} = \frac{E * (-\epsilon_a)X_a}{P} - \frac{T(-\epsilon_a)X_a}{P} - \frac{T(-\epsilon_n)X_n}{P} = 0 \tag{4.16}$$

Solving equation (4.16) with respect to T/P, assuming $\epsilon_a \neq 0$ gives the ad-valorem tax that maximizes welfare

$$\frac{T}{P} = t = \frac{E*}{P}(\frac{1}{1 + \frac{\epsilon_n X_n}{\epsilon_a X_a}}) \tag{4.17}$$

In reality, there are probably more than just two groups of alcohol users. It seems unfair to put a student, who occasionally gets drunk with friends and an uneducated misfit, who spends all days in the pub to the same category. Assuming that we know price elasticities and marginal external costs of k group of alcohol abusers, we might be able extend the model so that

$$t = \frac{1}{P}(\frac{\sum_{i=1}^{k} E_i \epsilon_i X_i}{\sum_{i=1}^{k} \epsilon_i X_i + \sum_{i=1}^{k} \epsilon_n X_n}) \tag{4.18}$$

Chapter 5

Parametrization of Model

In this section, parameter values from Model 1 are described. All values were estimated for 2012 if not stated otherwise. For important parameters that are uncertain, we usually consider three different values to obtain the mid, low (conservative) and high (non-conservative) estimates. We allow a ±30% variation to find the lower and upper limit.

5.1 Alcohol Market and Labor Tax

To calculate the **total consumption of pure alcohol** (or ethanol) in the Czech Republic, we first need to find out how many liters of pure alcohol were contained in the amount of beer, wine and spirits consumed (computed in Table 5.1).

Table 5.1: Per Capita Amount of Pure Alcohol Consumed

Beverage	**Per-capita consumption**	**Alcohol volume**	**Per-capita consumption of pure alcohol**	**% of Total pure alcohol consumed**
Beer	148.6 l/year	4.5%	6.687 l/year	57%
Wine	19.8 l/year	12%	2.376 l/year	20.2%
Spirits	6.7 l/year	40%	2.68 l/year	22.8%

Source: Own calculation based on Czech Statistical Office data

Initial alcohol consumption A is thus 11.743 l of pure ethanol per capita per year, which means 123 365 440,6 l of pure alcohol in total at the 2012 population level of the Czech Republic of 10 505 445 people (CSO, 2012).

The average price of one liter of beer, wine and spirits, taken from Budget Household Survey data from 2012 reaches 24.3 CZK, 66.18 CZK and 246.21 CZK respectively, where the average price of beer was calculated by multiplying the average price of bottled beer 20.24 CZK and the average price of draft beer 40.22 CZK by the rate of their occurrence (52.2% and 47.8%, RIBM 2014). The price of wine was similarly counted with both red and white wine and the price of spirits with two Czech most popular ones – vodka and rum.

For the purpose of our analysis we do not need to know the price of a liter of the particular drink, but the price of an accurate amount of the beverage containing exactly one liter of pure alcohol (22.22 l of 4.5% beer, 8.33 l of 12% wine and 2.5 l of 40% spirits). These prices p_a are 539.946 CZK for beer, 551.2794 CZK for wine and 615.525 CZK for spirits.

The current alcohol tax rate t_a is calculated as the sum of excise tax and VAT, which is the same for all the three kinds of alcohol – 21%, the basic rate (VAT of 1 liter of pure alcohol in beer, wine and spirits is therefore 113.39 CZK, 115.77 CZK and 129.26 CZK). On the other hand, excise tax differs for every one of them. For spirits it is 285 CZK/l, while for still wines, the excise tax does not apply at all. Calculation of excise tax on beer is a bit more complicated – it depends both on the size of brewery and the content of original wart extract (details can be found in Table 5.2).

Table 5.2: Excise Tax on Beer

Brewery size (hl of beer produced)	**Tax rate for 1% of original wart extract in 1 liter**
< 10 000	16 CZK
10 000 - 50 000	19.2 CZK
50 000 – 100 000	22.4 CZK
100 000 – 150 000	25.6 CZK
150 000 – 200 000	28.8 CZK
> 200 000	32 CZK

Calculating with the standardized rate of 0.31 CZK/l (over 90% of beer is being produced in the breweries with production over 200 000 hl) and the average 11 degrees Plato beer, we get beer excise tax of 3.41CZK/l of beer or 75.02

CZK/amount of beer containing 1 liter of pure alcohol.

Altogether, the current alcohol tax rate t_a per liter of pure alcohol is estimated to be 188.41 CZK for beer, 115.77 CZK for wine and 414.26 CZK for spirits.

In 2011, the implicit **tax rate on labor** was 39% in the Czech Republic (Eurostat, 2013). In 2012 real GDP was approximately the same and the government did not implement any new policies concerning income tax, so the tax rate on labor was probably the same than in the previous year. Therefore in this paper $t_L = 0.39$ is applied.

5.2 Drunk Driving

In 2012, the Police of the Czech Republic recorded a total of 4,974 traffic accidents caused by drunk driving. In these accidents, 45 persons were killed and 2,770 people injured. Alcohol in blood of drivers was also detected at 11,037 inspections of motor vehicles. Altogether there were 16,011 cases of drunk driver trips registered in 2012. Nevertheless, this value represents only a small fraction of the actual number.

According to data of the Ministry of Transport, drivers with a blood alcohol level higher than allowed amount account for approximately 2% of total kilometers traveled within the countries of the EU. Assuming 10 000 kilometers travelled per year per driver (GE Money Auto, 2011) , average trip length of 20 kilometers and the proportion of drivers in the population of 64.62% (Department of Transportation, 2006) gives **initial drunk driver trips** D of 67 886 186 with the proportion of registered drunk driving lower than 0.03%.

Expected fine per drunk-driver trip $t_D = 5.9$ CZK is calculated a half of the maximal penalty rate that can be charged in the Czech Republic for driving under the influence of alcohol (25 000 CZK) multiplied by the number of registered drunk driving, divided by real drunk driving.

5.3 External Costs

Levitt and Porter (2001) estimate that only 16.8% of injuries in alcohol-involved crashes are external. Applying the same ratio to alcohol-related fatalities in 2012 gives eight external fatalities and 471 external injuries. For fatalities, the marginal private cost *mpc* corresponds to estimates of the value of life. Czech Supreme Court assumes a value of life of 10 051 200 CZK , thus 80 409 760 CZK the estimated value of eight lives.

Estimating compensation for non-fatal injuries is more complicated. Under Czech law, every injury or social impairment caused by a traffic accident has a different value in points, on which amount depends the compensation. Value of one point is 120 CZK. Averaging all these compensation gives a value of 72 000 CZK (that means 33 912 000 CZK for 471 injuries), which we set as the marginal private cost *mpc* of non-fatal external injuries. Aggregating over the value of fatal and non-fatal injuries and dividing by alcohol consumption gives a value for $mpcH_{\overline{D}}D/A = 0.927$ CZK per liter of alcohol.

Based on data from the Ministry of Finance, we estimate the total costs of auto repair to be 500 mil. CZK. In the Czech Republic, the car accidents costs are almost entirely covered by mandatory car insurance. Average individual financial participation reaches only 9% of the damage in each accident. Dividing by alcohol consumption gives $(c_D - \eta_D)D/A = 3.68$ CZK.

For the calculation of government resource costs from implementing drunk driver penalties (including law, police and jailing costs), adjusted European average data from Anderson and Baumberg (2006) have been used. Values for the Czech Republic were obtained by multiplying European data and ratio of Czech inhabitants in the EU (2.09%), ratio between average Czech and EU alcohol consumption (116%) the 2006 mid year exchange rate EUR/CZK (27.495, source : Czech National Bank) and a conversion factor – ratio of CZ/EU productivity of labour (49.6%, source: Eurostat) for the productivity parameters and purchasing price parity ratio (79.3%, source: Eurostat). Estimated legal costs of alcohol-related crime are 5 900 million CZK. Alcohol-related car incidents are closely linked to alcohol-related costs of crime. Again using Anderson and Baumberg (2006), we assume that alcohol-related car incidents accounted for 88% of the previously mentioned amount, thus 5 192 million CZK and

$rD/A = 42.09$ CZK.

Using again the European data, we could estimate medical expenditures connected to treatment of alcohol related health problems to be CZK 6.7 billion. This estimate includes costs of treatment of diseases caused by alcohol consumption, own drunk driving and drunk driving of others. Unlike the U.S. healthcare system, Czechs have most of the medical services paid by government through their taxes. Variable payment υ_M (which consists mainly of cost of medicaments) must therefore be lower than in Parry et al. (2009) and we assume it to be 0.1.

All the above mentioned values give together $E^A = 106.93$ CZK per liter of pure alcohol. This value is the same for all the three beverages.

5.4 Elasticities and Marginal Efficiency Gain

Elasticities used to derive the optimal tax level are presented in Table 5.3.

Table 5.3: Applied Elasticities

Parameter		**Low**	**Mid**	**High**
Drinking with respect to leisure (compensated)	η^C_{Al}	0.1	-0.1	-0.2
Labor supply with respect to income	η_{LI}	-0.1	-0.1	-0.1
Labor supply with respect to wage rate	ϵ_{LL}	0.15	0.15	0.15
Drinking with respect to alcohol price - beer	η_{AA}	-0.9715	-0.9715	-0.9715
Drinking with respect to alcohol price - wine	η_{AA}	-1.088	-1.088	-1.088
Drinking with respect to alcohol price - spirits	η_{AA}	-1.2104	-1.2104	-1.2104

Elasticity of drinking with respect to leisure η^C_{Al} was drawn from Parry et al. (2009) who indicates and interval between 0.1 and -0.2 and -0.1 is used as mid value. In this case, using three different values is really appropriate because of limited evidence on this parameter, which is more suggestive than definitive.

Own–price alcohol elasticities have been estimated in numerous studies - among others, let us name Hogarty and Elzinga (1972), Gallet (2007), Fogarty (2010) and from the most recent ones Nelson (2014), Srivastava et al. (2014) and Meng et al. (2014). Significantly less authors have also focused on cross - price elasticities of alcohol beverages. In this thesis, we will use elasticities calculated by Janda et al. (2010), based on the data from Czech Household Budget Survey, presented in Table 5.4, which seems to be the most suitable for our purposes, because the estimate was made relatively recently and was based on data from the Czech market. It also focuses both on own and cross-price elasticities. Therefore, we assume own–price elasticity $\eta_{AA}$of beer, wine and spirits to be -0.9715, -1.088 and -1.2104 respectively.

We assume $\eta_{DA} = \eta_{AA}$ based on estimated responses of drunk driving and highway fatalities to alcohol prices.

Table 5.4: Alcohol Price Elasticities

	Beer	**Wine**	**Spirits**
Beer	**-0.9715**	-0.0681	0.0933
Wine	-0.1143	**-1.0880**	0.0491
Spirits	0.2047	0.2302	**-1.2104**

Source: Janda, Mikolasek, Netuka - Socially Optimal Taxation of Alcohol: The Case of Czech Beer (2010)

There is a vast amount of literature estimating **labor supply elasticity**. The majority of them agree on the fact that it is inelastic. For the purpose of this paper, we use the value of $\epsilon_{LL} = 0.15$ analogous to Parry et al. (2009), which is averaged over all male and female workers and hours worked. The latter gives an outcome of MEG tl of approximately 0.106.

Finally, **labor supply elasticity with respect to income** η_{LI} is estimated. It must be negative, as leisure is a normal good and it must also reflect both alcohol-consuming and light–consuming households. We use the value of $\eta_{LI} = -0.1$ that is also applied in both Saar (2011) and Parry et al. (2009).

5.5 Productivity Effect

According to the estimates by Anderson and Baumberg (2006) from Institute of Alcohol Studies, we could estimate total workplace productivity costs due to the lower state of health of alcohol abusers and those that arise from increased absence at work while influenced by alcohol consumption to be 4.7 billion CZK. For the revenue-neutral alcohol tax this implies a **productivity cost** $W_H H_A$ of 26.7 CZK - 49.50 CZK per liter of pure alcohol with a middle value of 38.1 CZK.

Chapter 6

Results - Optimal Taxation for the Czech Republic

Results of the simulation are presented in Table 6.1, Table 6.2 and Table 6.3 .

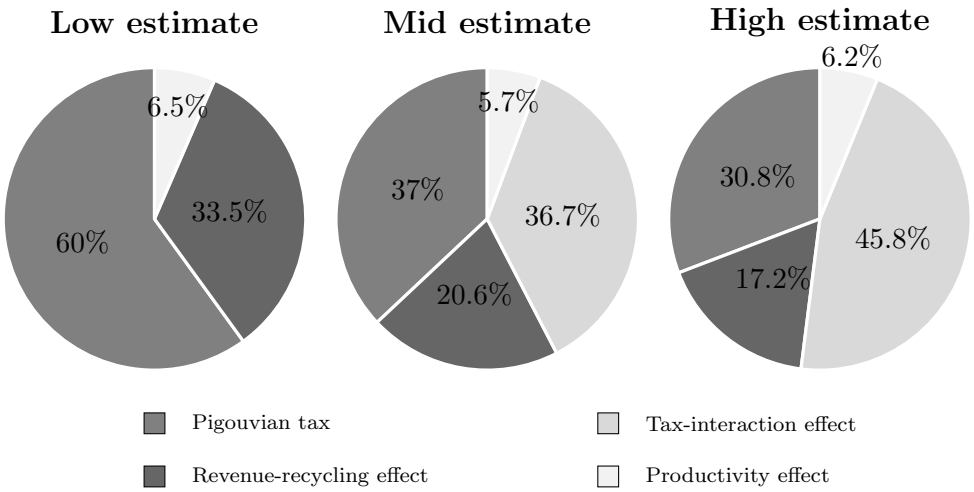
Table 6.1: Optimal Tax on Beer (CZK per liter of pure alcohol)

Components of alcohol tax	**Low**	**Mid**	**High**
Pigouvian	106.93	106.93	106.93
Revenue-recycling	59.54	59.54	59.54
Tax-interaction	0	106.03	159.05
Productivity	11.52	16.44	21.36
Total	**177.99**	**288.94**	**346.88**
Current		188.41	

As shown, the optimal tax rate for beer ranges from 177.99 CZK to 348.66 CZK per liter of pure alcohol with the mid estimate of 288.94 CZK. The low, mid and high estimate of optimal tax (a sum of VAT and excise tax) on 0.5 l of beer is therefore 4 CZK, 6.5 CZK and 7.8 CZK. While the low estimate is slightly below the current tax rate of 4.2 CZK per 0.5 l of beer, both mid and high estimate exceed the current tax level.

High estimate represents almost 200% of the low estimate, which seems to be a reasonable difference. Individual estimates differ in Tax-interaction effect and Productivity effect. The variability is caused mainly by differences in elasticities of drinking with respect to leisure (from 0.1 to -0.2) applied to derive low, mid and high estimates.

Figure 6.1: Structure of Estimated Optimal Tax on Beer



The most volatile component of the optimal tax is the Tax-interaction effect. On the one hand, it completely disappears under the low estimate, because under the given parameter values the substitution effect between alcohol and leisure, which decreases the labor supply, is offset by the income effect from the higher alcohol price that, on contrary, increases labor supply. On the other hand, it represent almost the same proportion of the optimal tax as the entire Pigouvian tax at the mid estimate. Finally, Tax – interaction effect under the high estimate is so high that it represents over 45% of the total optimal tax rate. The composition of the optimal tax is further described in Figure 6.1.

Similarly to results from the USA presented in Parry et al. (2009), the fiscal component (which we define by the Revenue-recycling component net of the Tax-interaction effect) of the total tax rate under mid and high estimate exceeds the Pigouvian tax. This fact highlights the need for both fiscal and externality consideration. Productivity effects play only a marginal role in the level of beer tax.

Table 6.2: Optimal Tax on Wine (CZK per liter of pure alcohol)

Components of alcohol tax	**Low**	**Mid**	**High**
Pigouvian	106.93	106.93	106.93
Revenue-recycling	52.75	52.75	52.75
Tax-interaction	0	86.71	130.07
Productivity	11.52	16.44	21.36
Total	**171.20**	**262.83**	**311.11**
Current		115.77	

In order to obtain the optimal beer tax, we had to calculate the optimal tax on wine and spirits as well. Alike the current tax, the estimated wine taxation is the lowest from all the three alcoholic beverages. The optimal tax on wine was estimated to be 171.20 CZK - 311.11 CZK per liter of pure alcohol with the mid value of 262.83 CZK. After the recalculation we get 20.54 CZK - 37.35 CZK per liter of wine, thus way above the current level of 13.88 CZK.

Table 6.3: Optimal Tax on Spirits (CZK per liter of pure alcohol)

Components of alcohol tax	**Low**	**Mid**	**High**
Pigouvian	106.93	106.93	106.93
Revenue-recycling	46.30	46.30	46.30
Tax-interaction	0	120.33	180.49
Productivity	11.52	16.44	21.36
Total	**164.75**	**290.00**	**355.08**
Current		414.26	

The current level of tax on spirits is significantly higher than those on wine and beer because of alleged higher social costs of its consumption. The results of our analysis show that although the optimal level of tax rate on spirits is still the highest from all the beverages presented, it is way below its current level for all low, mid and high estimates. The value of mid estimated tax on 1 liter of 40% spirit of 116 CZK represents only about 70% of the current tax.

The study of Janda et al. (2010) analyzes the recent development of Czech brewing industry. Using methodology of Anderson and Baumberg (2006) and statistical data about Czech alcohol consumption, an analogy of a model developed by Pogue and Sgontz (1989) is used to estimate the optimal tax on

alcohol, balancing social costs and benefits connected with the beer production and consumption. In order to maximize the welfare of society, alcohol consumers are divided into two groups - abusers and non-abusers, differing in volume and elasticity of alcohol demand.

Ranges of optimal taxes on each alcoholic beverage presented in Table 6.4 are results of calculation with different sets of parameters, varying in level of external abuse costs (with and without intangible costs) and assumptions about the number of abusers attributed to each alcoholic beverage.

Table 6.4: Optimal Tax Calculation - Model 2

	Tax per liter of ethanol(CZK)	**Tax per liter of the beverage(CZK)**
beer	85 - 415	3.58 - 17.45
wine	56 - 416	5.67 - 42.43
spirits	43 - 284	17.14 - 113.67

Source: Janda et al. (2010) - Socially Optimal Taxation of Alcohol: The Case of Czech Beer

Range of the optimal taxes calculated by Model 2 is generally wider than the one from Model 1, particularly regarding the lower bound. The fact that all the low estimates are much lower can be explained by the fact that the method used by Janda et al. (2010) considers only externality rationales. Whereas in Model 1, the highest tax is imposed on spirits (similarly to the current tax rate), in Model 2, the tax on spirits is the lowest. The interval of optimal taxes of beer and wine from Model 2 is a subset of the set of optimal values from Model 2. Similarly to Model 1, the optimal alcohol taxes in the Czech Republic seem to be higher than their current level.

Chapter 7

Conclusions

Czech brewing is a quickly developing industry and an important contributor to both Czech economy and well-being of majority of population thanks to its inseparable connection with Czech culture and a special status of beer among other commodities. In spite of the fact that average production per brewery gradually increases, Czech market has undergone a big boom of microbreweries, whose numbers are (unlike bigger breweries) still increasing. In 2012, Czech beer consumption overcame a decline from past few years and started to grow again, despite the reduction of consumption of draft beers in pubs which was offset by an increase of bottled-beer sales, especially beer specials with low alcohol content.

Regardless of numerous benefits of beer production, beer has unfortunately, similarly to any other beverage containing alcohol, a negative external effect. The scale of costs is very broad, including medical expenditures, productivity loss, drunken driving accidents and police and law costs. Social costs of beer production are also connected with social costs of tobacco use as beer and cigarettes are assumed to be complements. Alcohol taxes seem to be a suitable means of addressing these externalities. Using a static general-equilibrium model with a representative agent we found that in order to find the optimal level of beer taxation, which balances social costs and benefits, government should set the tax rates between 4 CZK and 7.8 CZK per 0.5 l of beer. Our analysis suggests that under most of the combinations of parameters taxes on beer in the Czech Republic are lower than their optimal levels. On the other hand, optimal tax was shown to be slightly under its current level when low values were applied to parameters with a high degree of uncertainty. This

implies the need for more empirical research on some model parameters. Besides externality correction, these optimal levels are also determined by fiscal considerations as increase of taxation is assumed to immediately change other governmental policies such as labor taxation or medical expenditures. By decomposing the estimated optimal tax into four components, we conclude that the fiscal component significantly affects the optimal tax rate as it may be as large, or even larger than the externality-correcting component. Apart from taxes on beer, our analysis also estimates tax on wine of 20.5 CZK/l - 37.4 CZK/l and tax on spirits of 65.9 CZK/l - 142 CZK/l, which shows that optimal tax rates on different alcoholic beverages should vary according to their characteristics.

In the future, this study could be extended by many different ways. As said above, more empirical research on some model parameters (e.g. leisure cross-price elasticities) is needed for a more accurate estimation of the optimal tax levels. Similarly to Parry et al. (2009), we could estimate the optimal tax levels decreasing public spending and increasing drunk driving penalties, as alcohol taxes are typically justified as means of raising government revenues. Intangible costs of alcohol consumption such as pain or psychical harm to families of alcohol abusers were not considered in our analysis - another expansion could therefore include these in our model. Finally, a similar type of analysis might be used to estimate the optimal taxes on other goods with negative external effects such as tobacco and cannabis.

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Appendix A

Analytical Derivations

Deriving equation (4.8):

Using (4.1) and (4.4), agents solve the following optimization problem:

$$V(t_A, t_L, I, G^P, \overline{D}) = MaxU(A, D, C, T(H) - L(H, \tau_D D, G^P) \\ +\lambda\left\{(1-t_L)w + G^T - K_M - K_D - (p_A + t_A)A - (\upsilon_D + t_D)D - \upsilon_M M - p_c C\right\}) \tag{A.1}$$

From partially differentiating (A.1):

$$\frac{\partial V}{\partial t_A} = -\lambda A;\ \frac{\partial V}{\partial t_L} = -\lambda w L;\ \frac{\partial V}{\partial G^P} = U_{G^P};\ \frac{\partial V}{\partial \overline{D}} = -\lambda H_{\overline{D}} mpc;\ \frac{\partial V}{\partial \overline{I}} = \lambda \tag{A.2}$$

Totally differentiating (A.1) with respect to t_A using (A.2), gives:

$$\frac{1}{\lambda}\frac{\partial V}{\partial t_A} = -A - W\frac{dt_L}{dt_A} + \frac{dI}{dt_A} + \frac{U_{G^P}}{\lambda}\frac{dG^P}{dt_A} - H_{\overline{D}} mpc\frac{dD}{dt_A} \tag{A.3}$$

Totally differentiating the government budget constraint (A.3) with respect to t_A, allowing t_L, G^T and G^P to vary, gives:

$$\frac{dG^T}{dt_A} - W\frac{dt_L}{dt_A} = t_L\frac{dW}{dt_A} + A + t_A\frac{dA}{dt_A} - s\frac{dM}{dt_A} + (t_D - r)\frac{dD}{dt_A} - \frac{dG^P}{dt_A} \tag{A.4}$$

Substituting $K_M = (1 - s - \nu_M)M$ and $K_D = (c_D - \nu_D)D$ (from the zero profit

condition for medical and auto insurance companies) into $I = G^T - K_M - K_D$ and totally differentiating with respect to t_A gives

$$\frac{dI}{dt_A} = \frac{dG^T}{dt_A} - (1 - s - \upsilon_M)\frac{dM}{dt_A} - (c_D - \upsilon_D)\frac{dD}{dt_A} \tag{A.5}$$

Substituting (A.4) and (A.5) in (A.3) and grouping terms gives:

$$\begin{aligned}\tfrac{1}{\lambda}\tfrac{\partial V}{\partial t_A} = -(1-\upsilon_M)\tfrac{dM}{dt_A} - (H_{\overline{D}}mpc + c_D - \upsilon_D - t_D + r)\tfrac{dD}{dt_A} \\ +t_A\tfrac{dA}{dt_A} + t_L\tfrac{dW}{dt_A} + (\tfrac{U_{G^P}}{\lambda} - 1)\tfrac{dG^P}{dt_A}\end{aligned} \tag{A.6}$$

Let us assume that medical services can be expressed as a simple function of alcohol consumption, own drunk driving and the drunk driving of others (as these variables drive medical care demand through their impact on health): $M = M(A, D, \overline{D})$.

Differentiating the expression with respect to t_A gives:

$$\frac{dM}{dt_A} = M_A\frac{dA}{dt_A} + M_D\frac{dD}{dt_A} + M_{\overline{D}}\frac{d\overline{D}}{dt_A} \tag{A.7}$$

In addition we define elasticities as:

$$\eta_{AA} = \frac{dA}{dt_A}\frac{p_A + t_A}{A}; \quad \eta_{DA} = \frac{dD}{dt_A}\frac{p_A + t_A}{D} \tag{A.8}$$

Substituting (A.7) and (A.8) in (A.6) gives, after some manipulation, equation (4.7).

Deriving equation (4.10):
From totally differentiating the government budget constraint (4.3) with respect to t_A,allowing t_L to vary with G^T and G^P fixed using (4.8) gives :

$$\mathrm{d}t_L/dt_A = -\frac{A+t_A\frac{dA}{dt_A}+(t_D-r)\frac{dD}{dt_A}-s\frac{dM}{dt_A}+t_L\left\{w\frac{\partial L}{\partial t_A}+\frac{\partial W}{\partial H}\frac{dH}{dt_A}\right\}}{w\left\{L+t_L\frac{\partial L}{\partial t_L}\right\}} \quad \text{(A.9)}$$

From (A.9) and the first equation in (4.10):

$$t_L w\frac{\partial L}{\partial t_L}\frac{dt_L}{dt_A} = MEGt_L\left\{A+t_A\frac{dA}{dt_A}+(t_D-r)\frac{dD}{dt_A}-s\frac{dM}{dt_A}+t_L\left\{w\frac{\partial L}{\partial t_A}+\frac{\partial W}{\partial H}\frac{dH}{dt_A}\right\}\right. \quad \text{(A.10)}$$

Substituting (4.8) and (A.10) into (4.7), with $dG^T/dt_A = dG^P/dt_A = 0$ gives:

$$\begin{aligned}(E^A-t^A)(-\tfrac{dA}{dt_A})+MEGt_L\left\{A+t_A\tfrac{dA}{dt_A}+(t_D-r)\tfrac{dD}{dt_A}\right\}\\ +(1+MEGt_L)t_L w\tfrac{\partial L}{\partial t_A}+(1+MEGt_L)t_L\tfrac{\partial W}{\partial H}\tfrac{dH}{dt_A}\end{aligned} \quad \text{(A.11)}$$

From the Slutsky equations:

$$\frac{\partial L}{\partial t_A} = \frac{\partial L^C}{\partial t_A}-\frac{\partial L}{\partial I}A; \quad \frac{\partial L}{\partial t_L} = -\frac{\partial L^C}{\partial \widetilde{w}}w-\frac{\partial L}{\partial I}wL \quad \text{(A.12)}$$

where superscript c denotes a compensated coefficient and $\partial L/\partial I$ is the income effect on labor supply.

From the Slutsky symmetry property:

$$\frac{\partial L^C}{\partial t_A} = -\frac{\partial A^C}{\partial t_A} \quad \text{(A.13)}$$

where $\widetilde{w} = (1-t_L)w$ denotes the net of tax wage.

In addition we define elasticities:

$$\epsilon_{LL} = \frac{\partial L^C}{\partial \widetilde{w}}\frac{\widetilde{w}}{L}; \quad \eta^C_{Al} = \frac{\partial A^C}{\partial \widetilde{w}}\frac{\widetilde{w}}{A}; \quad \eta_{LI} = \frac{\partial L}{\partial I}\frac{\widetilde{w}L}{L} \quad \text{(A.14)}$$

Equating (A.11) to zero, and substituting (A.12) and (A.13) gives (4.9), where g^A is defined in (4.10) and elasticities in (A.14).