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# Alcohol availability and alcohol-attributable mortality: Economic implications following a change in sales policy

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## **Abstract**

It is commonly known that irresponsible alcohol use can have adverse effects. For some people it results in health problems, for others in productivity loss, and some experience the worst possible outcome of alcohol misuse: death. This paper estimates the effect of reduced alcohol sales hours on alcohol-attributable mortality (AAM) in Estonia. Using novel mortality data from 1997 to 2015, this paper analyzes the effect of the alcohol sales policy at the county level and at the country level. By applying the difference-in-differences method and the ARIMA model, this paper finds that at the county level, the policy decreased AAM by 1.434 deaths per 100,000 per month, which is a 37% reduction from the average AAM prior to the policy. The country-wide policy reduced AAM on average by 1.563 deaths, which equals to a 39% reduction. These findings suggest that individuals who are the most at risk of dying from alcohol-attributable death causes benefit remarkably from reduced alcohol availability.

**Keywords:** Health policy; Mortality; Public health; Alcohol

**JEL:** I12, I18, H75

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# 1 Introduction and literature

Alcohol is one of the most important risk factors for mortality, accounting for about 5% of all deaths globally (World Health Organization, 2018). The harmful effects of alcohol use have been extensively discussed in the literature. Alcohol consumption and particularly heavy drinking have been causally related to more than 200 causes of death, including 36 for which alcohol is the single causal risk factor (Rehm et al., 2010; Rehm et al., 2009). This paper investigates the latter causes of death, hereinafter referred to as 100% alcohol-attributable mortality (AAM).

In order to address the adverse outcomes of alcohol use mentioned above, a number of alcohol policies have been shown to be cost-effective in reducing alcohol consumption (Babor et al. 2010). One of the World Health Organization's (WHO) "best buy"<sup>1</sup> interventions for harmful alcohol use is restricting access to retail alcohol. By restricting trading hours, impulse purchases are reduced. Multiple analyses have shown that restricting alcohol availability is effective in reducing alcohol use and thus alcohol misuse (Bassols and Castello, 2018; Stockwell et al., 2012; Yakovlev, 2018). Therefore, if limited access to alcohol leads to a decrease in alcohol consumption, we would expect that this would in turn reduce alcohol-related problems and AAM.

Most of the literature on alcohol policies regulating days and hours of alcohol sale analyze extending hours while a minority looks at the effect of restricting them. Dualibi et al. (2007) find that reducing on-premise opening hours leads to a decrease in murders. Hospitalization rates for alcoholic intoxication drop (Marcus and Siedler, 2015; Wicki and Gmel, 2011), and accidents at work decline (Bassols and Castello, 2018) when hours for the sale of alcohol are reduced. On the other hand, extending hours of alcohol sales leads to an increased risk of homicides (Sanchez et al., 2011) and to an increase in traffic accidents and alcohol-related crash fatalities (McMillan and Lapham, 2006). Thus, recent research confirms that regulating trading hours affects adverse outcomes of alcohol use.

This study analyzes the effect of reducing alcohol sales hours in Estonia. Compared to other member states in the EU, Estonia has a remarkably high rate of premature mortality<sup>2</sup>. Of the individuals who died prematurely in Estonia between 1997 and 2015 71.8% were men, and alcohol was involved in a remarkable share of the incidents (Estonian Institute of Economic Research, 2017). In 2015 the Estonian Health Insurance Fund spent €50.3 million on alcohol-related health issues. Spendings on alcohol-attributable health problems accounted for €3.5 million. Moreover, the years of life lost and lost productivity due to alcohol misuse cost the government yearly around 2% of the GDP (€400 million) whereas revenues from the alcohol tax were in 2016 about €250 million (Ministry of Social Affairs, 2017). Thus, alcohol misuse imposes a considerable economic burden in Estonia.

As with many other former Soviet states, Estonia experienced a severe economic crisis accompanied by high overall mortality after the fall of the Soviet Union. The overall mor-

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<sup>1</sup>The "best buys" address noncommunicable diseases (NCD's) in order to reduce the existing burden. Alcohol is one of the four key risk factors for NCD's.

<sup>2</sup>Premature mortality according to the WHO is mortality before the age of 70. However, since life expectancy in Estonia is lower than the EU-average, the premature mortality in this paper is defined as mortality that occurred before a person turned 65.

tality peaked in Estonia in 1994. Since 1997, where the current analysis begins, the overall mortality has seen a constant declining trend. During the same time period (1997-2015), AAM first increased until 2007-2008; since then it has followed a constant declining trend. In terms of the share of AAM in overall mortality (for age group 20-64), the initial share in 1997 was 7.1%. It peaked at 13.8% in 2007. In the following years it dropped and has been fairly constant since 2009 at around 10.8%.

In an effort to reduce the harmful use of alcohol, the Estonian government restricted alcohol sales hours in Tallinn, the capital of Estonia in 2007; one year later this policy was extended to the whole of Estonia. By using mortality data for the period 1997-2015, this paper measures the effect of the policy at the county level and at the country level. For the county-level analysis, the difference-in-differences (DiD) method is applied. At the country level, the effectiveness of the policy is measured by using the ARIMA model. This analysis finds that the alcohol sales policy was effective in reducing AAM at the county level by 1.434 deaths per 100,000 per month, which is a 37% reduction from the average AAM prior to the policy. At the country level, AAM decreased from the initial 4.050 deaths per month by 1.563 deaths, which equals to a 39% reduction. The country-wide policy was most effective for the age group 35-49 years; and men experienced a higher reduction in AAM than women. The effect measured at the county level is comparable in magnitude to the output of the country-wide analysis. This suggests that the population responded to both of the policies to a similar extent.

The strength of this paper is the data used. It is a full set of novel mortality data for a whole country. The data can be exploited to analyze the effect of the alcohol sales policy on a treated group as compared to a non-treated control group at the county level and additionally the data allows us to conduct a time-series analysis at the country level. This paper contributes to the literature in two ways. First, to analyze the effects of the alcohol sales policy this paper analyzes exclusively 100% AAM. By doing so, the measurement error of the policy effect is minimized and the most straightforward adverse outcome of alcohol use is analyzed. Moreover, as most papers look at single adverse outcomes of alcohol misuse (hospitalization, injuries) or at selected groups of alcohol-related deaths (traffic fatalities, homicides, suicides), this paper presents a more sophisticated view on the effects of policies regulating alcohol availability. By looking exclusively at death causes that are by definition to 100% attributable to alcohol misuse, we measure the responsiveness of the most vulnerable population group dying from alcohol misuse to such policies. Second, this paper offers new insights into the effect of reducing alcohol sales hours. There are only a few papers which have analyzed the effect of a reduction of sales hours. Most of the alcohol sales hours literature looks at the effect of extending the hours and the outcomes vary strongly depending on the setting and the magnitude of the extension. As some authors show, the implementation, change or the removal of a policy does not always lead to the outcomes expected under the assumption of *ceteris paribus* (Bénabou and Tirole, 2006; Gneezy and Rustichini, 2000). This counterintuitive effect to the outcome expected can potentially be influenced by individuals' preferences, beliefs, and perceptions (Gneezy and Rustichini, 2000), and by the lasting impact of the existing policy at the time of policy modification (Bruttel and Friehe, 2014). Thus, the well-documented effect of extending alcohol sales hours cannot be directly transferred to a policy reducing sales hours and thus, this paper will contribute to filling this gap in research.

The paper is organized as follows: The next Section describes the data and outlines the empirical strategy. The results are presented in Section 3. Section 4 discusses the robustness of the main outcomes. Finally, Section 5 discusses avenues for future research and conclusions.

## 2 Data and empirical strategy

### 2.1 Data

A full sample of administrative mortality data were accessed through the Estonian National Institute for Health Development. The confidential mortality data cover the period 1997-2015 and contain every death in Estonia. The data contain information on the underlying cause of death, the exact date of death and demographic information of the deceased, e.g. age, sex, county of residence, county of death, nationality. The mortality data are coded according to the 10<sup>th</sup> revision of the WHO's International Classification of Diseases (ICD-10) (World Health Organization, 1992).

The data set contains 327,034 individual observations. Of these, 11,532 observations (3.53%) are 100% AAM. Due to one outlier this number is adjusted by eliminating 57 AAM cases. In September 2001 Estonia was hit by a methanol tragedy that took place in Pärnu county, leading to an increased rate of AAM in this month. Since this incident is a one-time outlier with great magnitude, the identified methanol-deaths were excluded from the analysis. The AAM is the main variable of interest. It is constructed by including in total 36 causes of death (**Appendix A1**) that can be fully attributed to alcohol use. By using this variable the direct adverse effect of alcohol consumption is captured and thus the effectiveness of the alcohol sales policies can be evaluated. In Section 4 the robustness of the results based on analyzing AAM are verified by changing the dependent variable. The findings show that AAM is a good measure to analyze the effectiveness of the sales policy. The analyses in this study are based on aggregated monthly AAM per 100,000 population. The population data for each year was obtained from Statistics Estonia (Statistics Estonia, 2019) and was used to calculate the mortality rates per 100,000 throughout the whole analysis.

The alcohol sales policy was first implemented in the capital city of Tallinn ("county-level policy"), in Harju County. From August 1, 2007, off-premises alcohol sales were prohibited from 8 p.m. to 8 a.m. Since the mortality data is at county level, the effect of the Tallinn policy can only be measured at county level. Thus, the Harju County indicators are compared with the indicators of Tallinn city (**Appendix A2**), and as they are nearly identical, Harju County can be used to analyze the effectiveness of the Tallinn policy. On July 14, 2008, the policy was extended to the whole of Estonia ("country-wide policy") and since then alcohol off-premise sales are prohibited nationwide between 10 p.m. and 10 a.m. The data set suits well for the analysis of these policies as it covers 10 years prior to the Tallinn policy and 7 years after the nationwide policy was implemented.

To capture the economic developments in Estonia, the data for macroeconomic indicators were obtained from Statistics Estonia (Statistics Estonia, 2019). These include the chained-Euro value of GDP per capita<sup>3</sup>, the unemployment rate as the share of the unemployed in the labor force, and the Consumer Price Index (CPI) for alcohol (1997=100, monthly data) that expresses the change in the prices of alcoholic beverages.

## 2.2 Empirical strategy

To increase the explanatory power of this analysis, two different empirical strategies are applied. The county-level alcohol sales policy is evaluated using the DiD method; the country-wide policy is analyzed using the ARIMA analysis. Both results are verified for robustness in Section 4.

### *The county-level policy*

The alcohol sales policy was first introduced in Tallinn, and almost a year later implemented in all of Estonia<sup>4</sup>. This setting provides us with a treatment group (Harju County) and a control group (the rest of Estonia). In this analysis, the timeframe between 1/1997 and 6/2008 is observed, because the country-wide policy was implemented in 7/2008 and therefore a DiD-analysis cannot be performed after this date. Thus, we have a full 11 months of treatment that can be analyzed. Using a DiD approach, we compare the outcomes of AAM in Harju County to those in the rest of Estonia before and after the policy was implemented.

The underlying empirical model for the main DiD analysis is:

$$AAM_{s,t} = \beta_0 + \beta_1 Tallinn_{s,t} + \beta_2 Policy_{s,t} + \beta_3 (Tallinn_{s,t} \times Policy_{s,t}) + \beta_4 X_{s,t} + \varepsilon_{s,t}, \quad (1)$$

where  $AAM$  is the monthly 100% alcohol-attributable mortality in county  $s$  ( $s=1$  if Harju County;  $s=0$  if rest of Estonia) in time period  $t$ .  $Tallinn$  and  $Policy$  are dummy variables equal to 1 for Harju County, i.e. Tallinn;  $Policy$  is equal 1 for the period the policy was valid.  $X_{s,t}$  includes covariates, i.e. the chained-euro value of GDP per capita and unemployment rate as the share of the unemployed in the labor force, to capture economic conditions that could influence the AAM trend. The error term is  $\varepsilon_{s,t}$ .

The main outcome of interest is the DiD coefficient  $\beta_3$ . It provides information on the treatment effect of the alcohol sales policy, i.e. it measures the difference between the change in AAM in Harju County and the change in AAM in the rest of Estonia. If the parallel trends assumption holds, then Harju and the rest of Estonia would have experienced the same mean time trend in AAM if the policy would not have been implemented

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<sup>3</sup>The chained-Euro value of GDP is calculated by setting real GDP "equal to nominal GDP in some base year and then "chaining" forward and backward from the base year using these growth rates. Estimates of real GDP growth from this chain aggregation method never have to rely on potentially irrelevant price structures that prevailed many years before or after the period in question; they also have the great advantage of being independent of the choice of base year" (Whelan 2000)

<sup>4</sup>As mentioned above, the effect of Tallinn policy is measured at the county level.

(Garlick, 2018). If the assumption is violated, it can lead to biased estimation of the policy effect. The visual test (**Figure B2**) approaches point to reasonable evidence that the parallel trend holds. This outcome provides support for the DiD analysis.

### *The country-wide policy*

For the purpose of measuring the effect of the country-wide policy, the ARIMA method is applied. This method combines autoregressive (*AR*) as well as moving average (*MA*) processes and includes the integrate (*I*) process of the data, i.e. differentiating the data in order to make the time-series data stationary (Box et al., 2015). Stationarity of the data is central since stationary data is adjusted for any underlying trends, i.e. the time series data has a constant variance and mean over time. Since the raw data is not stationary, stationarity is achieved through differentiation of the data. With the help of a visual examination of a correlogram and with the Dickey-Fuller unit root test, it can be confirmed that the differenced data is stationary. A partial correlogram, differentiation of the dependent variable and a correlogram were used to identify the ARIMA model which best fits the data. The model fit was evaluated using the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). For each sub-group the ARIMA was tested separately to find the best fit.

The main ARIMA analysis is based on the following specification:

$$AAM_t = \beta_0 + \beta_1 EstPolicy_t + \beta_2 TlnPolicy_t + \beta_3 CPI_t + \beta_4 GDP_t + \beta_5 unempl_t + \varepsilon_t, \quad (2)$$

where  $AAM_t$  is the monthly 100% alcohol-attributable mortality at time  $t$ . The variable  $EstPolicy_t$  is a dummy variable equal to 1 if the country-wide policy is in effect;  $TlnPolicy_t$  is equal to 1 if the county-level policy is effective. In order to account for economic developments in Estonia during the period observed, the chained-euro value of GDP per capita ( $GDP_t$ ) and the unemployment rate ( $unempl_t$ ) are used. Additionally, to control for the change in alcohol prices, the Consumer Price Index ( $CPI_t$ ) for alcohol is included. The error term is represented by  $\varepsilon_t$ .

## 3 Results

In Section 3.1 the effect of the county-level policy is analyzed by using the DiD approach. Section 3.2 presents the findings for the country-wide policy effect based on the ARIMA analysis.

### 3.1 Policy effect at the county level

As described above, the effect of the county-level policy is best evaluated with the DiD-method. After the policy was implemented in Tallinn city, AAM in Harju County experienced an increase in the first few months. Since the residents of Tallinn anticipated

that they might not be able to buy alcohol spontaneously in the evenings, this may have led to an increase in alcohol hoarding at home. As Estonians prefer to drink alcohol at home already<sup>5</sup>, the increased alcohol availability at home might have led to increased consumption and, thus, to an increase in AAM. This assumption is supported by the data on the frequency of alcohol consumption in the recent 12 months between 2004 and 2014 (Statistics Estonia, 2019). All areas except for North Estonia experienced a drop in the frequency of alcohol consumption among men between 2006 and 2008. In 2008, men in North Estonia consumed alcohol more frequently per week than they had in the years before. The data on consumption frequency among women is not as clear.

Table 1: The effect of county-level policy 1997m1-2008m6

	AAM per 100,000 per month
Tallinn	-1.614*** (0.261)
Policy	1.211*** (0.321)
Tallinn*Policy	-1.434*** (0.434)
GDP	0.000254*** (0.0000377)
Unemployment rate	0.0714** (0.0319)
Observations	276
Standard errors in parentheses	
* $p < 0.10$ , ** $p < 0.05$ , *** $p < 0.01$	

The outcomes in **Table 1** show that the Tallinn policy was effective in reducing AAM in Harju County. Prior to the policy mean AAM was 3.906 deaths per 100,000 per month. After the introduction of the policy, AAM in Harju was 1.434 deaths lower than it would have been without the policy. Thus, the alcohol sales restriction was effective in reducing AAM by 37% at county level. The coefficients, although rather small, are statistically significant and indicate that an increase in GDP and a rise in unemployment have both increasing impact on AAM.

### 3.2 Policy effect at the country level

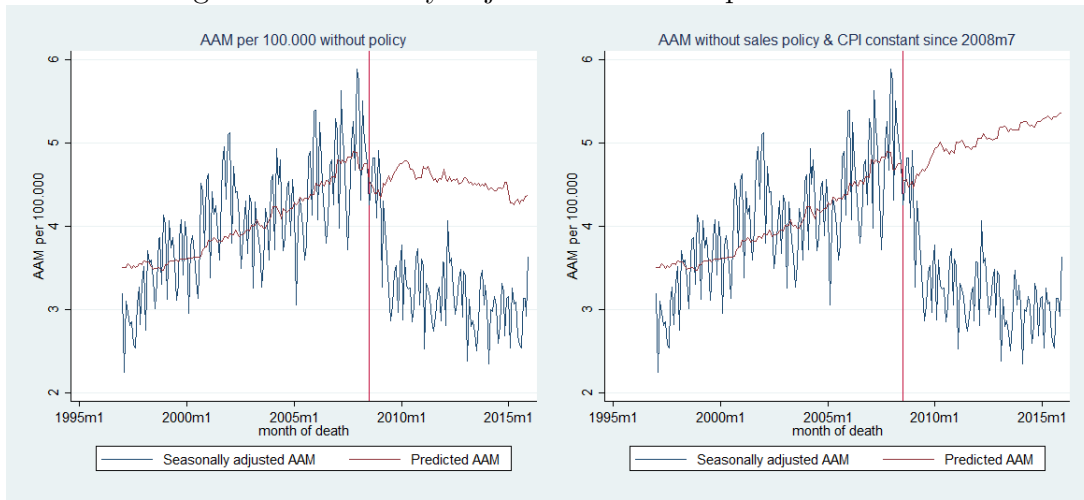
This section presents the main outcomes of the country-wide alcohol sales policy on AAM. **Figure 1** shows seasonally adjusted AAM and predicted AAM. In this figure we clearly see how AAM would have developed if the policy had not been implemented. The graph on the left predicts AAM from July 2008 onwards, while keeping the policy dummy at zero. It is evident that without the policy (red vertical line) AAM would have been much higher with a slightly falling trend. The graph on the right predicts AAM from July

<sup>5</sup>In the Nordic countries—such as Estonia, Latvia, Lithuania—about 90% of beer consumption is at home, while in Southern Europe more than 60% is in bars (Lifelong Learning Programme).



2008 onwards, while keeping the policy dummy at zero and the CPI of alcohol constant. During the period observed, the alcohol prices were increased multiple times. By keeping the CPI of alcohol constant, we control for the effect of increasing alcohol prices on AAM as we would expect change in alcohol prices to have an effect on AAM. This assumption is verified in the graph on the right in **Figure 1**. We see that if the CPI of alcohol had not been increased after July 2008, AAM would have been even higher and had a steeper upward trend. The essence of this observation is that visually it seems the policy had an effect on AAM, and the effect was amplified due to a constant increase in alcohol prices. In the following section, the effect of the alcohol sales policy is quantified.

Figure 1: Seasonally adjusted AAM and predicted AAM



Source: Author's own calculation

### 3.2.1 The effect of reduced alcohol availability on AAM

**Table 2** shows the estimates of the effect of alcohol sales regulation on AAM using the ARIMA method, while accounting for underlying trends, seasonality and additional economic indicators. The main finding is that restricting alcohol availability reduced AAM on average by 1.563 deaths per 100,000 population per month. The average AAM prior to the policy was 4.050 deaths, thus AAM was reduced by 39%. The magnitude of this effect is comparable with the findings of other authors. Kypri et al. (2011) found that restricting pub closing times in an Australian city led to a 37% decrease in police-recorded assaults and that this outcome was long-lasting and still observable 5 years later (Kypri et al., 2014). A similar result was found by Wicki and Gmel (2011) who found that a reduction in off-premise sales hours in the canton of Geneva in Switzerland led to a decrease in hospitalization rates for alcoholic intoxication by 25-40%, depending on the demographic group analyzed. Thus, the magnitude of the effect of the alcohol sales policy in Estonia has also been found by other authors in similar settings.

Furthermore, **Table 2** provides information on the effect of the CPI of alcohol on AAM. The CPI has a significant effect of reducing AAM on average by 0.01 deaths per 100,000 population per month. This is an important insight into the effects of alcohol policies on

Table 2: The effect of country-wide policy (AAM per 100,000)

	ARIMA
EstPolicy	-1.563*** (0.349)
TlnPolicy	0.448 (0.282)
CPI	0.00119 (0.0102)
GDP	0.000419*** (0.000117)
Unemployment rate	0.0886*** (0.0327)
Observations	216
Standard errors in parentheses	
* $p < 0.10$ , ** $p < 0.05$ , *** $p < 0.01$	

AAM in Estonia—according to the outcomes, both alcohol sales regulation and increasing alcohol prices reduce AAM. An additional finding is the positive effect of the GDP on AAM. When GDP increases, and thus the economic situation in the country improves, AAM experiences an increase as well (**Table 2**). This could be interpreted as improved financial situation of individuals leads to an increased consumption of alcohol, and thus to an increase in harmful alcohol use.

Yet, the ARIMA analysis is not suitable for all cases. For instance, it finds the Tallinn policy (*TlnPolicy*) had no statistically significant effect on AAM (**Table 2**). This could be accurate, however there are other potential reasons for the insignificance. First, in the ARIMA analysis the effect of a country-wide policy was measured. Thus, it could be that the effect of the local policy (Tallinn policy) was not strong enough to influence the mortality at the country level. Moreover, due to the specific nature of the Harju data, the ARIMA approach is not suitable to evaluate the effect of the local policy; more specifically, the number of observations within the timeframe is too small as the Tallinn policy was effective during an 11-month period. At this time mortality fluctuated strongly, which could be traced back to hoarding behavior of alcohol consumers in Tallinn, as discussed earlier.

The following two heterogeneity analyses provide a more detailed view of the policy effectiveness. Since different age groups, but also males and females, respond differently to alcohol policies, these population sub-groups will be analyzed separately.

### 3.2.2 Heterogeneity analysis: by age group

In order to cover most of the active labor force in Estonia, this age group analysis is limited to the following groups: 20-34, 35-49, 50-64 years. **Appendix A3** reports the mean AAM per age group before both of the policies were implemented, during the Tallinn pol-

icy and after the Estonia-wide policy was in effect. For the period that the Tallinn policy was in effect, AAM decreased for the age groups 20-34 and 35-49, whereas it increased for the oldest age group. However, after the implementation of the Estonia-wide policy, the AAM is lower for all age groups as compared to the pre-policy timeframe.

Table 3: The effect of country-wide policy by age group (AAM per 100,000 population within the age group)

	Age 20-34	Age 35-49	Age 50-64
EstPolicy	-0.213 (0.389)	-3.706*** (0.879)	-2.634** (1.203)
TlnPolicy	-0.192 (0.349)	-0.519 (0.632)	2.529*** (0.853)
CPI	-0.00474 (0.00497)	0.0714** (0.0298)	-0.0939** (0.0369)
GDP	0.0000489* (0.0000269)	0.00102*** (0.000346)	0.000594 (0.000447)
Unemployment rate	0.0340* (0.0200)	0.338*** (0.0882)	-0.0472 (0.111)
Observations	228	216	216

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table 3** reports the estimated effects of the alcohol sales policies and other economic variables on AAM by age group. The youngest age group (20-34 years) had no statistically significant outcomes. However, the insignificance most likely results from the number of monthly alcohol-attributable deaths which is too small within this age group. Moreover, due to the low number of alcohol-attributable deaths, the data could not be seasonally adjusted. Thus, the number of observations is higher for this age group. And yet, although the outcomes are statistically not significant, the effect of the Tallinn policy as well as the country-wide policy is negative.

The country-wide policy was most effective for the age group 35-49 years. It reduced monthly AAM within this group by 3.706 deaths, which is equal to a reduction of 54.9% of the initial mean AAM prior to the country-wide policy<sup>6</sup>. The outcome is statistically significant at the 1% level. Moreover, this age group is vulnerable to an increase in unemployment. Higher unemployment increases the mortality attributable to alcohol.

The outcomes for the oldest age group (50-64 years) provide us with further compelling insights into the responsiveness of the sub-groups to the policies. While the Estonia-wide policy decreased AAM by 2.634 deaths per month, which is equal to a reduction by 26.3%, the initial Tallinn policy had the opposite effect. It increased the mortality within this age group by 2.529 deaths. Nonetheless, the long-term effect of the Estonia-wide policy is significant at the 5% level and negative. Additionally, this age group (50-64 years) is also

<sup>6</sup>If we observe only the time prior to the Tallinn policy, then the country-wide policy reduced AAM within the age groups 20-34, 35-49 and 50-64 by 20.9%, 54.9% and 26.3%, respectively.

responsive to an increase in alcohol price. An increase in the CPI by one unit decreases AAM in this age group by 0.09 deaths per 100,000 per month.

### 3.2.3 Heterogeneity analysis: by sex

Table 4: The effect of sales policy by sex per 100.000 population within the sex

	Male	Female
EstPolicy	-2.504*** (0.577)	-0.731** (0.299)
TlnPolicy	0.776* (0.447)	0.197 (0.182)
CPI	0.0131 (0.0188)	-0.0116 (0.00846)
GDP	0.000799*** (0.000225)	0.0000612 (0.000109)
Unemployment rate	0.140** (0.0639)	0.0386 (0.0243)
Observations	216	216

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

When analyzing the AAM of the male and female population separately, we see that the policy was successful in reducing AAM for both sexes (**Table 4**). Among men, AAM was reduced by 2.504 deaths per 100,000 males per month. For females, the reduction was 0.731 deaths. Both outcomes are statistically significant. Considering the initial AAM per month, i.e. 6.538 among men and 1.946 among women, the scope of the policy's effectiveness becomes clearer. More precisely, in absolute numbers, men experienced a larger decrease in AAM; however, in relative terms, both sexes experienced approximately the same decrease in AAM.

To sum up, the effect measured with the DiD-analysis (-1.434) is comparable to the output of the ARIMA analysis (-1.563) in its magnitude, and both outcomes are statistically significant. These two outcomes indicate that reducing alcohol sales hours affects Estonians throughout the whole country to a similar extent. The heterogeneity analyses gave an additional insight into the responsiveness of the sub-groups to the policy. Thus, a reduction in alcohol sales hours has a significant and long-lasting negative effect on AAM. Therefore, it can be stated that the policy of restricting alcohol sales hours was effective in Estonia. Both the DiD method and the ARIMA analysis showed that the population reacted to both policies to a similar extent. In the next section the robustness of the outcomes will be tested.

## 4 Robustness checks

The robustness of the county-level and country-wide outcomes are tested in this section by performing several placebo tests and sensitivity analyses.

### 4.1 Robustness check: the county-level policy

A placebo policy is created a year prior to the real county-level policy to verify the results from **Section 3.1**. The results are presented in **Table 5**. The effect of the real policy on AAM is strong and significant (-1.280), whereas the placebo policy is not significant. This is the outcome we would expect in the event that the real policy was the underlying cause for the reduction in AAM.

Another way to verify the outcomes is to test the effect of the county-level policy on death causes that are not related to alcohol consumption. If we expect that the alcohol sales policy only has an effect on alcohol-attributable and alcohol-related death causes, there should be no effect of such a policy on death causes that are not related to alcohol ("non-alcohol mortality (NAM)"). The NAM variable is constructed by subtracting all alcohol-attributable and alcohol-related death causes (Rehm et al., 2017) from the overall mortality. Thus, what is left are death causes that are not related to alcohol consumption. NAM follows a continuous downward trend over the whole period whereas AAM has an increasing trend before the policy was implemented and reversed once the policy was implemented (**Figure B3**).

Now a quantitative analysis of the policy effect on NAM can be conducted. In **Table 5**, we see the effect of the county-level policy on AAM and NAM. Whereas the policy has a statistically significant effect on AAM<sup>7</sup>, the effect on NAM is not significant and has the opposite sign.

### 4.2 Robustness check: the country-wide policy

We begin with a visual verification of the country-wide policy effect. In **Figure 2**, the Regression Discontinuity Design (RDD) is applied to AAM. RDD is mainly used to estimate treatment effects in nonexperimental settings (Lee and Lemieux, 2010). Here, we only use the graphical presentation of the RDD approach as it is informative and helpful to underpin the aforementioned argument that only the real policy should have an effect on AAM. The left graph in **Figure 2** represents placebo policy two years prior to the real policy and the right graph is the real country-wide policy with cut-offs in 2006m7 and 2008m7, respectively. As one year before the country-wide policy the county-level policy was implemented, and it could distort the interpretation of the placebo policy, the placebo policy was selected to be two years prior to the real policy implementation. As expected, we see no structural discontinuity in the left graph, as the placebo policy

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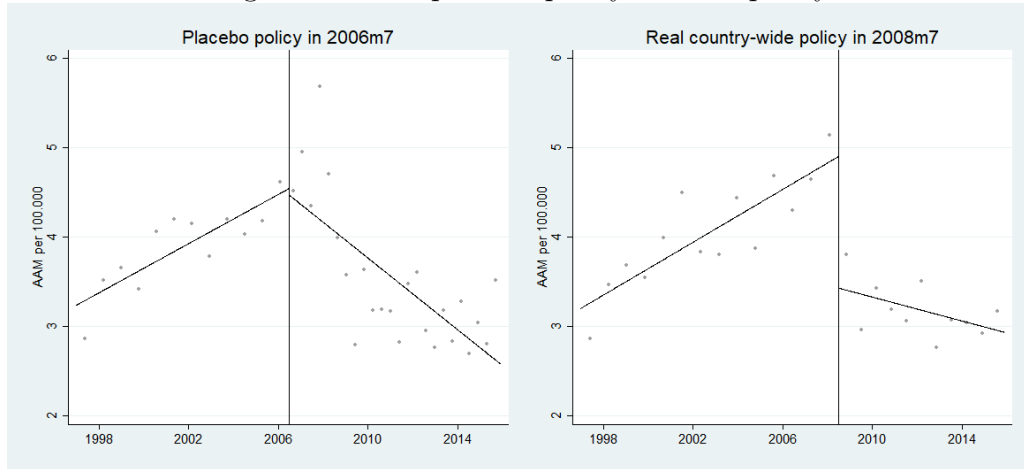
<sup>7</sup>Here, the effect of the policy on AAM differs slightly from the outcome in Section 3.2, because a different timeframe was used. In all previous tests the analysis started in 1997, however in this sensitivity test the analysis could only be conducted for data starting from 2001. This however does not influence the interpretation of the outcomes in **Table 5**.

Table 5: Robustness check of the outcomes

County-level policy (DiD analysis)			
Placebo test		Sensitivity analysis	
Real policy	-1.280***	AAM	-1.022**
Placebo policy	-0.201	NAM	2.439
Country-wide policy (ARIMA analysis)			
Placebo test		Sensitivity analysis	
Real policy	-1.586***	AAM	-1.118***
Placebo policy	-0.262	NAM	-3.783*

has no effect on AAM. In contrast, in the right graph the discontinuity is very apparent. Thus, it can be concluded that while the placebo policy has no effect, the AAM experienced a structural break during the time as the real country-wide policy was implemented.

Figure 2: RDD placebo policy vs. real policy



Next, the effect of the placebo policy can be tested empirically. In **Table 5**, it is evident that the real policy has a highly significant effect on AAM while the placebo policy has no effect at all. Thus, the visual observation in **Figure 2** is supported by the empirical findings. As an intermediate conclusion, it may be noticed that only the real policies had a significant effect on AAM whereas the placebo policies were ineffective (**Table 5**).

Finally, the effect of the country-wide policy can be tested on NAM. **Table 5** shows that the effect on NAM is significant at the 10% level. Although the reduction in NAM seems to be larger than the reduction in AAM, this is misleading as the mean AAM is in absolute numbers much smaller. While the mean AAM prior to the country-wide policy was 4.050 per 100,000, the mean NAM was 68.764 deaths per month. Thus, AAM decreased

by 28% while NAM decreased by 6% during that period. Therefore, the outcomes for AAM and NAM in **Table 5** are not directly comparable.

This paper has a number of potential limitations that will be addressed now. One limitation is that something else may have happened in Estonia when the policy was implemented and this could have caused the drop in AAM. To the best of my knowledge this can be ruled out. Although Estonia suffered a financial crisis within this timeframe, this is taken account for via GDP and unemployment. Moreover, during the financial crisis in the mid-90's AAM increased in Estonia. Thus, if any impact, we would rather expect an increase in AAM and not the observed decrease. Further, one might argue that the strong drop in AAM could be due to changed data collection methods. This can be ruled out as well, as death is a straightforward outcome and during the whole period of this analysis there was no switch in ICD-versions. Additionally, the data is a full set. Thus, as we have the exact outcome, we do not have to estimate anything and therefore the results are considered to be accurate. Also, analyzing the data for a whole country is a benefit as most papers analyze often parts of a country or at regional level.

The above-mentioned potential problems should be taken into account for such an analysis, but they do not apply to this paper. In particular, all the outcomes were verified with robustness tests and sensitivity analyses. These tests addressed the potential limitations and confirmed the robustness of the outcomes. Furthermore, it can be speculated that besides a direct effect on AAM, the policy had also an effect on alcohol-related mortality and overall morbidity in Estonia. Thus, the genuine effect of the alcohol sales policy is probably underestimated.

## 5 Discussion and conclusion

Alcohol use, especially alcohol misuse, and its adverse outcomes, present substantial problems for the economy and society, and thus it poses a major challenge for policy-makers. Using a full sample of mortality data, this study analyzes the effect of reducing alcohol sales hours on AAM.

Since the Estonian alcohol sales policy was first introduced at the county-level, and expanded a year later to the whole country, this study applies the DiD method for the initial policy and the ARIMA method to investigate the causal effect of the policy at the country level. The findings of this paper support other literature that reducing alcohol availability has a negative effect on adverse outcomes of alcohol use. The estimates at both county- and country levels suggest that reducing alcohol sales hours is effective in reducing AAM in Estonia.

At the county level, the evidence suggests that AAM was reduced by 1.434 deaths per 100,000 population in the treated area compared to the control area. At the country level AAM was reduced by 1.563 deaths per 100,000 population per month, i.e. by 39%. It was most effective for the age group 35-49. Furthermore, the male population was most

responsive to the policy; however, the relative drop in AAM for male and female populations was approximately the same.

As for policy implications, the results of this paper give the following insights. First, alcohol sales regulation, and thus reduced alcohol availability, is an effective policy to reduce AAM. It has a protective effect on the male population and the older age groups, and the effect is long-lasting. Moreover, these findings suggest a very clear implication for public health: a reduction by 39% in monthly AAM per 100,000 population is, especially for Estonia, a very big impact as it reduces the years of life lost, productivity loss is reduced and less taxes are spent on alcohol-attributable and alcohol-related health problems.

One topic for future research would be to analyze the effect of alcohol sales policy on different types of alcohol consumers; more precisely, to analyze whether the main risk-groups, e.g. binge drinkers, alcohol addicts, youths, middle-aged men, are responsive to this policy and to what extent. Estonia is still a relatively under-researched area. There is much to discover, and the findings are relevant not only for Estonia, but for the whole Baltic region and potentially for other former Soviet states as well. Thus, there is a lot more that could potentially be achieved by future research.



## 6 Appendix

### A Tables

Table A1: 100% alcohol-attributable causes of death

ICD 10	Description
E24.4	Alcohol-induced pseudo-Cushing's syndrome
F10	Mental and behavioural disorders due to use of alcohol
F10.0	Acute intoxication
F10.1	Harmful use
F10.2	Dependence syndrome
F10.3	Withdrawal state
F10.4	Withdrawal state with delirium
F10.5	Psychotic disorder
F10.6	Amnesic syndrome
F10.7	Residual and late-onset psychotic disorder
F10.8	Other mental and behavioural disorders
F10.9	Unspecified mental and behavioural disorder
G31.2	Degeneration of nervous system due to alcohol
G62.1	Alcoholic polyneuropathy
G72.1	Alcoholic myopathy
I42.6	Alcoholic cardiomyopathy
K29.2	Alcoholic gastritis
K70	Alcoholic liver disease
K70.0	Alcoholic fatty liver
K70.1	Alcoholic hepatitis
K70.2	Alcoholic fibrosis and sclerosis of liver
K70.3	Alcoholic cirrhosis of liver
K70.4	Alcoholic hepatic failure
K70.9	Alcoholic liver disease, unspecified
K85.2	Alcohol-induced acute pancreatitis
K86.0	Alcohol-induced chronic pancreatitis
R78.0	Finding of alcohol in blood
T51	Toxic effect of alcohol
T51.0	Ethanol
T51.1	Methanol
T51.8	Other alcohols
T51.9	Alcohol unspecified
X45	Accidental poisoning by and exposure to alcohol
X65	Intentional self-poisoning by and exposure to alcohol
Y15	Poisoning by and exposure to alcohol, undetermined intent
Y90	Evidence of alcohol involvement determined by blood alcohol level

Selection based on Rehm et al. (2010)

Table A2: Harju County vs. Tallinn city, 2008

	Harju County	Tallinn city
Mean annual population	549,950	397,100
GDP per capita, euros	17,750	20,423
male-female ratio	0.85	0.82
20-24 y.o. ratio on total county/city population	0.08	0.09
25-29 y.o. ratio on total county/city population	0.08	0.08
30-34 y.o. ratio on total county/city population	0.08	0.08
35-39 y.o. ratio on total county/city population	0.07	0.07
40-44 y.o. ratio on total county/city population	0.06	0.06
45-49 y.o. ratio on total county/city population	0.07	0.07
50-54 y.o. ratio on total county/city population	0.07	0.07
55-59 y.o. ratio on total county/city population	0.06	0.07
60-64 y.o. ratio on total county/city population	0.05	0.05
Unemployment rate	4.4	4.4
Employment rate (age group 20-64)	81.5	81.2
Number of alcohol sales licences per 1000 inhabitants	4	4.1

Table A3: Mean AAM per 100.000 population within the age group

	No policies 1997m1-2007m7	Tallinn-policy 2007m8-2008m6	Estonia-wide policy 2008m7-2015m12
Age group 20-34	1.020	0.823	0.573
Age group 35-49	6.750	6.718	3.865
Age group 50-64	9.999	14.38	8.418
<i>N</i> months	127	11	90

## B Figures

Figure B1: AAM within age group 50-64, per 100,000

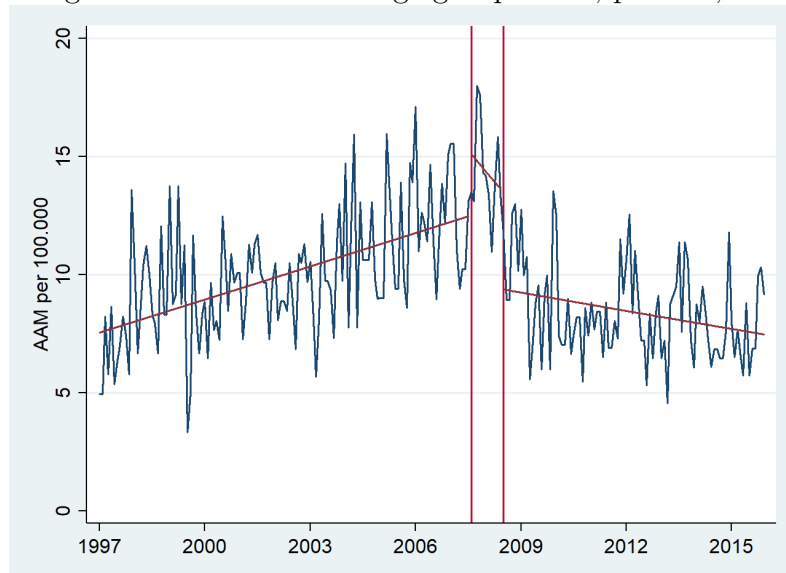


Figure B2: Visual verification of the parallel trends assumption

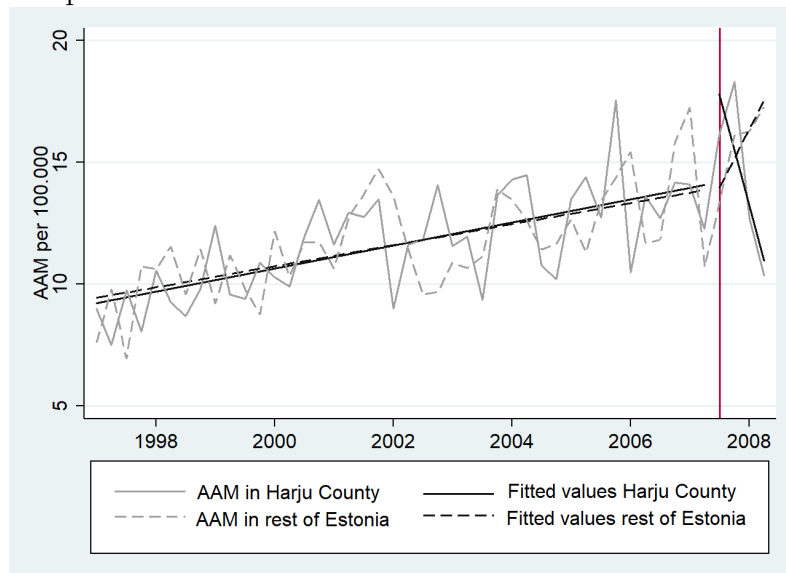
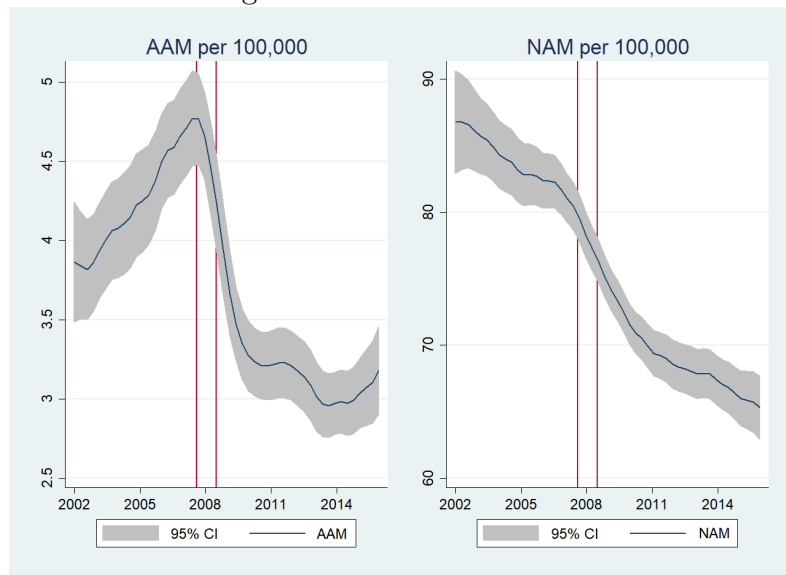


Figure B3: AAM and NAM



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