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Effects of minimum unit pricing for alcohol in South Africa across different drinker groups and wealth quintiles: a modelling study

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ABSTRACT

Objectives To quantify the potential impact of minimum unit pricing (MUP) for alcohol on alcohol consumption, spending and health in South Africa. We provide these estimates disaggregated by different drinker groups and wealth quintiles.

Design We developed an epidemiological policy appraisal model to estimate the effects of MUP across sex, drinker groups (moderate, occasional binge, heavy) and wealth quintiles. Stakeholder interviews and workshops informed model development and ensured policy relevance.

Setting South African drinking population aged 15+.

Participants The population (aged 15+) of South Africa in 2018 stratified by drinking group and wealth quintiles, with a model time horizon of 20 years.

Main outcome measures Change in standard drinks (SDs) (12 g of ethanol) consumed, weekly spend on alcohol, annual number of cases and deaths for five alcohol-related health conditions (HIV, intentional injury, road injury, liver cirrhosis and breast cancer), reported by drinker groups and wealth quintile.

Results We estimate an MUP of R10 per SD would lead to an immediate reduction in consumption of 4.40% (−0.93 SD/week) and an increase in spend of 18.09%. The absolute reduction is greatest for heavy drinkers (−1.48 SD/week), followed by occasional binge drinkers (−0.41 SD/week) and moderate drinkers (−0.40 SD/week). Over 20 years, we estimate 20 585 fewer deaths and 900 332 cases averted across the five health-modelled harms. Poorer drinkers would see greater impacts from the policy (consumption: −7.75% in the poorest quintile, −3.19% in richest quintile). Among the heavy drinkers, 85% of the cases averted and 86% of the lives saved accrue to the bottom three wealth quintiles.

Conclusions We estimate that MUP would reduce alcohol consumption in South Africa, improving health outcomes while raising retail and tax revenue. Consumption and harm reductions would be greater in poorer groups.

Strengths and limitations of this study

- ► This study presents the first epidemiological policy appraisal model of a minimum unit price applied to South Africa. Previous similar modelling work has been limited to high-income countries.
- ► Our model provides equity-relevant information by presenting results disaggregated by wealth quintiles, allowing for a more nuanced consideration of the potential impact of the policy.
- ► Our model has also benefited from a thorough programme of stakeholder engagement ensuring contextual and policy relevance.
- ► A key limitation is the alcohol pricing data, which is drawn from a relatively small sample in one locality. Further research would benefit from improved pricing data, specifically the different prices paid for alcohol by different population groups.
- ► Second, the model has not explored the financial impact on the poorest groups beyond increased alcohol expenditure. Further research should include exploration of broader financial benefits such as reduced private expenditure on healthcare or improved labour market outcomes.

BACKGROUND

In South Africa (SA), there are high levels of reported abstinence coupled with high levels of binge drinking among those who do drink, resulting in significant levels of alcohol-related harm.[1] This harm is not distributed evenly throughout society with the lower socioeconomic groups experiencing higher levels of harm, particularly for infectious diseases such as HIV.[2] The periodic prohibition of alcohol during the COVID-19 lockdown demonstrates political leaders' acceptance that alcohol causes harm to SA and signals a potential willingness to take strong action.[3] Provincial governments, such as the Western Cape, are considering a number of alcohol policy approaches, including the introduction of minimum unit pricing (MUP).[4]

MUP is a policy whereby a legal floor price is introduced, below which a fixed volume of ethanol cannot be sold to the public. It has already been introduced in several areas, which experience high levels of alcohol harm, including Scotland and Australia's Northern Territory. Evidence suggests that MUP has been effective at reducing alcohol consumption, particularly among the heaviest drinkers, as they commonly drink the very cheap alcohol targeted by this policy.[5 6]

A limitation of transferring the current evidence for MUP is its focus on high-income countries. Transferring this evidence to SA would be problematic as it has very different drinking patterns, a very different harm profile with infectious disease and injury contributing significantly to the burden of alcohol, it has an informal sector, which is challenging to capture and it has very high levels of income inequality likely to result in differential baseline prices and price responsiveness.

The current alcohol landscape is rooted in the country's recent political history. In 1926, apartheid legislation prohibited African and Indian access to licensed premises or employment by licence holders. As a result, when the democratically elected government took power in 1994 they inherited a significant number of shebeens. Shebeens are (largely) unlicensed bars or pubs, found in townships, often open late and with a reputation for violence and risky sexual behaviour. Homebrew (mainly beer made from sorghum or other ingredients such as pineapple) can be purchased from shebeens along with other types of branded alcohol supplied by large alcohol manufacturers and mainly distributed through larger licensed outlets using bulk discounts. Although beer is the most popular drink, the consumption of large quantities of cheap wine is also prevalent and can be linked back to farm labourers being paid in cheap wine.[7]

The South African government currently use alcohol excise tax to compensate for some of the social costs they attribute to alcohol consumption.[8 9] The system is based on targets for the proportion of the price that constitutes tax (excise tax plus value-added tax (VAT)). This varies by drink type with wine lowest followed by beer then spirits. The government has indicated a willingness to innovate and pursue public health improvements via fiscal policy with the introduction of a sugar tax in 2018. However, in a country with high levels of socioeconomic inequality, there are concerns regarding possible financial impact of pricing policies on the poorest groups.[10] Evidence on public health pricing policies often fails to consider distributional impact by income-groups.[11]

When designing public health economic models for unique policy contexts, ongoing engagement with local stakeholders is essential. The purpose of engagement is twofold: to shape the direction of the research using expert local knowledge (including understanding the problem, guiding model development and ensuring policy relevance) and to provide channels for communication creating potential for the evidence to contribute to policy design.[12–14]

We aimed to: (1) present estimates of the change to alcohol consumption, individual expenditure, retail and tax revenue following the introduction of a South African MUP, using a purpose built model, (2) estimate the impact on a limited number of alcohol-related health conditions and associated healthcare costs, (3) explore the potential equity implications via the demonstration of impact by both drinker group and wealth quintile, (4) highlight parameters that are particularly influential to the results and areas that require further research.

METHODS

We built an epidemiological policy appraisal model coded in R (code available here), using a comparative risk assessment approach with multistate life tables.[15] A stakeholder mapping exercise was carried out following scoping conversations with three academic experts from three South African institutions. Following this, a shortlist of policy professionals, civil society members and local academics was drawn up and checked via the scientific and ethical review process. They were engaged via scoping interviews and three workshops, at the beginning, middle and end of the modelling process. Stakeholders informed key decisions including the specific policy to simulate, levels of the MUP, health outcomes of interest, assumptions on homebrew switching behaviour and validation of our choice of data sources.

Two distinct sections of the model were defined (figure 1):

I. Price to consumption: baseline prices were estimated for drinker groups (heavy drinkers, occasional binge drinkers, moderate drinkers) and wealth groups. Consumption was estimated at the individual level, this includes the proportion of alcohol drunk that is homebrew. Following a change in price, the new price and subsequent consumption levels were estimated. This accounts for both mean and peak weekly alcohol consumption.

II. Consumption to harm: the relationship between mean and peak consumption and alcohol-related harm and associated costs were estimated.

There is no single data set that can provide all the required data for the model and, thus, a combination of survey data sets, market research data, and evidence from published literature were used (figure 2).

Price to consumption

Baseline consumption and prices

Our model started by estimating mean and peak alcohol consumption at current alcohol prices at the individual level. We categorised drinkers into three exhaustive and mutually exclusive groups; moderate (less than 15 standard drinks (SDs) per week); occasional binge (less than 15 drinks per week but more than 5 on one occasion) and heavy (15 or more drinks per week). An SD in SA is currently 15 mL or 12 g of pure ethanol. We generated price distributions for wealth and drinker groups using real price data linked to individual drinking from the International Alcohol Control Study (IAC)[16] survey 2014/2015 completed in the metropolitan district of Tshwane. The IAC asked for highly detailed data about prices in both

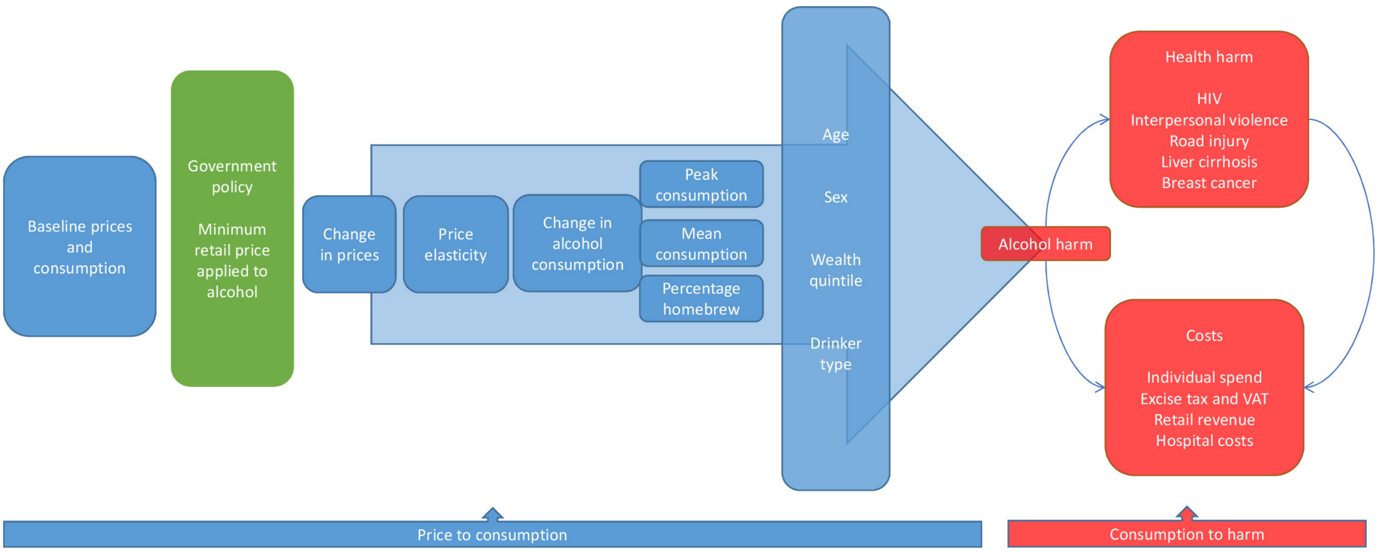

Figure 1 Conceptual model framework.

on-trade and off-trade locations and took into account container size, drink type and number of drinks purchased. Alcohol was treated as one commodity as the 863 price observations were distributed between drinker and wealth groups instead of by alcohol type. Wealth quintiles were chosen as our measure of socio-economic status as income was not available in the pricing data set, whereas asset ownership and common demographic data such as age, sex and education were available. A detailed description of the above is given in the appendix parts 1 to 6.

Applying an MUP

A government policy of legislating for an MUP of R5, R10 and R15 per South African SD was introduced. Prices below the MUP threshold were increased to the threshold, while products above were unaffected. We did not include prices for homebrew. The distribution of prices faced by each wealth/drinker group was used to calculate the mean price per SD before and after the policy. This then provided a percentage change in the mean price (table 1).

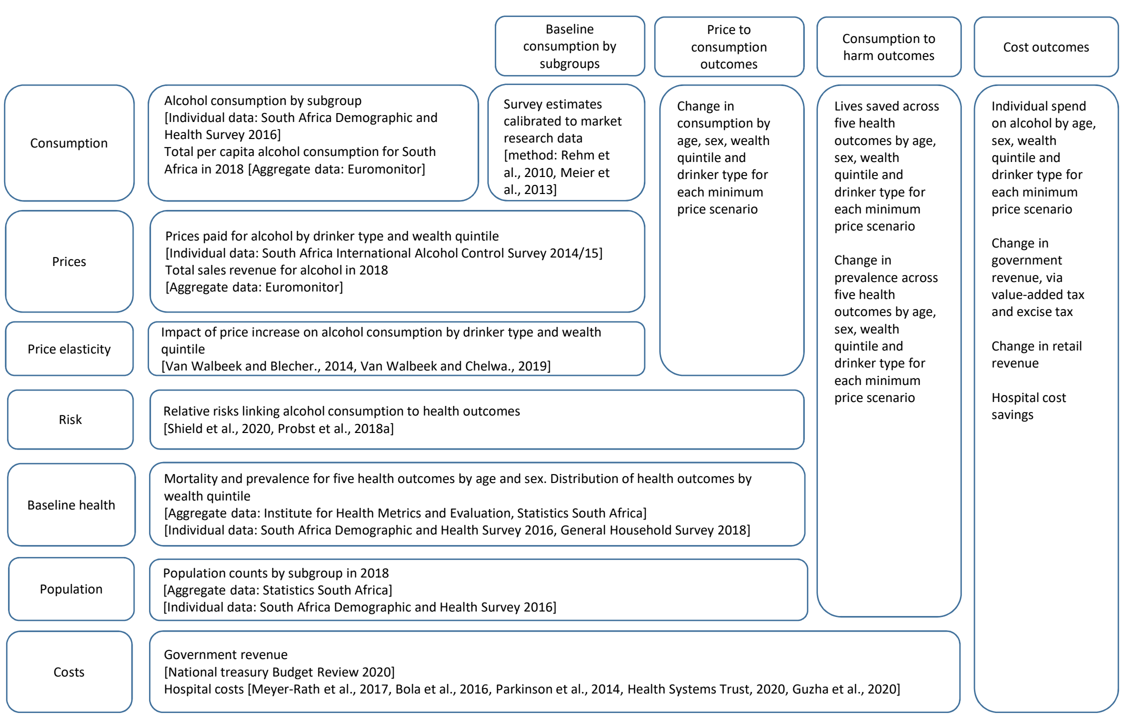

Figure 2 Data inputs for model.

Table 1 Price and elasticity data inputs by wealth quintile and drinker group

	Q1	Q2	Q3	Q4	Q5
Baseline price per standard drink					
Moderate	R9.13	R9.13	R9.13	R11.6	R11.6
Occasional binge	R7.97	R10.0	R10.1	R13.4	R11.1
Heavy	R7.78	R9.65	R9.23	R10.6	R12.8
Percentage change in mean price following R10 MUP					
Moderate	22%	22%	22%	20%	20%
Occasional binge	37%	16%	24%	11%	19%
Heavy	33%	26%	25%	24%	21%
Price elasticities used in the model					
Moderate	−0.53	−0.53	−0.31	−0.31	−0.31
Occasional binge	−0.29	−0.29	−0.17	−0.17	−0.17
Heavy	−0.24	−0.24	−0.14	−0.14	−0.14

*Standard drink in South Africa defined as 15ml or 12 grams of pure ethanol
MUP, minimum unit pricing; Q1, poorest.

Elasticity of demand for alcohol

The change in price was translated into a change in individual consumption using an elasticity of demand for alcohol. We used previously published elasticities for SA, calculated separately by drinker group: −0.4 to –0.22, –0.18 for moderate, occasional binge and heavy drinkers, respectively,[4] and adjusted for wealth quintile using additional evidence from SA[17] (table 1) (online supplemental appendix 7).

Those who drank both recorded alcohol and homebrew dampened the policy impact by switching some of their drinking to homebrew. Stakeholders indicated that 30% of the reduction in recorded alcohol could be assumed as being compensated for via an equivalent increase in homebrew. This was varied between 0% (no switching) and 100% (full switching) in the sensitivity analysis.

Individual spend, tax and retail revenue

Total retail spend was computed by aggregating population-weighted individual spend. This figure was increased by 1.25 (100/80) as consumption was calibrated to 80% of official sales volume data.[18]

As an MUP is applied before VAT is calculated, we estimated VAT as 15% of the total aggregate spend. Excise tax was calculated by starting with the total 2018 alcohol excise tax revenue from the Treasury Budget Report.[9] This was adjusted by percentage change in volume of alcohol sold (we used a fixed ratio between volume and excise tax). Retail revenue was calculated by taking VAT and excise taxation away from total spend (online supplemental appendix 8).

Consumption to harm

Relative risks and potential impact fractions

We used published estimates of relative risks associated with different levels of alcohol consumption (online supplemental appendix 9). We then used these to calculate relative risks for each outcome for each individual.

We used potential impact fractions (PIFs), a widely used approach in epidemiological modelling, to estimate the impact of a change in exposure to risk on a change in outcomes.[19] We incorporated population weights and computed the PIFs by sex, wealth group and drinker groups (online supplemental appendix 10).

Baseline health

Baseline deaths and cases (population prevalence) of the five disease and injury conditions (HIV, road injury, intentional injury, liver cirrhosis and breast cancer) were apportioned by drinker group, sex and wealth quintile. The probability of death for each disease was calculated for baseline and taken away from overall probability of death for each single year of age given in the life table to give a probability of death from non-modelled causes. This probability of death from non-modelled causes remained constant at every policy scenario. The probability of death from the five diseases of interest then varied according to the policy level and the corresponding PIF. A more detailed description is given in online supplemental appendices 11 and 12.

Projecting the population

We modelled counterfactual population structure (ie, in the absence of the policy) over 20 years, starting from 2018.[20] We created multistate life tables in which the population faces a probability of mortality for each of the five disease/injury conditions and for non-modelled causes each year. The model generated alternative population impact fractions (as above) for baseline and for each policy scenario. Using the relevant population impact fraction and rerunning the multistate life table enabled a calculation of the difference between baseline and the policy. HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking immediately, whereas the health impact on liver cirrhosis and breast cancer are subjected to lags in the effect[21] (online supplemental appendix 13).

The life tables for the 20-year time horizon were used in combination with the probability of having the disease and the PIFs under each policy, to estimate the number of cases.

Hospital costs

Prevalence of disease/injury at each policy scenario for each year of the model was multiplied by the proportion who receive hospital treatment and the relevant hospital cost applied (online supplemental appendix 14). We converted all costs to 2018 prices using the Consumer Price Index.[22] Future costs were discounted at 5%.

Sensitivity analysis

We explored key uncertainties in the model using scenario analysis informed by previous published alcohol modelling work,[23] our knowledge of the limitations of the data and stakeholder input. For each alternative scenario, relevant results were compared with central estimates. The key parameters explored were elasticities, proportion of abstainers, HIV baseline estimates, socioeconomic gradients of health, proportion of switching to homebrew and discount rates for costs (online supplemental appendix 15).

Patient and public involvement

Patients were not involved in this study.

RESULTS

Estimated consumption and spend impact

Our findings are presented primarily for an R10 MUP, but with some comparisons across all three pricing levels. The policy appraisal results are reported by quintile further disaggregated by drinker group (table 2). In the model, drinking prevalence increases with wealth (27% up to 38%) as does the prevalence of heavy drinking, ranging from 14% among Q1 up to 20% for Q5. Among all drinker groups, mean consumption is either similar or demonstrates no clear pattern between wealth quintiles. On aggregate, there was a gradient in average baseline weekly spend with the rich paying an average R257.36 per week compared with R148.03 in the lowest wealth group.

Our model estimated, for an MUP of R10, an immediate reduction in population alcohol consumption of 4.40% (−0.93 SD/week) and an increase in spend of 18.09%. Moderate drinkers showed the greatest percentage decrease in their drinking, followed by occasional binge then heavy drinkers (−8.71%, −4.51%, −4.19%). However, this translated to a larger absolute reduction in consumption for heavier drinkers (−1.48 SD/week) than either occasional binge or moderate drinkers (−0.41 and to −0.40).

Our model estimated that there would be an increase in individual spend on alcohol consumption of R32.77 billion in the year following the introduction of the policy. The government would see an increase in VAT as a result of the increased prices although a reduction in excise taxation due to the reduced volume of alcohol sold. Retail revenue would also increase (table 3).

Estimated health impact

Across the five health conditions included in the model, an R10 minimum price estimated 20 585 lives saved and 9 00 332 cases averted of the disease/injury conditions over the 20-year time horizon. For R5 (R15), we estimated 95 (45 326) lives saved and 4126 (2 038 319) cases averted, respectively. The impact differed by drinker group and by wealth quintile (figure 3). The greatest health benefits accrued to the heaviest drinkers, with the dominant effect related to HIV infections, especially in the bottom three quintiles. Among the heavy drinkers, 85% of the cases averted and 86% of the lives saved accrued to the bottom three quintiles. Occasional binge drinkers achieved most of their positive health impact via a reduction in interpersonal violence and road injury as both of these conditions are linked to binge drinking. There was a small increase in HIV incidence among occasional binge drinkers. The high prevalence of HIV is the source of an important competing risk and the avoidance of death related to acute conditions led to longer exposure to the risk of HIV infection. As expected, the cases saved of liver cirrhosis accrued to the heavy drinkers, as this condition relates to heavy drinking in the long term. Q2 realised the highest number of HIV cases averted due to having the highest proportion of cases at baseline.

Healthcare cost savings accrued over the 20 years and were greatest for intentional injury (table 4). The health cost savings are provided by quintile in online supplemental appendix 16.

Results across policy levels

Comparing across the three policy levels demonstrates the relative impact between wealth quintiles remained largely consistent as the MUP level increased for moderate and occasional binge drinkers (figure 4). For heavy drinkers the wealth gradient becomes more pronounced at R15 particularly with regards to the change in consumption.

The sensitivity analysis that produced the most variable results were the alternative elasticity estimates. Two of the alternative scenarios (−0.8 applied to all drinkers and −0.86/−0.5 applied to Q1 and Q2 with −0.5 applied to Q3 – Q5) produced much greater consumption impacts (−14%, – 18%) coupled with much smaller increases in individual spend (5.4%, 0.1%). All other results are included in online supplemental appendix 15.

DISCUSSION

Our analysis estimates that MUP may offer an effective approach to reducing alcohol consumption and related harm in SA. For an MUP of R10, we estimate an immediate reduction in consumption of 4.40%, increase in individual spend of 18.09% and an increase in retail revenue and taxation. In terms of health impact, we estimate 20 585 lives saved and 9 00 332 cases averted in total across HIV, intentional injury, road injury, liver cirrhosis and breast cancer over 20 years. Regarding the equity impact, our model estimates that the distribution of health outcomes is generally pro-poor, critically important, given these groups also see the greatest relative increase in their alcohol expenditure.

Our research aligns with studies from other countries, which suggest that minimum pricing will reduce alcohol sales and also corresponds to mechanisms, such as greater impact with a rising MUP threshold and greater impact on the poor, found in the international literature.[24 25] We add to the South African minimum pricing evidence currently available[26] by incorporating health outcomes,

Table 2 Consumption and spend R10 policy estimates

	Overall	Q1	Q2	Q3	Q4	Q5
Survey respondents	10336 (100%)	2098 (19%)	2227 (19%)	2337 (21%)	2066 (20%)	1608 (21%)
All drinkers						
n (%)*	3311 (33%)	551 (27%)	690 (30%)	823 (33%)	685 (35%)	562 (38%)
Baseline consumption (standard drinks per week)	21.22	20.83	21.40	20.97	21.98	20.89
Baseline spending (R per week)	R208.74	R148.03	R192.82	R186.95	R231.78	R257.36
Change in consumption (%)	−4.40%	−7.75%	−6.42%	−3.76%	−3.41%	−3.19%
Change in consumption (standard drinks per week)	−0.93	−1.50	−1.29	−0.76	−0.72	−0.65
Change in spending (R per week)	R37.95	R32.81	R32.52	R38.27	R42.64	R43.07
Moderate						
n (%)*	1336 (12%)	206 (10%)	272 (13%)	354 (12%)	273 (13%)	231 (15%)
Baseline consumption (standard drinks per week)	5.05	5.01	5.49	4.90	4.86	4.98
Baseline spending (R per week)	R49.97	R42.75	R48.84	R43.54	R54.38	R56.59
Change in consumption (%)	−8.71%	−12.20%	−12.89%	−7.14%	−6.35%	−6.43%
Change in consumption (standard drinks per week)	−0.40	−0.55	−0.63	−0.33	−0.29	−0.30
Change in spending (R per week)	R5.79	R3.52	R3.91	R6.16	R6.97	R7.30
Occasional binge						
n (%)*	433 (4%)	76 (4%)	89 (4%)	109 (5%)	91 (4%)	68 (4%)
Baseline consumption (standard drinks per week)	9.53	9.69	9.27	9.59	9.27	9.82
Baseline spending (R per week)	R96.87	R68.13	R84.04	R94.63	R120.59	R109.00
Change in consumption (%)	−4.51%	−10.16%	−4.21%	−4.05%	−1.89%	−3.32%
Change in consumption (standard drinks per week)	−0.41	−0.89	−0.37	−0.37	−0.17	−0.32
Change in spending (R per week)	R14.58	R16.69	R9.28	R17.86	R11.31	R16.42
Heavy						
n (%)*	1542 (16%)	269 (14%)	329 (14%)	360 (16%)	321 (17%)	263 (20%)
Baseline consumption (standard drinks per week)	36.72	35.02	39.53	36.20	38.22	35.16
Baseline spending (R per week)	R360.19	R244.13	R356.68	R320.18	R394.90	R439.14
Change in consumption (%)	−4.19%	−7.15%	−5.75%	−3.41%	−3.23%	−2.85%
Change in consumption (standard drinks per week)	−1.48	−2.34	−2.15	−1.19	−1.19	−0.97
Change in spending (R per week)	R69.68	R57.17	R65.17	R67.85	R77.47	R75.08

Data for 10336 survey respondents.
*Numbers refer to absolute sample size, percentages incorporate survey weights, the relevant base is indicated in the top row of their column.
Q1, poorest.

accommodating homebrew and exploring differential impacts by wealth groups. Van Walbeek and Chelwa[26] who produced an economic model to simulate the impact of a MUP on consumption (with no epidemiological modelling) suggest both a higher reduction in consumption and a greater difference in consumption impact between heavy and moderate drinkers. The difference in our estimates is largely due to different price estimates. Their prices are crucially far more heterogeneous between drinker groups, outweighing the impact of the price elasticities. Our prices are drawn from a detailed survey asking for real prices paid by beverage, container and location, which allows us to calculate real prices per SD. Van Walbeek and Chelwa used an average unit value derived from reported monthly alcohol consumption (calculated using quantity/frequency questions) and one

Table 3 Aggregate spend, taxation and retail revenue

Change from baseline in billion rand, per year			
	R5 MUP	R10 MUP	R15 MUP
Individual spend	R1.24	R32.77	R78.29
Taxation			
VAT	R0.16	R4.27	R10.21
Excise tax	–R0.03	–R1.24	–R3.40
Retail revenue	R1.11	R29.74	R71.48

MUP, minimum unit pricing; VAT, value-added tax.

variable asking for monthly spend on alcohol,[26] which gave very low prices for heavy drinkers. Their prices may be too low and ours too high for the heaviest drinkers. If this is the case, our findings may present a conservative estimate of the potential impact of the policy.

Our study has a number of strengths relevant to providing policy-relevant research in LMICs. In the absence of detailed market research purchasing data, we demonstrate how survey, administrative data and the academic literature can be used, in partnership with local stakeholders, to build a contextually relevant epidemiological policy appraisal model. A further strength is our focus on stakeholder engagement from project inception increasing the likelihood of findings being taken into consideration during policy decision-making.[27] MUP was chosen as the policy to model as it was seen as both innovative and potentially well targeted for the South African heavy drinking culture. Stakeholders were pleased the estimates combined improved health with increased taxation and increased retail revenue, as supporting business was considered politically important. The financial cost of MUP is borne by drinkers and there were concerns about how this may impact poorer groups and we recommend this as an area for further research.

A limitation of our study is the lack of high-quality pricing data for SA. Previous studies in HIC have found that moderate drinkers, even those on lower incomes,

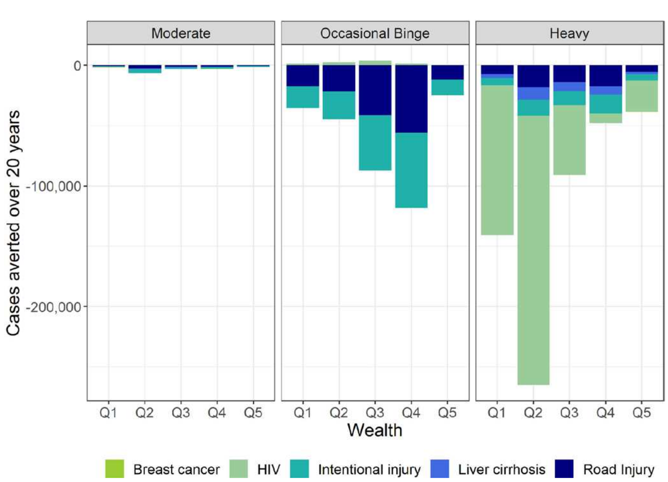

Figure 3 Cases averted by condition, split by drinker group and wealth quintile.

Table 4 Healthcare cost savings over 20 years, millions

	R5 MUP	R10 MUP	R15 MUP
Antiretroviral therapy costs	–R0.15	R565.82	R1356.51
Intentional injury hospital costs	R32.55	R4304.13	R9088.97
Road injury hospital costs	R16.46	R1975.45	R4265.68
Liver cirrhosis hospital costs	R0.66	R27.60	R68.19
Breast cancer hospital costs	R0.22	R4.00	R10.59

purchase relatively little cheap alcohol,[24] while the price data used in our model suggest that all drinker groups purchase some cheap alcohol. It is unclear whether this is a true reflection of alcohol purchasing patterns in SA or a limitation of the data. In addition, although we adjusted the off-trade wine prices to be consistent with industry sources, we know that the proportion of wine in the survey is less than the market share. As wine constitutes some of the cheapest available alcohol, an MUP may have a bigger impact than our estimates suggest. If the price of wine increased, we may expect drinkers to switch to other

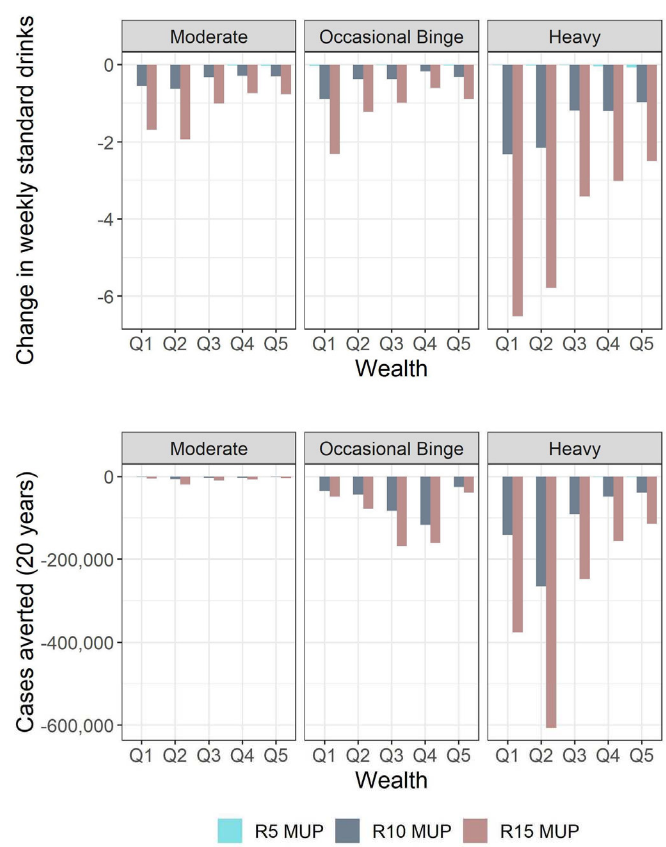

Figure 4 Comparing the three policy levels: change in mean weekly drinks and cases averted by drinker and wealth group. MUP, minimum unit pricing.

cheaper alcohol, however, a key strength of MUP is that the policy applies across all alcohol types, and so drinkers are not able to do this.

Related to this, limitation is the treatment of all drinks as one commodity. South African evidence has suggested that cheap wine has a much higher price elasticity than other drink types.[8] If cheap wine is the drink primarily affected, then this elasticity would lead to less of an increase in individual spend, potentially even a saving, smaller gains to retailers and less of a loss to excise tax revenue as wine enjoys substantially lower rates.

We recommend the following avenues for further research. First, the collection of improved pricing data, specifically the different prices paid for alcohol by different population groups, to explore further the most appropriate level of MUP. Second, the exploration of the financial impact on the poorest groups including any financial benefits such as reduced expenditure on healthcare or improved labour market outcomes. Third, in an alcohol market that includes retailers operating outside of the regulated space (despite largely selling recorded alcohol purchased from licensed outlets), it would be important to understand enforcement mechanisms and the supply chain in order for the policy to maximise effectiveness. However, it should be noted that the IAC pricing data suggest most of the lowest prices are to be found at large supermarkets and bottle stores, which offer bulk discounts rather than small local shebeens that sell alcohol often to be drunk on the premises.

CONCLUSION

Our model estimates that minimum pricing would reduce alcohol consumption in SA, improving health outcomes while raising retail and tax revenue. Consumption and harm reductions would be greater in poorer compared with richer groups. We estimate that minimum pricing is a targeted policy that has the potential to bring health and financial benefits to a country, which suffers a very high burden of alcohol-related harm.

Twitter Colin Angus @VictimOfMaths

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Contributors All authors conceptualised the study. NG completed the modelling and stakeholder engagement under the supervision of CA, SD, PM and CP. NG wrote the first draft. All authors refined various drafts of the manuscript and approved the final version.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval Ethical approval for engaging with stakeholders was granted by the South African Medical Research Council (Protocol ID: EC005-4/2019) and the School of Health and Related Research at the University of Sheffield, UK (Reference Number: 023357). All data for the model came from secondary sources and were managed according to an approved information governance plan.

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Contents

Supplementary Material

Price to consumption

Our model starts by estimating mean and peak alcohol consumption at current alcohol prices at the individual level. The proportion of alcohol consumption which is homebrew is also estimated. This process utilised both alcohol frequency questions and seven day recall questions asked in the same survey. As survey data significantly underreports consumption we calibrate these estimates to market research data using statistical methods established in the literature [1-3]. Following the shift of mean consumption, peak consumption is re-estimated using a simple regression model created at baseline. We categorise drinkers into three exhaustive and mutually exclusive groups; moderate (less than 15 standard drinks per week); occasional binge (less than 15 drinks per week but more than 5 on one occasion); and heavy (15 or more drinks per week). A standard drink in South Africa is currently 15ml or 12 grams of pure ethanol. We compute a regression model for wealth quintiles using the South African Demographic and Health Survey (SADHS) data and use it to predict wealth quintiles in the International Alcohol Control (IAC) dataset to generate price distributions for wealth and drinker groups. Alcohol is treated as one commodity due to data constraints.

1. Estimating baseline consumption using South African Demographic and Health Survey (SADHS)

The SADHS survey asked the following questions:

Table 1: Survey questions

Survey	**Alcohol questions** **[answers]**
SADHS 2016	Have you ever consumed a drink that contains alcohol such as beer, wine, ciders, spirits, or sorghum beer? Probe: Even one drink? [yes, no] Was this within the last 12 months? [yes, no] In the last 12 months, how frequently have you had at least one drink? [5 or more days a week, 1-4 days per week, 1-3 days a month, less often than once a month] During each of the last 7 days, how many standard drinks did you have? [use showcard, record total number of drinks consumed each day starting with the day before the day of the interview and proceeding backwards] During the last 7 days, how many standard home-made beers or other homemade alcohol did you have? [use showcard, record number] In the past 30 days, have you consumed five or more standard drinks on at least one occasion? [yes, no]

Process of adjusting the SADHS estimates

Drinkers were categorised by their drinking frequency and by whether or not they had reported any drinking in the last seven days.

Table 2: Frequency of alcohol consumption responses

Drinking occasion frequency	count	Reported drinks in last 7 days	Reported zero drinks in last 7 days
5 or more days a week	293	266	27 (6 binge, 21 drinker)
1-4 days per week	668	565	103 (29 binge, 74 drinker)
1-3 days per month	1163	799	364 (all drinkers)
less often than once a month	1187	404	783 (all drinkers)
NA	7025		

Firstly readjusting those with a seven day drinking pattern (pink numbers)
The pink numbers are respondents who say they only drink 1 -3 days per month or less often than once a month but they have drank in the last 7 days. If this were multiplied by 52 it would be an overestimate.

Drink frequency 1 – 3 days per month
Assume for those that drink 1-3 days per month we have caught their one drinking week in the month and multiply by 12 to get their annual consumption. There are 799 people in this category.

Drink frequency less than once per month
Assume for those who drink less often than once a month but who did drink in the last week we have caught their one drinking week in the month. Multiply by 6, to get the annual figure. There are 404 people in this category.

The yellow numbers are ok as respondents report drinking every week and have a seven day drinking pattern.

Readjusting those without a seven day drinking pattern but who say they drink (blue and red numbers)
Drink frequency 5 or more days per week
Use the mean standard drinks for drinkers (and binge drinkers) who reported the same frequency but who do have a seven day pattern, there are 266 people (yellow). This is computed separately for sex and drinker group.
Drink frequency 1 - 4 days per week
Use the mean standard drinks for drinkers (and binge drinkers) who report the same frequency but who do have a seven day pattern, there are 565 people (yellow). This is computed separately for sex and drinker group.
Drink frequency 1 – 3 days per month
Use the mean adjusted annual drinks (adjusted above) of the equivalent frequency group who did report a drinking pattern, said no to drinking 5 or more, split by sex. This uses observations from 799 people (pink).
Drink frequency less than once per month
Use the mean adjusted annual drinks (adjusted above) of the equivalent frequency group who did report a drinking pattern, said no to drinking 5 or more, and split by sex, This uses observations from 404 people (pink).

Alternatively those who drink less than once a month, assume they drink 2.5 standard drinks (midpoint of 1 – 4) 6 times a year. This would mean they drink 2.5 drinks * 6 months = 15 standard drinks, again this is of a similar magnitude.

Process of adjusting peak drinks
Using the same process as above we also applied a peak drink to those observations which did not have one. However before this we checked all those who reported binge drinking had a peak drink at minimum of 5, which they did.

Comparing the adjusted SADHS data with the estimates using only 7 day recall we see that as expected prevalence of drinking increases and per capita estimates reduce (Table 3).

Table 3: Comparing adjusted with unadjusted statistics

	Prevalence of drinking		Sample size: drinkers	Annual litres of alcohol - per capita			Annual litres of alcohol - Just drinkers		
	Female	Male		Total	Female	Male	Total	Female	Male
SADHS (7 day recall only)	9.3%	32.7%	n = 1949 (report drinks	2.2	0.65	4.5	10.6	6.54	12.2

Population weights applied			in the 7 day recall) females = 571 males = 1378						
SADHS adjusted (7 day recall plus adjustments based on frequency questions) Population weights applied	18%	54%	n = 3311 females = 1125 males = 2186	1.65	0.50	3.4	5.0	2.59	6.25

Figure 1: Density plot of female drinkers before and after the shift

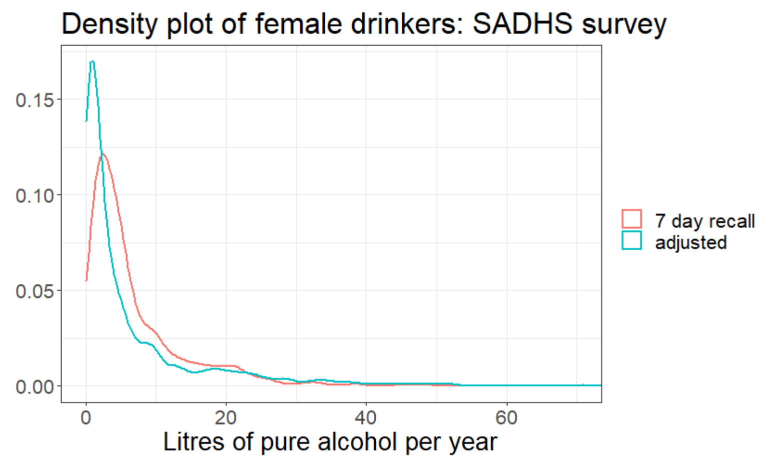
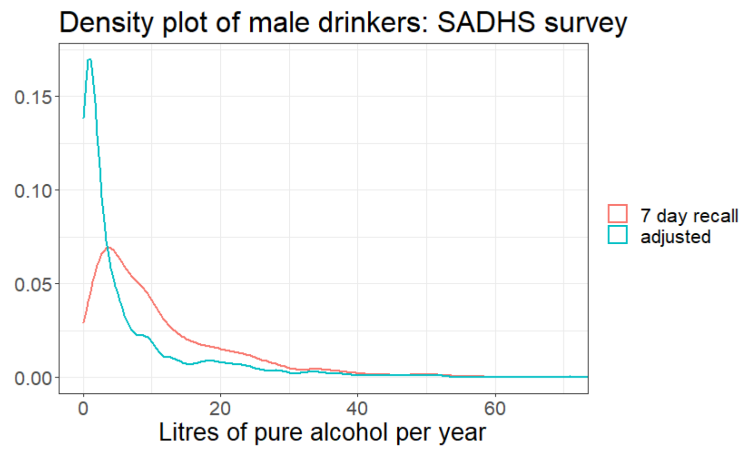


Figure 2: Density plot of male drinkers before and after the shift



Incorporating the frequency data into the seven day recall moves the distribution towards the left (Figures 1 and 2). This is logical as the sample will now include those drinkers who stated that they drink but did not record any for the last seven days, it also adjusted down those who claim to drink less than weekly but who did recall drinks for the last seven days. This pattern gives some confidence in the dataset and utilises the strengths of capturing heavy drinking well and including occasional drinkers.

2. Uplifting consumption

Surveys provide important data about drinking patterns within the population but, as previously mentioned, they provide total consumption estimates that are far smaller than that indicated by government sources or market research data [4]. There are established ways of adjusting alcohol consumption survey data to account for this via statistical calibration techniques [2,3]. The following steps outline how we tailored the methods to the South Africa context:

- First a cap was applied to all drinkers of 68 litres of alcohol per year or 150 grams of alcohol per day. As the model includes long term effects (20 years) the cap is needed as a higher level of alcohol cannot be sustained in the long term [5]. This cap impacted one woman and ten men. Of this small group only two men drunk both homebrew and recorded alcohol and so their total consumption was reduced to 68 litres and then split into recorded and homebrew using their previous percentage split.

- Survey coverage level was calculated as the difference between total per capita consumption recorded in the SADHS survey and per capita consumption using Euromonitor recorded sales data for 2018. 80% of the sales data is used to account for spillage, stockpiling and tourist consumption. This sales figure was then increased to take account of the 4.15% of total alcohol consumed in the survey reported as homebrew (representing unrecorded alcohol in the model). The comparison of total consumption according to the survey and the adjusted official sales data was used to create the multiplication factor.

- For female and male subgroups the mean litres of alcohol was adjusted by the multiplication factor.

- This new mean and the relationship between mean and standard deviation, established in the literature [2], was used to compute a standard deviation and then fit a "shifted" gamma distribution (maintaining the cap of 68 litres) using the mean and standard deviation, calculated for male and females separately.

$$\hat{\sigma}_{shifted} = 1.174 \times \hat{\mu}_{shifted} + 1.003 \times sex$$

- It is possible to stop at this point; however, there are two limitations with this method. Firstly, there is no empirical evidence that under coverage is distributed as implied by the shifts needed to fit the adjusted consumption to the gamma. Secondly, that shifting consumption to a gamma can artificially reduce the long tail of heavy drinkers [3].
- Therefore, a gamma distribution was fitted to the original sample of drinkers by sex and percentiles were taken across both distributions. Percentage differences in consumption were calculated at each percentile. These increases were then applied to the percentiles of the original survey sample
- Each individuals total consumption was split into homebrew and recorded alcohol using the original percentage split (this assumes underreporting is equal across homebrew and recorded alcohol)
- Results were compared (Table 4 and Figures 3 and 4). There is a fairly small difference between the two methods, more visible for males than females. It appears adjusting by percentiles only makes a difference at the extremes, lowering the left hand peak slightly but also falling below the Gamma shifted distribution after 60litres of alcohol per year meaning there is a smaller number of the very high drinkers. The percentile adjusted distribution was used for the main model.

Table 4: Comparing pre and post shift data

Females – litres of alcohol per year	Mean	Min	Max
SADHS Survey data (weighted mean and capped)	2.57	0.09	68
Gamma fitted to survey (difference due to weights)	2.50	0.09	68
Gamma shift	10.78	1	68
Adjusting each percentile (weighted mean)	10.74	0.5	68
Males – litres of alcohol per year			
SADHS Survey data (weighted mean and capped)	6.13	0.09	68
Gamma fitted to survey (difference due to weights)	5.6	0.09	68
Gamma distribution shifted	18.55	1	68
Adjusting each percentile (weighted mean)	19.2	0.5	68

Figure 3: Comparing distributions pre and post shift females

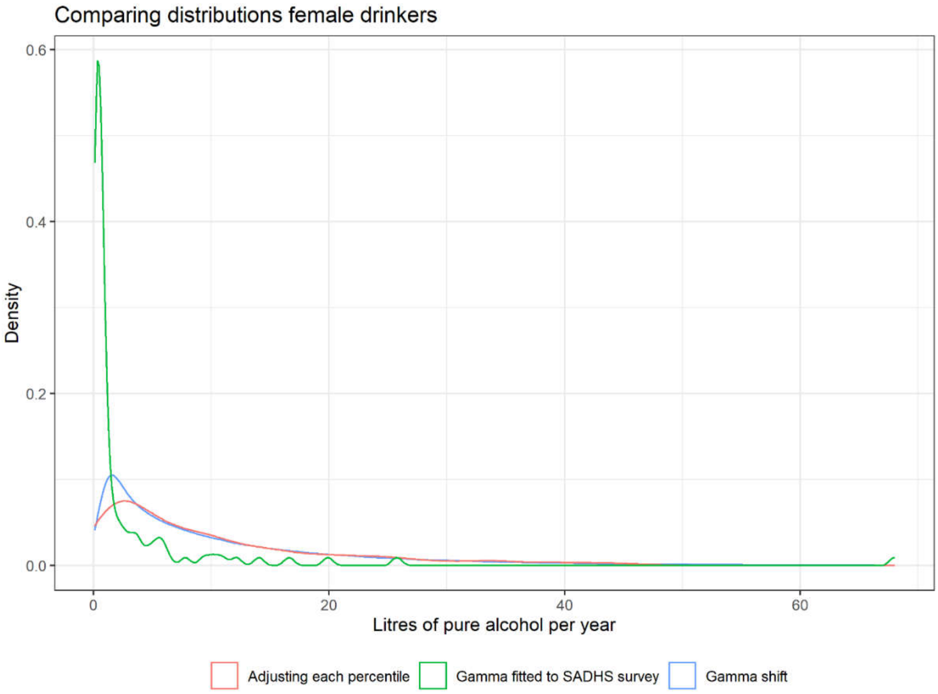
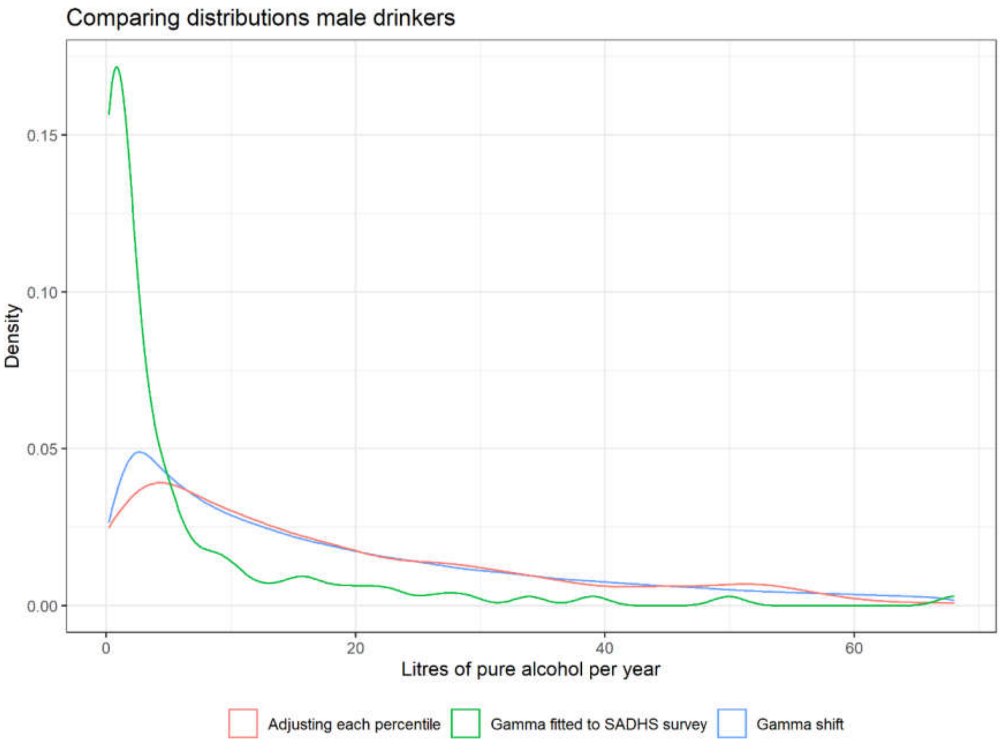


Figure 4: Comparing distributions pre and post shift males



3. Uplifting peak consumption

Peak drinking is important as it will influence health harms directly. Following the method used in the Sheffield Alcohol Policy Model [6], the following linear regression model was fitted, for all drinkers, to the non-shifted SADHS data, relating peak drinking to mean consumption, age and sex.

```
peak_model <- lm(dk_peak_SADHS ~ lit_SADHS + age_band_4 + sex)
```

The model was used to compute fitted values for the non-shifted data. The model assumes there is a linear relationship between peak and mean consumption, the magnitude of which is allowed to vary by age and sex.

After the mean consumption was shifted as above the corresponding new peak consumption was computed using the following formula:

$$peak_{ij}\ (shifted) = peak_{ij}\ (SADHS) \times (E(peak_{ij}\ (shifted))/E(peak_{ij}\ (SADHS))$$

The linear relationship between mean and peak discovered in the SADHS survey is maintained for the shifted mean and peak consumption which assumes individuals under reported peak and mean consumption by the same magnitude. The prediction error for the model is of the same magnitude for all levels of consumption.

The predictions were checked to ensure that peak drinking was never predicted below mean daily drinking. There were 88 people (out of the 3311 drinkers) for whom this was true. These people had their peak drinking increased to match their mean daily drinking.

4. Wealth quintiles

In order to match wealth groups between the two datasets an ordered choice model was created using SADHS data with wealth quintile (1 – 5) as the dependent variable, using the MASS package in R [7]. Wealth groups were chosen as the best available measure to capture socioeconomic status that allowed us to match between the SADHS and IAC dataset. Although income was asked in the IAC dataset many of the respondents refused to answer resulting in a very small sample.

All the variables that were common across the two datasets were included in the initial model, these were not just asset ownership but also age, sex, educational level and population group (race). Stepwise regression was performed using the step.AIC function. This chooses the best variables to include by running the regression with all variables in and then taking one out and computing a goodness of fit measure (the AIC). If the goodness of fit measure is improved then that model is preferred, it runs this for many models until it finds the model with the highest AIC. This method resulted in the selection of the following variables: age, sex, population group, education level, car, landline, electricity, fridge, computer, radio, tv. The only variable it removed was mobile phone which fitted anecdotally with conversations we had with stakeholders in South Africa regarding how much poorer people prioritise mobile phones.

polr(formula = wealth ~ car + electricity + tv + fridge + radio + telephone + computer + age + edu + pop_group, data = SADHS, Hess = TRUE)

The goodness of fit matrix evaluates the success of the model, comparing the closeness of the predicted and observed outcome (Table 5). The model never predicts the poorest as the richest or the richest as the poorest.

Table 5: Goodness of fit matrix

	Prediction					
		Poorest	Poorer	Middle	Richer	Richest
Actual	Poorest	1300	593	196	9	0
	Poorer	299	975	744	192	17
	Middle	62	612	1042	595	26
	Richer	5	236	763	818	244
	Richest	0	10	108	422	1068

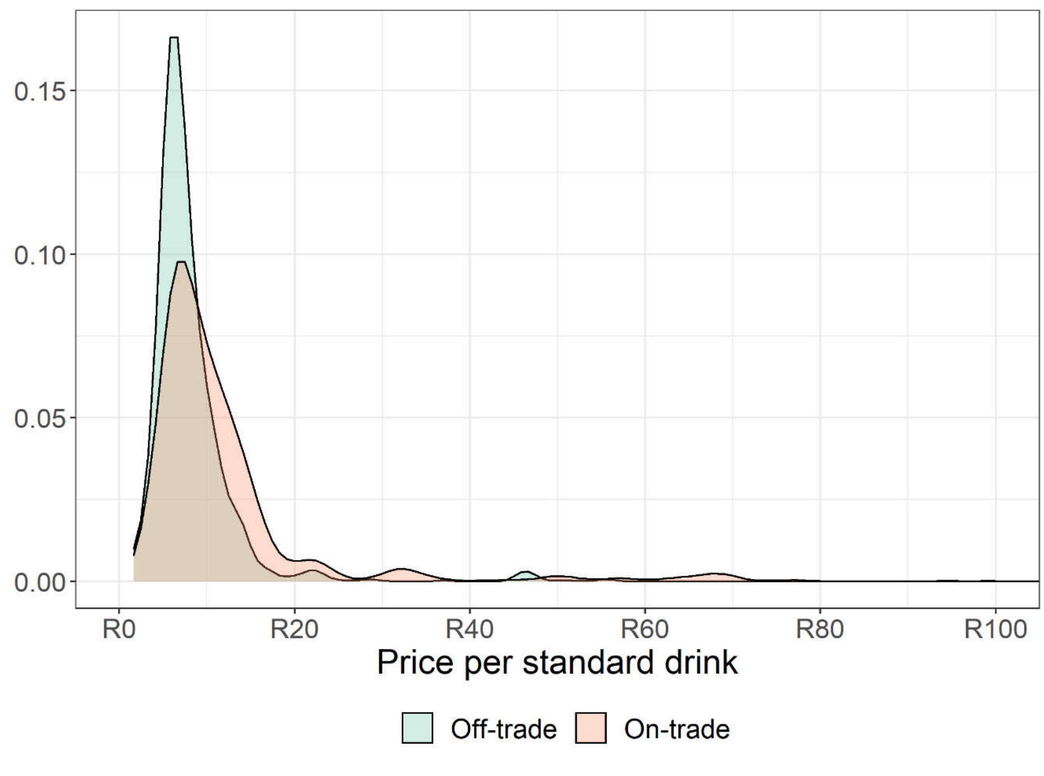
5. International Alcohol Control Study 2014 for prices

The IAC dataset provides prices by drinking location by beverage, by container size and also asks whether the individual binge drinks, demographic data is also collected. The survey asked for the price in Rands by location, for example they ask for the price of a beer paid at a pub for each container size. There are 17 drinking locations (12 on trade and 5 off trade) and 12 drink types. On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).

Prices were disaggregated by population subgroups rather than by drink type (wine/beer/spirits etc). This was consistent with the South Africa specific price elasticities which were calculated for drinker groups whilst treating alcohol as a single commodity. The IAC respondents were categorised into drinker groups using the definitions above. Each price was weighted by the number of units (e.g. bottles, glasses, cans) sold, the container size of those units and the number of drinking occasions in 6 months (Figure 5). Every price observation was validated using data from the South African Consumer Price Index. Prices were increased to 2018 to account for inflation.

Figure 5: Distribution of off-trade and on-trade prices, standard drink is 15ml or 12grams of pure ethanol.

On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).



The off-trade wine prices were adjusted using data from the South Africa Wine Industry Statistics [8] who report the proportions of still wine sold (which makes up 93% of total volume of wine sold) in the off-trade in 2018 that falls within different price bands, this data was used to adjust downwards the off-trade wine (Table 6). The price observations were sorted in ascending order and a cumulative volume variable created. The price closest to the 49th percentile was then adjusted down to R3.74 and all prices below adjusted using the same proportion.

The prices at the very bottom were adjusted so they could not go below R2.50. The same adjustment process was applied to each of the four groups.

Table 6: Price distribution for off-trade wine

Retail price per litre of wine for 2018	Price per standard drink (15ml) assuming 12% abv	Cumulative percentage of total still wine sold at price SAWIS data	Cumulative percentage of IAC data for off-trade wine pre-adjustment	Cumulative percentage of IAC data for off-trade wine post-adjustment
Less than R30	Less than R3.75	49%	33%	51%
> R30 – R48	> R3.75 – R6	82%	60%	83%
> R48 - R72	> R6 – R9	89%	77%	89%
> R72 - 108	> R9 – R13.5	95%	89%	95%
> R108	> R13.5	100%	100%	100%

As the Tschwane prices were collected in one locality, they were validated against national data sources. Beer is by far the most popular drink, accounting for over 50% of the alcohol sold so beer prices are critical. We accessed data from the South Africa Consumer Price Index for January 2020 to compare the Gauteng province (where Tshwane is located) with other provinces. Beer, which accounts for over 50% of alcohol sold in South Africa, Guateng is at R13.76 for a 330ml can. The average across the eight prices listed above is R13.66 which is very close to Guateng’s price, therefore we assume the same price distributions across the whole of South Africa.

Finally, prices were validated with all stakeholders including individuals resident in townships who could provide anecdotal evidence relating to cheap alcohol available at shebeens.

6. Base prices by subgroup

All IAC drinkers were now categorised by drinker type and by wealth quintile (Table 7). Wealth quintile was predicted using the ordered choice model created using the SADHS data. Drinkers in the lowest wealth quintile appear the least likely to drink in moderation leaving a very small sample size (this is not weighted by number of drinks). It is therefore not possible to create price distributions for all 15 categories.

Table 7: Count of IAC price observations and respondents within each category

	Moderate obs (individuals)	Occasional Binge obs (individuals)	Heavy obs (individuals)
Poorest	2 (2)	29 (23)	35 (24)
Poorer	8 (8)	23 (18)	28 (20)
Middle	11 (11)	132 (90)	88 (40)
Richer	23 (20)	95 (59)	60 (30)
Richest	93 (68)	135 (93)	101 (50)

The mean price for each of these drinker categories demonstrates there is wealth gradient (Table 8).

Table 8 Mean price of standard alcoholic drink (15ml of pure alcohol) for each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R6.79	R7.97	R7.78
Poorer	R9.43	R10.0	R9.65
Middle	R10.2	R10.1	R9.23
Richer	R11.3	R13.4	R10.6
Richest	R11.7	R11.1	R12.8

In order to ensure adequate sample size the poorest/poorer/middle and richer/richest categories were aggregated for moderate drinkers (Table 9). This represents the final group of prices used in the model.

Table 9 Mean price of standard alcoholic drink (15ml of pure alcohol) within each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R9.13	R7.97	R7.78
Poorer	R9.13	R10.0	R9.65
Middle	R9.13	R10.1	R9.23
Richer	R11.6	R13.4	R10.6
Richest	R11.6	R11.1	R12.8

7. Adjusting the elasticities

The starting point for elasticities -0.4, -0.22 and -0.18 for moderate, occasional binge and heavy drinkers respectively [9]. We adjusted these elasticities to incorporate an income gradient using -0.86 and -0.5 elasticity for low and high socioeconomic status [10]. To remain on the conservative side we will count the bottom two quintiles as low SES and the top three as high.

Table 10: Elasticities by wealth and drinker group

Drinker type	Q1	Q2	Q3	Q4	Q5
Moderate	-0.53	-0.53	-0.31	-0.31	-0.31
Occasional binge	-0.29	-0.29	-0.17	-0.17	-0.17
Heavy drinkers	-0.24	-0.24	-0.14	-0.14	-0.14

8. Individual spend, tax and retail revenue

Spend

The total retail spend at baseline, and each scenario, was computed by adding up all the individual spends multiplied by their population weights. This figure was then increased by 1.25 (100/80) to take account for the fact that consumption had only been calibrated to 80% of official sales volume data. This was repeated at R5, R10 and R15.

Government revenue, VAT, excise tax and retail revenue

The following steps were taken in our calculations:

- Calculate VAT by assuming 15% of the base retail spend is VAT
- Import base excise tax from Treasury Budget Report for 2018
- Calculate total volume consumed of alcohol at all four scenarios
- Calculate the percentage change in volume from baseline for each of the three policies
- Apply the percentage change in volume to base excise tax (this assumes a fixed ratio between volume and excise tax)
- Calculate retail revenue by: spend - vat - excise tax

It is likely this is conservative for excise tax revenue as generally the cheaper alcohol, which this policy targets, generates a lower proportion of excise tax than the more expensive so we can consider this a lower band on the excise tax revenue.

Consumption to harm

9. Relative risks

Relative risks were calculated for each of the health outcomes of interest at baseline, and each policy scenario using published relative risk equations [11,12]. The same relative risk equations are used for morbidity (or prevalence) and mortality. HIV risk is derived from a stepped function for mean drinking, intentional injuries and road injury from a continuous function of mean drinking differing by whether the individual binge drinks, liver cirrhosis and breast cancer from a continuous function of mean drinking, for breast cancer this is only for females (Table 10).

Table 11: Relative risk equations used

Health Condition	**Relative risk Current drinkers**	**Relative risk former drinkers**	**ICD-10 codes**
HIV	Low SES $RR = 2.99$ if x > 61/49 grams per day (males/females) $RR = 1.94$ if x > 0 $RR = 1$ otherwise Higher SES $RR = 1.54$ if x > 61/49 grams per day (males/females) $RR = 1$ otherwise	RR = 1	B20-24
Intentional Injuries **(self-harm and interpersonal violence)**	Drinkers $RR = \exp(00199800266267306 . x)$ Heavy episodic drinkers (HED) $RR = \exp(00199800266267306 . x + 0.647103242058538)$	RR = 1	ICD-10 codes: X60 – Y09 Y35 –36 Y870 Y871
Road Injury **(pedestrian, cyclist, motorcyclist, motor vehicle, other road)**	Drinkers $RR = \exp(0.00299550897979837 . x)$ Heavy episodic drinking $RR = \exp(0.00299550897979837 . x + 0.959350221334602)$	RR = 1	V01–04, V06, V09–80, V87, V89, V99
Breast Cancer	Females only $RR = \exp(0.01018 . x)$	RR = 1	C50
Liver	if x <= 1 $1 + x . \exp((\beta_1 + \beta_2) . \sqrt{\frac{1 + 0.1699981689453125}{100}})$ If x > 1 $\exp((\beta_1 + \beta_2) . \sqrt{\frac{x + 0.1699981689453125}{100}})$	RR = 3.26 for both females and males	K70, K74

	Female b1 = 2.351821 b2 = 0.9002139 Male b1 = 1.687111 b2 = 1.106413		
x = grams of alcohol consumed per day among current drinkers HED = drinking 60 grams or more on one drinking occasion			

10. Potential impact fractions

Potential impact fractions (PIFs) were calculated by dividing relative risk under each policy by relative risk at baseline. These incorporated population weights and were computed by sex *(i)*, wealth group *(j)* and drinker group *(k)*.

$$PIF_{ijk} = \frac{\text{relative risk}_{ijk}\ \text{(policy)}}{\text{relative risk}_{ijk}\ \text{(baseline)}}$$

11. Socioeconomic gradients of ill health

Health outcomes in South Africa are not evenly distributed throughout the population, with the poor often bearing a higher burden of disease, depending on the illness. Data analysis was carried out using General Household Survey (GHS) data for 2018. The ordered choice regression model computed previously, using SADHS data, was applied to the GHS data to split the survey population into wealth quintiles compatible with the foundational dataset (SADHS). Percentage within each wealth quintile with the disease was computed (Table 11). Liver cirrhosis was not one of the health conditions included in the survey and breast cancer was not specifically included although the broader category of cancer was. Sensitivity analysis was carried out using alternative gradients.

Table 12: Raw count of General Household Survey data 2018

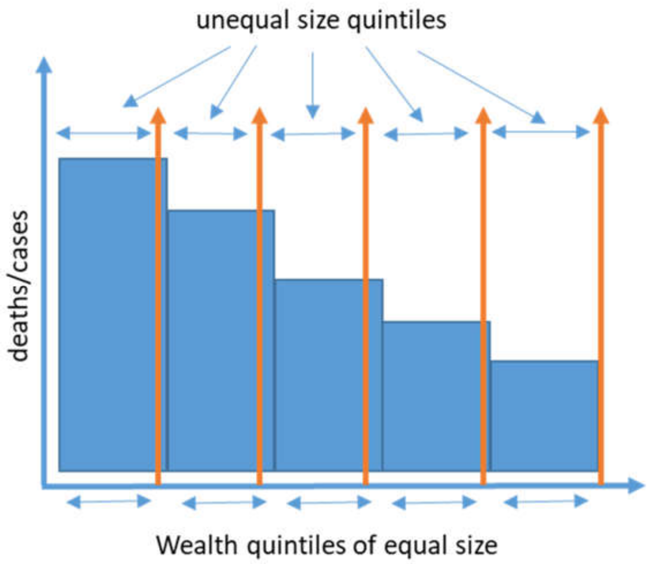
	poorest	**poorer**	**middle**	**richer**	**richest**
15+ raw count (648 NAs)	4966	11462	14396	9633	7630
HIV raw count percentage	395 0.08	684 0.06	614 0.04	155 0.02	41 0.005
Intentional injuries* raw count percentage	11 0.002	30 0.0027	24 0.0018	11 0.0012	3 0.0002
Road injuries** raw count percentage	7 0.0016	26 0.0022	22 0.0016	32 0.0033	13 0.00015
Cancer raw count percentage	2 0.00038	27 0.0012	41 0.0026	27 0.0029	68 0.008

nb: percentages within each quintile were calculated incorporating the survey weights

* gunshot wounds; severe trauma due to violence, assault, beating; intentional poisoning; accidental poisoning; fire and burn; crime related injury – left out sports related, disability related and other
** motor vehicle -occupant, motor vehicle – pedestrian, bicycle related

12. Distributing baseline deaths and cases and calculating probabilities

The deaths/cases (which come disaggregated by sex) at baseline is split between the five wealth quintiles using the GHS data to account for the socioeconomic gradient, as explained above. However, a preparatory step was necessary as the proportions of the population (using the SADHS proportions) in each quintile were not perfectly equal, for example for Q1, Q2, Q3, Q4, Q5 corresponded to 0.19, 0.19, 0.20, 0.21, 0.21 for females and 0.19, 0.20, 0.21, 0.20, 0.21 for males. The probability of death was calculated for each quintile first by assuming the population was split into quintiles of equal size. The total deaths/cases for each quintile using the SADHS proportions was then calculated by applying the relevant probability of death/cases for that part of the quintile which overlapped with the underlying equally sized quintile. This concept can be best illustrated on a graph.



$$Number_{cases}(SADHS_{Q1}) = Pop_{SADHSQ1} \times Prob_{EqualQ1}$$

$$Number_{cases}(SADHS_{Q2}) = (Pop_{EqualQ1} - Pop_{SADHSQ1}) \times Prob_{EqualQ1} + (Pop_{SADHSQ1} + Pop_{SADHSQ2} - Pop_{EqualQ1}) \times Prob_{EqualQ2}$$

$\ldots.\,and\ so\ on$

The existence of relative risk equations implies that the baseline mortality/morbidity will also not be distributed equally between drinker groups, one would expect a higher proportion of the baseline cases to exist amongst heavy drinkers, followed by occasional binge, moderate then abstainers. In order for the baseline mortality/morbidity to vary by drinker group the total risk, for each disease, is calculated for each drinker group group, by sex and wealth quintile. The proportional share of risk between drinker groups is then calculated and used to distribute the mortality/morbidity, which has already been assigned to each quintile, between each drinker group within that quintile.

The model uses iHME data for deaths and cases of disease and population statistics (Statistics South Africa) from 2018. Life tables to get the probability of death by single year of age were only available for 2017 from iHME so these were used. The 2018 population is split proportionally into the sex/wealth/drinker groups using the SADHS proportions.

The probability of death for each disease is calculated for the baseline scenario and taken away from overall probability of death for each single year of age given in the life table to give a probability of death from non-modelled causes. This probability of death from non-modelled causes remains constant at every policy scenario. The probability of death from the five diseases of interest then vary according to the policy level and the corresponding potential impact fraction.

We model counterfactual population structure (i.e. in the absence of the policy) over 20 years, starting from 2018 using current population estimates from Statistics South Africa, plus birth projections for 2020 to 2023 and assume current age-, sex- and wealth-specific mortality rates remain constant [13]. Birth cohorts for years beyond 2023 are not modelled as they would not have reached the age at which we model alcohol consumption (15+) within the time horizon.

We create multistate life tables in which the population faces a probability of mortality for each of the five disease/injury conditions and for other cause mortality each year. This approach allows us to simulate prevalence of and mortality from multiple diseases simultaneously, assuming diseases are independent of one another. The model generates alternative population impact fractions (as above) for baseline and for each policy scenario. Using the relevant population impact fraction and rerunning the multistate life table enables a calculation of the difference between baseline and the policy.

13. Baseline health and lagged health impact

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking immediately whereas the health impact on liver cirrhosis and breast cancer are subject to lags in the effect, meaning the reduced drinking does not translate to a reduced health risk immediately [14]. Breast cancer starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Appendix part 9).

The life tables for the 20 year time horizon are saved for each of the policy scenarios. They are then used in combination with the probability of having the disease and the potential impact fraction under each policy, to estimate the number of cases.

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking from the first year of the drinking reduction whereas liver cirrhosis and breast cancer are subject to lags in the effect. Breast cancer only starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Table 12).

Table 13: Modelled time-lags by condition – proportion of overall change in risk experienced in each year following a change in consumption (Holmes et al., 2012)

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Breast cancer	0	0	0	0	0	0	0	0	0	0	10	20	30	40	50	60	70	80	90	100
Liver Cirrhosis	21	34	43	50	56	61	65	69	73	76	79	82	85	88	90	92	94	96	98	100

14. Hospital multipliers and costs

The prevalence of disease/injury at each policy scenario for each year of the 20 year time horizon was multiplied by the proportion who would then go on to receive hospital treatment (Table 13) and the relevant hospital cost applied (Table 14). The costs taken from the literature were increased by inflation where necessary to reach the baseline year of 2018. Future costs were discounted at 5% as recommended by the Department of Health in the guidelines for pharmacoeconomic submissions [15].

Table 14: Estimated multiplier from population prevalence to hospital admission

Condition	Multiplier (cases in population who go on to receive healthcare treatment)	Source
HIV	0.62	UNAIDS estimates that 62% of people living with HIV in 2018 in South Africa were on treatment [16]
Intentional Injury	0.41	Survey estimating trauma admissions [17] combined with iHME data from the same year to predict multipliers.
Road injury	0.19	Survey estimating trauma admissions [17] combined with iHME data from the same year to predict multipliers.
Liver Cirrhosis	0.5	Paper on liver cirrhosis in sub-Saharan Africa suggests 50% of patients are admitted to hospital with end-stage liver disease [18].
Breast Cancer	0.75	All studies found estimate what proportion present with late stage breast cancer (51%) but not what proportion never receive hospital treatment [19]. Therefore an estimate of 0.75 is used.

Table 15: Hospital costs and sources

Condition	Cost per patient	Source
HIV	R 3,318.62 (2017/18)	This is the annual cost. Taken from a systematic literature review of per patient costs of HIV services in South Africa [20]. There are many different levels of treatment, this cost is only for first-line treatment, so this is conservative.
Intentional Injury	R58,928 (2013)	This retrospective case note review included 143 violence related emergency hospital admissions from January to March 2013. Average inpatient stay was 9.8 days with treatments including emergency surgery, intensive care and resuscitation beds on admission [21].
Road injury	R56,592.17 (2012)	A prospective cohort study followed 100 patients admitted following a Road traffic injury between late 2011 and early 2012 at Edendale Hospital Pietermartizburg [22].
Liver Cirrhosis	R2,967 (2018)	50% multiplier used above comes from paper suggesting 50% of liver cirrhosis patients get admitted to hospital with end stage liver disease. Treatment for end stage liver disease includes A specific study on liver cirrhosis was not found so general costs have been used from the district health baromenter. Expenditure per patient day equivalent (district hospitals) was R2967 (average taken from

		across the 9 provinces). This assumes just one patient day. Conservative. [23]
Breast Cancer	Early stage R14,915 Late stage R16,869 (2015)	This retrospective case review included 200 women at a government hospital in South Africa. The average cost is different depending on whether they were diagnosed at an early (56%) or late (44%) stage [24].

15. Sensitivity Analysis

Parameter	Central estimate	Alternative plausible values	Rationale	Results
Price elasticities	-0.53 moderate Q1, Q2 -0.31 moderate Q3, Q4, Q5 -0.29 occasional binge Q1, Q2 -0.17 occasional binge Q3, Q4, Q5 -0.24 heavy Q1, Q2 -0.14 heavy Q3, Q4, Q5			Central estimates Consumption - 4.40% Spend 18.09 % Lives saved 20,585 Cases saved 900,332
		Scenario 1 -0.40 moderate -0.22 occasional binge -0.18 heavy	Scenario 1 Applies estimates based only on drinker type, removing any wealth gradient.	Scenario 1 Consumption - 4.50% Spend 17.86% Lives saved 18,717 Cases saved 825,935
		Scenario 2 -0.5 for high income drinkers (applied to quintiles 3, 4, 5) -0.86 for low income drinkers (applied to quintiles 1,2 to be conservative)	Scenario 2 Estimates using NIDs data for two subsets of the population, the top 50% and bottom 50% of households by total household expenditure [10].	Scenario 2 Consumption - 14.16% Spend 5.4% Lives saved 52,419 Cases saved 2,331,362
		Scenario 3 -0.8	Scenario 3 Van Walbeek and Blecher [10] literature review of South African specific price elasticities found Selvanathan and Selvanathan [25] estimated -0.8 which corresponds closely to price elasticity estimates for beer (-0.8), wine (-0.9) and spirits (-0.9) produced by SALBA (2010).	Scenario 3 Consumption - 17.96% Spend 0.1 % Lives saved 64,494 Cases saved 2,891,284
Proportion of abstainers in the population	82% female non-drinkers 45% male non-drinkers	67% female non-drinkers 36% male non-drinkers	Stakeholders have indicated scepticism about the prevalence of non-drinking	Central estimates Consumption - 4.40% Spend 18.09 %

			reported in SADHS (and all alcohol studies). Currently the model only adjusts the consumption of those who report anything at all. We will increase the survey weightings of drinkers in the SADHS so that 67% of females do not drink and 36% of males. Based on a South African study which used both surveys and biomarkers [26].	Lives saved 20,585 Cases saved 900,332 Alternative scenario Consumption - 4.48% Spend 17.77% Lives saved 15,616 Cases saved 678,929
HIV baseline estimates	iHME 2018 estimates female 77,499 deaths 4,772,473 cases male 70,186 deaths 2,799,754 cases	Thembisa 2018 estimates female 35,487 deaths 4,542,677 cases male 36,345 deaths 2,578,747 cases	Stakeholders highlighted the difference between GBD estimates and local estimates for HIV deaths. The Thembisa model was built by local academics and is used by UNAIDs [27].	Central estimates Lives saved 20,858 Cases saved 900,332 HIV lives saved 10,229 HIV cases averted 429,205 Alternative scenario Lives saved 16,086 Cases saved 907,930 HIV lives saved 5,486 HIV cases averted 423,850
Socioeconomic gradients of ill health	HIV Q1 (poorest) – 20% Q2 – 36% Q3 – 32% Q4 – 9% Q5 – 3% Intentional Injury/Road Injury/Liver Cirrhosis Q1 – 9% Q2 – 29% Q3 – 26% Q4 – 26% Q5 – 10%	Scenario 1 Changing the liver cirrhosis gradient to match the one used for breast cancer	Scenario 1 Stakeholders indicated that for long-term conditions like cirrhosis wealthier groups could well be over-represented in SA. They suggested sensitivity analysis by applying values for a condition that is less concentrated amongst the poor.	Central estimates Liver cirrhosis lives saved/cases averted Q1 133 / 3,528 Q2 432 / 11,298 Q3 295 / 7,801 Q4 288 / 7,639 Q5 82 / 2,158 Scenario 1 Liver cirrhosis lives saved/cases averted Q1 95 / 2509 Q2 104 / 2722

	Breast cancer Q1 – 7% Q2 – 7% Q3 – 22% Q4 – 18% Q5 – 47%	Scenario 2 HIV Q1 (poorest) – 25% Q2 – 22% Q3 – 20% Q4 – 18% Q5 – 14% Intentional injury/ Road injury/Liver cirrhosis Q1 – 20% Q2 – 20% Q3 – 19% Q4 – 20% Q5 – 22% Breast cancer Q1 (poorest) – 21% Q2 – 21% Q3 – 20% Q4 – 19% Q5 – 18%	Scenario 2 Recent data from another South African survey is used to provide plausible alternative socioeconomic gradients across all the conditions used in the model [28].	Q3 235 / 6203 Q4 200 / 5316 Q5 359 / 9563 Central estimates aggregate lives saved / cases averted Q1 4,088 / 176,663 Q2 7,375 / 313,360 Q3 4000 / 177,604 Q4 3,759 / 167,934 Q5 1,364 / 64,771 Scenario 2 aggregate lives saved / cases averted Q1 2,858 / 127,516 Q2 5,246 / 225,067 Q3 5,758 / 255,667 Q4 3,153 / 139,2253 Q5 3,969 / 197,191
Discount rates for costs	5% discount rate	Scenario 1 0% discount rate	Discount rate was changed to 0%	Central estimate Health costs saved R6.88 billion Scenario 1 Health costs saved R11.10 billion

Homebrew switching	30%	Scenario 1 0% Scenario 2 100%	The assumption that drinkers will make up 30% of the reduction in drinking recorded alcohol with homebrew comes from consultation with the stakeholders at workshop two. To test the importance of this assumption on the results a null impact and a 100% impact are introduced. 100% would mean that any homebrew drinkers will not receive any positive health impacts from the policy as all of their reduction in recorded alcohol will be replaced with homebrew alcohol.	Central estimate Consumption - 4.40% Lives saved 20,585 Cases saved 900,332 Scenario 1 Consumption - 4.56% Lives saved 21,479 Cases saved 937,507 Scenario 2 Consumption - 4.03 % Lives saved 19,156 Cases saved 844,471

16. Healthcare cost savings by quintile

Table 16: Health care costs for each of the three policy scenarios split by wealth quintile

	Q1	Q2	Q3	Q4	Q5
R5 MUP					
HIV	-R0.01	-R0.07	-R0.04	-R0.03	-R0.01
Intentional injury	R1.41	R5.22	R5.42	R12.8	R7.72
Road injury	R0.71	R2.73	R2.80	R6.39	R3.82
Liver cirrhosis	R0.02	R0.12	R0.11	R0.27	R0.14
cancer	R0.00	R0.00	R0.01	R0.05	R0.15
R10 MUP					
HIV	R162.00	R291.00	R71.10	R8.72	R33.3
Intentional injury	R495.57	R801.23	R1150.94	R1487.35	R369.03
Road injury	R232.98	R399.34	R520.70	R658.80	R163.64
Liver cirrhosis	R3.03	R9.64	R6.62	R6.45	R1.86
cancer	R0.30	R0.22	R0.80	R0.93	R1.75
R15 MUP					
HIV	R403.19	R618.29	R190.50	R79.85	R64.67
Intentional injury	R1136.23	R2029.50	R2558.09	R2350.20	R1014.96
Road injury	R536.83	R1013.46	R1173.35	R1080.17	R4618.76
Liver cirrhosis	R7.42	R23.50	R17.60	R15.20	R4.51
cancer	R0.76	R0.65	R2.24	R2.30	R4.65

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Contents

Supplementary Material

Price to consumption

Our model starts by estimating mean and peak alcohol consumption at current alcohol prices at the individual level. The proportion of alcohol consumption which is homebrew is also estimated. This process utilised both alcohol frequency questions and seven day recall questions asked in the same survey. As survey data significantly underreports consumption we calibrate these estimates to market research data using statistical methods established in the literature [1-3]. Following the shift of mean consumption, peak consumption is re-estimated using a simple regression model created at baseline. We categorise drinkers into three exhaustive and mutually exclusive groups; moderate (less than 15 standard drinks per week); occasional binge (less than 15 drinks per week but more than 5 on one occasion); and heavy (15 or more drinks per week). A standard drink in South Africa is currently 15ml or 12 grams of pure ethanol. We compute a regression model for wealth quintiles using the South African Demographic and Health Survey (SADHS) data and use it to predict wealth quintiles in the International Alcohol Control (IAC) dataset to generate price distributions for wealth and drinker groups. Alcohol is treated as one commodity due to data constraints.

1. Estimating baseline consumption using South African Demographic and Health Survey (SADHS)

The SADHS survey asked the following questions:

Table 1: Survey questions

Survey	**Alcohol questions** **[answers]**
SADHS 2016	Have you ever consumed a drink that contains alcohol such as beer, wine, ciders, spirits, or sorghum beer? Probe: Even one drink? [yes, no] Was this within the last 12 months? [yes, no] In the last 12 months, how frequently have you had at least one drink? [5 or more days a week, 1-4 days per week, 1-3 days a month, less often than once a month] During each of the last 7 days, how many standard drinks did you have? [use showcard, record total number of drinks consumed each day starting with the day before the day of the interview and proceeding backwards] During the last 7 days, how many standard home-made beers or other homemade alcohol did you have? [use showcard, record number] In the past 30 days, have you consumed five or more standard drinks on at least one occasion? [yes, no]

Process of adjusting the SADHS estimates

Drinkers were categorised by their drinking frequency and by whether or not they had reported any drinking in the last seven days.

Table 2: Frequency of alcohol consumption responses

Drinking occasion frequency	count	Reported drinks in last 7 days	Reported zero drinks in last 7 days
5 or more days a week	293	266	27 (6 binge, 21 drinker)
1-4 days per week	668	565	103 (29 binge, 74 drinker)
1-3 days per month	1163	799	364 (all drinkers)
less often than once a month	1187	404	783 (all drinkers)
NA	7025		

Readjusting those with a seven day drinking pattern (pink numbers)

The pink numbers are respondents who say they only drink 1 -3 days per month or less often than once a month but have drunk in the last 7 days. If this were multiplied by 52 it would be an overestimate. Therefore, we assumed for those that drink 1-3 days per month we have captured their one drinking week in the month and multiply by 12 to get their annual consumption. There are 799 people in this category. We assumed for those who drink less often than once a month but who did drink in the last week we have caught their one drinking week that occurs every two months. We multiplied by six, to get the annual figure. There are 404 people in this category. The yellow numbers do not require adjustment as respondents report drinking every week and have a seven day drinking pattern.

Readjusting those without a seven day drinking pattern but who say they drink (blue and red numbers)

For those with a drink frequency of five or more days per week we used the mean standard drinks for drinkers who reported the same frequency but who do have a seven day pattern, there are 27 people that this applies to (blue).

For those with a drink frequency of 1 – 4 days per week we used the mean standard drinks for drinkers who report the same frequency but who do have a seven day pattern, there are 103 people in this group (blue).

For those with a drink frequency of 1 – 3 days per month we used the mean adjusted annual drinks (adjusted in 2.2.1.3.1) of the equivalent frequency group who did report a drinking pattern. There are 364 drinkers in this group (red).

All of the above estimates were computed for sex and binge drinking subgroups.

For those with a drink frequency of less than once per month we used the mean adjusted annual drinks (adjusted in 2.2.1.3.1) of the equivalent frequency group who did report a drinking pattern. This is computed for subgroups based on sex and binge drinking. There are 783 people in this group (red)

Process of adjusting peak drinks

Using the same process as above we applied a peak drink to those observations without one. As an additional check we validated that all those reporting binge drinking had a peak drink at minimum of 5.

Comparing the adjusted SADHS data with the estimates using only 7 day recall as expected prevalence of drinking increases and per capita estimates reduce (Table 6). The prevalence estimates are now broadly similar to the NiDs and GISAH estimates (Table 3).

Table 3: Comparing adjusted with unadjusted statistics

	Prevalence of drinking		Sample size: drinkers	Annual litres of alcohol - per capita			Annual litres of alcohol - Just drinkers		
	Female	Male		Total	Female	Male	Total	Female	Male
SADHS (7 day recall only) Population weights applied	9.3%	32.7%	n = 1949 (report drinks in the 7 day recall) females = 571 males = 1378	2.2	0.65	4.5	10.6	6.54	12.2
SADHS adjusted (7 day recall plus adjustments based on frequency questions) Population weights applied	18%	54%	n = 3311 females = 1125 males = 2186	1.65	0.50	3.4	5.0	2.59	6.25

Figure 1: Density plot of female drinkers before and after the shift

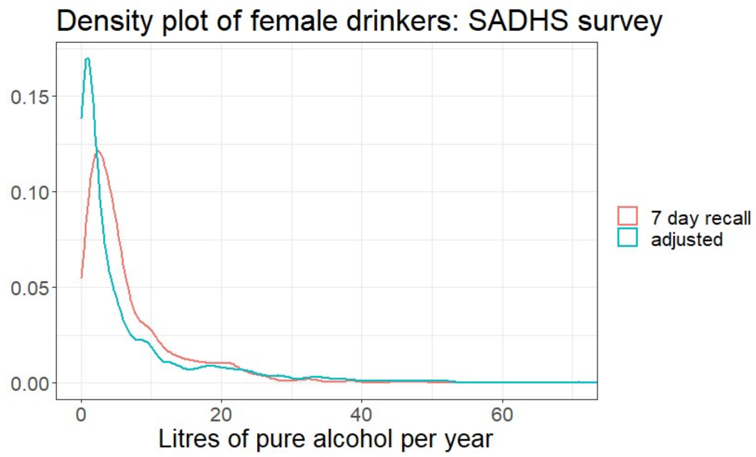
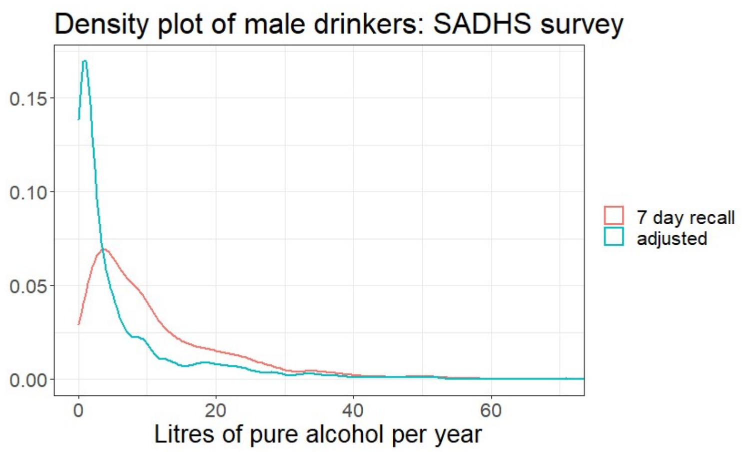


Figure 2: Density plot of male drinkers before and after the shift



Incorporating the frequency data into the seven day recall moves the distribution towards the left (Figures 1 and 2). This is logical as the sample will now include those drinkers who stated that they drink but did not record any for the last seven days, it also adjusted down those who claim to drink less than weekly but who did recall drinks for the last seven days. This pattern gives some confidence in the dataset and utilises the strengths of capturing heavy drinking well and including occasional drinkers.

2. Uplifting consumption

Surveys provide important data about drinking patterns within the population but total consumption estimates are far smaller than that indicated by administrative sources [4]. As this is a global phenomenon there are established statistical calibration methods in the academic literature. The steps are broadly as follows:

- compute the ratio between survey and sales per capita consumption (known as coverage)
- use this ratio to adjust the mean for each subpopulation of interest
- use the new mean to estimate an associated standard deviation based on a published relationship, estimated using regression on a large global dataset [2]

$$\hat{\sigma}_{shi} = 1.174 \times \hat{\mu}_{shi} + 1.003 \times female$$

- use the new mean and standard deviation to generate the shape and rate parameters and fit a gamma distribution

This method relies on three assumptions. Firstly that the sales data accurately reflects per capita consumption. Secondly, that the true proportion of abstainers has been captured by the survey, and finally that under-estimation of consumption is the same across all population groups.

Two additional key limitations have been identified with regards to this method. Firstly, there is no empirical evidence that under-coverage is distributed as implied by the shifts needed to fit the adjusted consumption to the gamma. Secondly, that shifting consumption to a gamma can artificially reduce the long tail of heavy drinkers [3]. To address the second point a proposed method is to fit a gamma distribution to the survey and for each percentile of the distribution calculate the percentage consumption increase and apply these percentage shifts to the corresponding percentile of the survey data.

The following steps outline, in detail, how we calibrated the SADHS dataset to Euromonitor figures:

- First a cap was applied to all drinkers of 68 litres of alcohol per year or 150 grams of alcohol per day. As the model includes long term effects (20 years) the cap is needed as a higher level of alcohol cannot be sustained in the long term [5]. This cap impacted one woman and ten men. Of this small group only two men drunk both homebrew and recorded alcohol and so their total consumption was reduced to 68 litres and then split into recorded and homebrew using their previous percentage split.

- Survey coverage level was calculated as the difference between total per capita consumption recorded in the SADHS survey and per capita consumption using Euromonitor recorded sales data for 2018. 80% of the sales data is used to account for spillage, stockpiling and tourist consumption. This sales figure was then increased to take account of the 4.15% of total alcohol consumed in the SADHS survey reported as homebrew (representing unrecorded alcohol in the model). The comparison of total consumption according to the survey and the adjusted official sales data was used to calculate a coverage of 27%.

- For female and male subgroups the mean litres of alcohol was adjusted by the multiplication factor. This adjusted mean was used to estimate an associated standard deviation based on a previously established relationship between the two. These were then used to fit a "shifted" gamma distribution (maintaining the cap of 68 litres), calculated for male and females separately.

- A gamma distribution was fitted to the original sample of drinkers, by sex, and percentiles were taken across this and the shifted distribution. Percentage differences in consumption were calculated. These increases were then applied to the percentiles of the original survey sample.

- Each individual's total consumption was split into homebrew and recorded alcohol using the original percentage split (this assumes underreporting is equal across homebrew and recorded alcohol).

- Results were compared visually and via a table (Table 7 and Figures 8 and 9). There is a small difference between the two methods, more visible for males than females. It appears adjusting by percentiles only makes a difference at the extremes, lowering the left hand peak slightly but also falling below the Gamma shifted distribution after 60 litres of alcohol per year for men meaning there is a smaller number of the very high drinkers.

The percentile adjusted distribution was used for the main model base on expert opinion.

Table 4: Comparing pre and post shift data

Females – litres of alcohol per year	Mean	Min	Max
SADHS Survey data (weighted mean and capped)	2.57	0.09	68
Gamma fitted to survey (difference due to weights)	2.50	0.09	68
Gamma shift	10.78	1	68
Adjusting each percentile (weighted mean)	10.74	0.5	68
Males – litres of alcohol per year			
SADHS Survey data (weighted mean and capped)	6.13	0.09	68
Gamma fitted to survey (difference due to weights)	5.6	0.09	68
Gamma distribution shifted	18.55	1	68
Adjusting each percentile (weighted mean)	19.2	0.5	68

Figure 3: Comparing distributions pre and post shift females

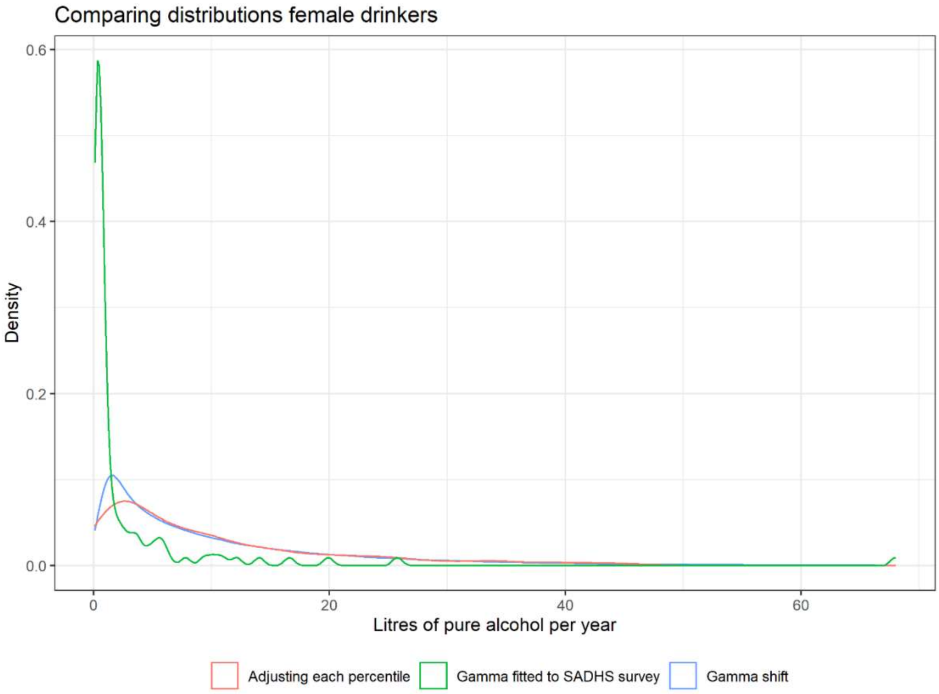
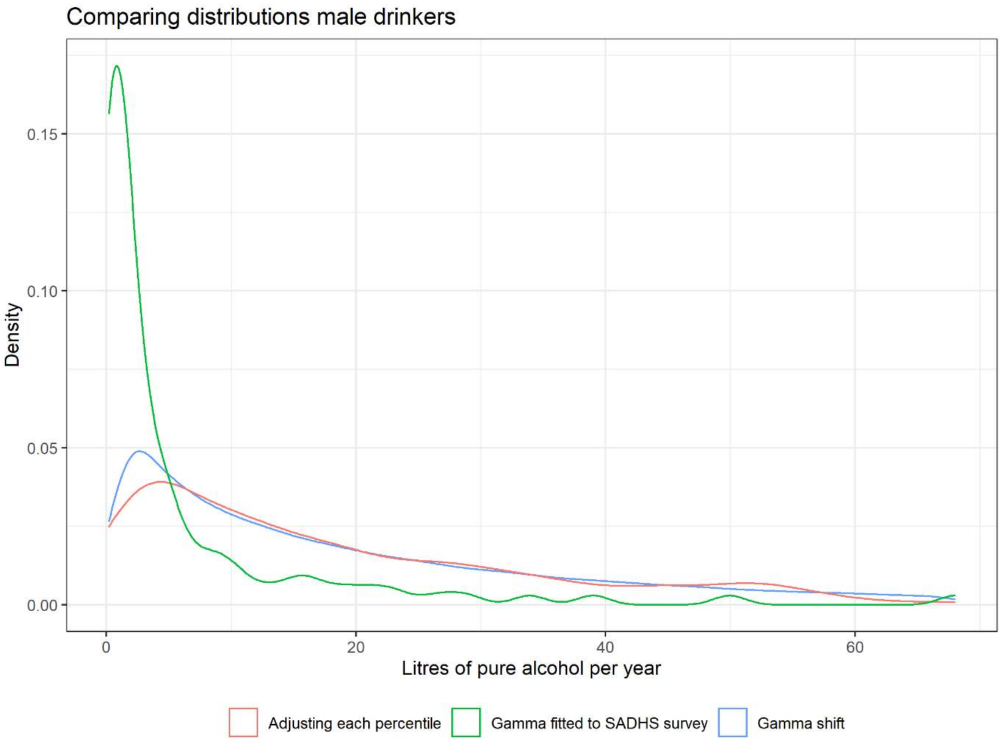


Figure 4: Comparing distributions pre and post shift males



3. Uplifting peak consumption

Peak drinking measures the highest number of drinks consumed on a single drinking occasion and therefore relates to intoxication which is associated with harms such as road injury, interpersonal violence and self-harm. Following the method used in the Sheffield Alcohol Policy Model [6], the following linear regression model was fitted, for all drinkers, to the non-shifted SADHS data, relating peak drinking to mean consumption, age and sex.

$$peak_{\ ij}(SADHS) = \beta_0 + \ \beta_1 \times ageband + \ \beta_2 \ \times sex$$

The model was used to compute fitted values for the non-shifted data. The model assumes there is a linear relationship between peak and mean consumption, the magnitude of which is allowed to vary by age and sex.

After the mean consumption was shifted as above the corresponding new peak consumption was computed using the following formula:

$$peak_{\ ij}(shifted) = \mathrm{peak}_{ij}\ (SADHS) \times \left(\frac{E(peak_{ij}(shifted))}{E(peak_{ij}(SADHS))}\right)$$

The linear relationship between mean and peak estimated from the SADHS survey is maintained for the shifted mean and peak consumption, this assumes individuals under reported peak and mean consumption by the same magnitude. The method also assumes the prediction error for the model is of the same magnitude for all levels of consumption.

The predictions were checked to ensure that peak estimates were not below mean daily drinking. There were 88 people (out of the 3311 drinkers) for whom this was true. These people had their peak drinking increased to match their mean daily drinking.

4. Wealth quintiles

In order to match wealth groups between the two datasets an ordered choice model was created using SADHS data with wealth quintile (1 – 5) as the dependent variable, using the MASS package in R [7]. Wealth groups were chosen as the best available measure to capture socioeconomic status that allowed us to match between the SADHS and IAC dataset. Although income was asked in the IAC dataset many of the respondents refused to answer resulting in a very small sample.

All the variables that were common across the two datasets were included in the initial model, these were not just asset ownership but also age, sex, educational level and population group (race). Stepwise regression was performed using the step.AIC function. This chooses the best variables to include by running the regression with all variables in and then taking one out and computing a goodness of fit measure (the AIC). If the goodness of fit measure is improved then that model is preferred, it runs this for many models until it finds the model with the highest AIC. This method resulted in the selection of the following variables: age, sex, population group, education level, car, landline, electricity, fridge, computer, radio, tv. The only variable it removed was mobile phone which fitted anecdotally with conversations we had with stakeholders in South Africa regarding how much poorer people prioritise mobile phones.

The goodness of fit matrix evaluates the success of the model, comparing the closeness of the predicted and observed outcome (Table 5). The model never predicts the poorest as the richest or the richest as the poorest.

Table 5: Goodness of fit matrix

		Prediction				
Actual		Poorest	Poorer	Middle	Richer	Richest
	Poorest	1300	593	196	9	0
	Poorer	299	975	744	192	17
	Middle	62	612	1042	595	26
	Richer	5	236	763	818	244
	Richest	0	10	108	422	1068

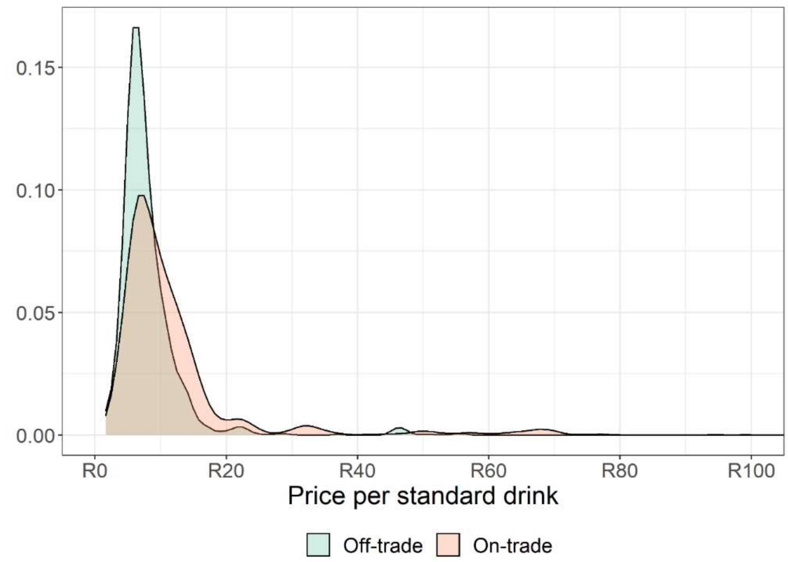
5. International Alcohol Control Study 2014 for prices

The IAC dataset provides prices by drinking location by beverage, by container size and also asks whether the individual binge drinks, demographic data is also collected. The survey asked for the price in Rands by location, for example they ask for the price of a beer paid at a pub for each container size. There are 17 drinking locations (12 on trade and 5 off trade) and 12 drink types. On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).

Prices were disaggregated by population subgroups rather than by drink type (wine/beer/spirits etc). This was consistent with the South Africa specific price elasticities which were calculated for drinker groups whilst treating alcohol as a single commodity. The IAC respondents were categorised into drinker groups using the definitions above. Each price was weighted by the number of units (e.g. bottles, glasses, cans) sold, the container size of those units and the number of drinking occasions in 6 months (Figure 5). Every price observation was validated using data from the South African Consumer Price Index. Prices were increased to 2018 to account for inflation.

Figure 5: Distribution of off-trade and on-trade prices, standard drink is 15ml or 12grams of pure ethanol.

On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).



The off-trade wine prices were adjusted using data from the South Africa Wine Industry Statistics [8] who report the proportions of still wine sold (which makes up 93% of total volume of wine sold) in the off-trade in 2018 that falls within different price bands, this data was used to adjust downwards the off-trade wine (Table 6). The price observations were sorted in ascending order and a cumulative volume variable created. The price closest to the 49th percentile was then adjusted down to R3.74 and all prices below adjusted using the same proportion. The prices at the very bottom were adjusted so they could not go below R2.50. The same adjustment process was applied to each of the four groups.

Table 6: Price distribution for off-trade wine

Retail price per litre of wine for 2018	Price per standard drink (15ml) assuming 12% abv	Cumulative percentage of total still wine sold at price SAWIS data	Cumulative percentage of IAC data for off-trade wine pre-adjustment	Cumulative percentage of IAC data for off-trade wine post-adjustment
Less than R30	Less than R3.75	49%	33%	51%
> R30 – R48	> R3.75 – R6	82%	60%	83%
> R48 - R72	> R6 – R9	89%	77%	89%
> R72 - 108	> R9 – R13.5	95%	89%	95%
> R108	> R13.5	100%	100%	100%

As the Tschwane prices were collected in one locality, they were validated against national data sources. Beer is by far the most popular drink, accounting for over 50% of the alcohol sold so beer prices are critical. We accessed data from the South Africa Consumer Price Index for January 2020 to compare the Gauteng province (where Tshwane is located) with other provinces. Beer, which accounts for over 50% of alcohol sold in South Africa, Guateng is at R13.76 for a 330ml can. The average across the eight prices listed above is R13.66 which is very close to Guateng's price, therefore we assume the same price distributions across the whole of South Africa.

Finally, prices were validated with all stakeholders including individuals resident in townships who could provide anecdotal evidence relating to cheap alcohol available at shebeens.

6. Base prices by subgroup

All IAC drinkers were now categorised by drinker type and by wealth quintile (Table 7). Wealth quintile was predicted using the ordered choice model created using the SADHS data. Drinkers in the lowest wealth quintile appear the least likely to drink in moderation leaving a very small sample size (this is not weighted by number of drinks). It is therefore not possible to create price distributions for all 15 categories.

Table 7: Count of IAC price observations and respondents within each category

	Moderate obs (individuals)	Occasional Binge obs (individuals)	Heavy obs (individuals)
Poorest	2 (2)	29 (23)	35 (24)
Poorer	8 (8)	23 (18)	28 (20)
Middle	11 (11)	132 (90)	88 (40)
Richer	23 (20)	95 (59)	60 (30)
Richest	93 (68)	135 (93)	101 (50)

The mean price for each of these drinker categories demonstrates there is wealth gradient (Table 8).

Table 8 Mean price of standard alcoholic drink (15ml of pure alcohol) for each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R6.79	R7.97	R7.78
Poorer	R9.43	R10.0	R9.65
Middle	R10.2	R10.1	R9.23
Richer	R11.3	R13.4	R10.6
Richest	R11.7	R11.1	R12.8

In order to ensure adequate sample size the poorest/poorer/middle and richer/richest categories were aggregated for moderate drinkers (Table 9). This represents the final group of prices used in the model.

Table 9 Mean price of standard alcoholic drink (15ml of pure alcohol) within each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R9.13	R7.97	R7.78
Poorer	R9.13	R10.0	R9.65
Middle	R9.13	R10.1	R9.23
Richer	R11.6	R13.4	R10.6
Richest	R11.6	R11.1	R12.8

7. Adjusting the elasticities

The starting point for elasticities -0.4, -0.22 and -0.18 for moderate, occasional binge and heavy drinkers respectively [9]. We adjusted these elasticities to incorporate an income gradient using -0.86 and -0.5 elasticity for low and high socioeconomic status [10]. To remain on the conservative side we will count the bottom two quintiles as low SES and the top three as high.

Table 10: Elasticities by wealth and drinker group

Drinker type	Q1	Q2	Q3	Q4	Q5
Moderate	-0.53	-0.53	-0.31	-0.31	-0.31
Occasional binge	-0.29	-0.29	-0.17	-0.17	-0.17
Heavy drinkers	-0.24	-0.24	-0.14	-0.14	-0.14

8. Individual spend, tax and retail revenue

Alcohol consumption expenditure
The total retail spend at baseline, and each scenario, was computed by adding up all the individual spends multiplied by their population weights. When the SADHS consumption estimates were shifted to calibrate to market research data only 80% of the consumption figure was used to take account of spillage, stockpiling and tourism, but the 20% of alcohol remains in the headline sales revenue. Therefore to make it comparable we estimate the total sales revenue by increasing the modelled alcohol consumption revenue by 1.25 (100/80).

Government revenue, VAT, excise tax and retail revenue
The following steps outline how we computed government and retail revenue:

1. Calculate VAT by assuming 15% of the base retail spend is VAT
2. Import 2018 base excise tax from Treasury Budget Report [11]
3. Calculate total volume consumed of alcohol at all four scenarios (baseline/R5/R10/R15)
4. Calculate the percentage change in volume from baseline for each of the three policies
5. Apply the percentage change in volume to base excise tax (we assume a fixed ratio between volume and excise tax)
6. Calculate retail revenue by: spend - vat - excise tax

It is likely this is a conservative approach to modelling excise tax revenue as generally the cheaper alcohol, which this policy targets, generates a lower proportion of excise tax than the more expensive, so we can consider this a lower band on the excise tax revenue.

Consumption to harm

9. Relative risks

Relative risks were calculated for each of the health outcomes of interest at baseline, and each policy scenario using published relative risk equations [12,13]. The same relative risk equations are used for morbidity (or prevalence) and mortality. HIV risk is derived from a stepped function for mean drinking differing by socioeconomic status, intentional injuries and road injury from a continuous function of mean drinking differing by whether the individual binge drinks, liver cirrhosis and breast cancer from a continuous function of mean drinking, for breast cancer this is only for females (Table 10).

Table 11: Relative risk equations used

Health Condition	**Relative risk Current drinkers**	**Relative risk former drinkers**	**ICD-10 codes**
HIV	Low SES $RR = 2.99$ if x > 61/49 grams per day (males/females) $RR = 1.94$ if x > 0 $RR = 1$ otherwise Higher SES $RR = 1.54$ if x > 61/49 grams per day (males/females) $RR = 1$ otherwise	RR = 1	B20-24
Intentional Injuries **(self-harm and interpersonal violence)**	Drinkers $RR = \exp(00199800266267306\,.\,x)$ Heavy episodic drinkers (HED) $RR = \exp(00199800266267306\,.\,x + 0.647103242058538)$	RR = 1	ICD-10 codes: X60 – Y09 Y35 –36 Y870 Y871
Road Injury **(pedestrian, cyclist, motorcyclist, motor vehicle, other road)**	Drinkers $RR = \exp(0.00299550897979837\,.\,x)$ Heavy episodic drinking $RR = \exp(0.00299550897979837\,.\,x + 0.959350221334602)$	RR = 1	V01–04, V06, V09–80, V87, V89, V99
Breast Cancer	Females only $RR = \exp(0.01018\,.\,x)$	RR = 1	C50
Liver	if x <= 1 $1 + x.\exp((\beta_1 + \beta_2)\,.\sqrt{\frac{1 + 0.1699981689453125}{100}})$ If x > 1 $\exp((\beta_1 + \beta_2)\,.\sqrt{\frac{x + 0.1699981689453125}{100}})$	RR = 3.26 for both females and males	K70, K74

	Female b1 = 2.351821 b2 = 0.9002139 Male b1 = 1.687111 b2 = 1.106413		
x = grams of alcohol consumed per day among current drinkers HED = drinking 60 grams or more on one drinking occasion			

10. Potential impact fractions

Potential impact fractions (PIFs) were calculated by dividing relative risk under each policy by relative risk at baseline. These incorporated population weights and were computed by sex *(i)*, wealth group *(j)* and drinker group *(k)*.

$$PIF_{ijk} = \frac{\text{relative risk}_{ijk}\text{ (policy)}}{\text{relative risk}_{ijk}\text{ (baseline)}}$$

11. Socioeconomic gradients of ill health

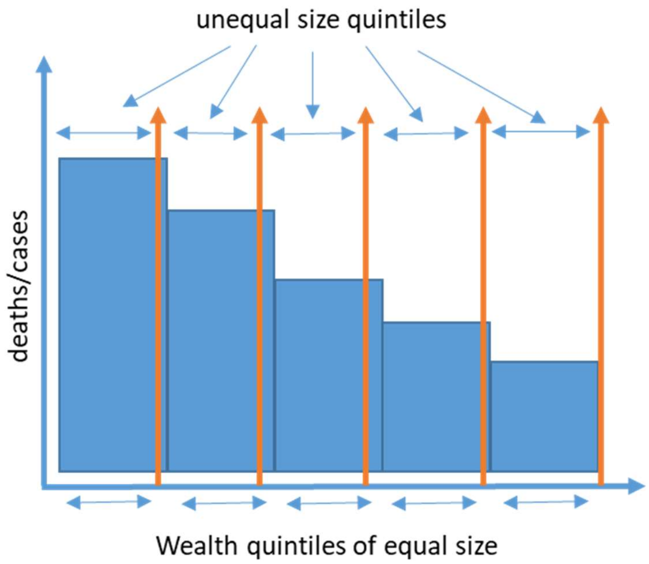
Health outcomes in South Africa are not evenly distributed throughout the population, with the poor often bearing a higher burden of disease, depending on the illness. Data analysis was carried out using General Household Survey (GHS) data for 2018. The ordered choice regression model computed previously, using SADHS data, was applied to the GHS data to split the survey population into wealth quintiles compatible with the foundational dataset (SADHS). Percentage within each wealth quintile with the disease was computed (Table 11). Liver cirrhosis was not one of the health conditions included in the survey and breast cancer was not specifically included although the broader category of cancer was. Sensitivity analysis was carried out using alternative gradients.

Table 12: Raw count of General Household Survey data 2018

	poorest	poorer	middle	richer	richest
15+ raw count (648 NAs)	4966	11462	14396	9633	7630
HIV raw count percentage	395 0.08	684 0.06	614 0.04	155 0.02	41 0.005
Intentional injuries* raw count percentage	11 0.002	30 0.0027	24 0.0018	11 0.0012	3 0.0002
Road injuries** raw count percentage	7 0.0016	26 0.0022	22 0.0016	32 0.0033	13 0.00015
Cancer raw count percentage	2 0.00038	27 0.0012	41 0.0026	27 0.0029	68 0.008
nb: percentages within each quintile were calculated incorporating the survey weights * gunshot wounds; severe trauma due to violence, assault, beating; intentional poisoning; accidental poisoning; fire and burn; crime related injury – left out sports related, disability related and other ** motor vehicle -occupant, motor vehicle – pedestrian, bicycle related					

12. Distributing baseline deaths and cases and calculating probabilities

The deaths/cases (which come disaggregated by sex) at baseline is split between the five wealth quintiles using the GHS data to account for the socioeconomic gradient, as explained above. However, a preparatory step was necessary as the proportions of the population (using the SADHS proportions) in each quintile were not perfectly equal, for example for Q1, Q2, Q3, Q4, Q5 corresponded to 0.19, 0.19, 0.20, 0.21, 0.21 for females and 0.19, 0.20, 0.21, 0.20, 0.21 for males. The probability of death was calculated for each quintile first by assuming the population was split into quintiles of equal size. The total deaths/cases for each quintile using the SADHS proportions was then calculated by applying the relevant probability of death/cases for that part of the quintile which overlapped with the underlying equally sized quintile. This concept can be best illustrated on a graph.



$$Number_{cases}(SADHS_{Q1}) = Pop_{SADHSQ1} \times Prob_{Equal}$$

$$Number_{cases}(SADHS_{Q2}) = (Pop_{EqualQ1} - Pop_{SADHSQ1}) \times Prob_{EqualQ1} + (Pop_{SADHS} + Pop_{SADHSQ2} - Pop_{EqualQ1}) \times Prob_{EqualQ2}$$

$\ldots.\ and\ so\ on$

The existence of relative risk equations implies that the baseline mortality/morbidity will also not be distributed equally between drinker groups, one would expect a higher proportion of the baseline cases to exist amongst heavy drinkers, followed by occasional binge, moderate then abstainers. In order for the baseline mortality/morbidity to vary by drinker group the total risk, for each disease, is calculated for each drinker group group, by sex and wealth quintile. The proportional share of risk between drinker groups is then calculated and used to distribute the mortality/morbidity, which has already been assigned to each quintile, between each drinker group within that quintile.

The model uses iHME data for deaths and cases of disease and population statistics (Statistics South Africa) from 2018. Life tables to get the probability of death by single year of age were only available for 2017 from iHME so these were used. The 2018 population is split proportionally into the sex/wealth/drinker groups using the SADHS proportions.

The probability of death for each disease is calculated for the baseline scenario and taken away from overall probability of death for each single year of age given in the life table to give a probability of death from non-modelled causes. This probability of death from non-modelled causes remains constant at every policy scenario. The probability of death from the five diseases of interest then vary according to the policy level and the corresponding potential impact fraction.

We model counterfactual population structure (i.e. in the absence of the policy) over 20 years, starting from 2018 using current population estimates from Statistics South Africa, plus birth projections for 2020 to 2023 and assume current age-, sex- and wealth-specific mortality rates remain constant [14]. Birth cohorts for years beyond 2023 are not modelled as they would not have reached the age at which we model alcohol consumption (15+) within the time horizon.

We create multistate life tables in which the population faces a probability of mortality for each of the five disease/injury conditions and for other cause mortality each year. This approach allows us to simulate prevalence of and mortality from multiple diseases simultaneously, assuming diseases are independent of one another. The model generates alternative population impact fractions (as above) for baseline and for each policy scenario. Using the relevant population impact fraction and rerunning the multistate life table enables a calculation of the difference between baseline and the policy.

13. Baseline health and lagged health impact

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking immediately whereas the health impact on liver cirrhosis and breast cancer are subject to lags in the effect, meaning the reduced drinking does not translate to a reduced health risk immediately [15]. Breast cancer starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Appendix part 9).

The life tables for the 20 year time horizon are saved for each of the policy scenarios. They are then used in combination with the probability of having the disease and the potential impact fraction under each policy, to estimate the number of cases.

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking from the first year of the drinking reduction whereas liver cirrhosis and breast cancer are subject to lags in the effect. Breast cancer only starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Table 12).

Table 13: Modelled time-lags by condition – proportion of overall change in risk experienced in each year following a change in consumption (Holmes et al., 2012)

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Breast cancer	0	0	0	0	0	0	0	0	0	0	10	20	30	40	50	60	70	80	90	100
Liver Cirrhosis	21	34	43	50	56	61	65	69	73	76	79	82	85	88	90	92	94	96	98	100

14. Hospital multipliers and costs

The prevalence of disease/injury at each policy scenario for each year of the 20 year time horizon was multiplied by the proportion who would then go on to receive hospital treatment (Table 13) and the relevant hospital cost applied (Table 14). The costs taken from the literature were increased by inflation where necessary to reach the baseline year of 2018. Future costs were discounted at 5% as recommended by the Department of Health in the guidelines for pharmacoeconomic submissions [16]. All sources were sense checked with a South African stakeholder with health economics expertise.

Table 14: Estimated multiplier from population prevalence to hospital admission

Condition	Multiplier (cases in population who go on to receive healthcare treatment)	Source
HIV	0.62	UNAIDS estimates that 62% of people living with HIV in 2018 in South Africa were on treatment [17]
Intentional Injury	0.41	Survey estimating trauma admissions [18] combined with iHME data from the same year to predict multipliers.
Road injury	0.19	Survey estimating trauma admissions [18] combined with iHME data from the same year to predict multipliers.
Liver Cirrhosis	0.5	Paper on liver cirrhosis in sub-Saharan Africa suggests 50% of patients are admitted to hospital with end-stage liver disease [19].
Breast Cancer	0.75	All studies found estimate what proportion present with late stage breast cancer (51%) but not what proportion never receive hospital treatment [20]. Therefore an estimate of 0.75 is used.

Table 15: Hospital costs and sources

Condition	Cost per patient	Source
HIV	R 3,318.62 (2017/18)	This is the annual cost. Taken from a systematic literature review of per patient costs of HIV services in South Africa [21]. There are many different levels of treatment, this cost is only for first-line treatment, so this is conservative.
Intentional Injury	R58,928 (2013)	This retrospective case note review included 143 violence related emergency hospital admissions from January to March 2013. Average inpatient stay was 9.8 days with treatments including emergency surgery, intensive care and resuscitation beds on admission [22].
Road injury	R56,592.17 (2012)	A prospective cohort study followed 100 patients admitted following a Road traffic injury between late 2011 and early 2012 at Edendale Hospital Pietermartizburg [23].
Liver Cirrhosis	R2,967 (2018)	50% multiplier used above comes from paper suggesting 50% of liver cirrhosis patients get admitted to hospital with end stage liver disease. Treatment for end stage liver disease includes A specific study on liver cirrhosis was not found so general costs have been used from the district health baromenter. Expenditure per patient day equivalent (district hospitals) was R2967 (average taken from

		across the 9 provinces). This assumes just one patient day. Conservative. [24]
Breast Cancer	Early stage R14,915 Late stage R16,869 (2015)	This retrospective case review included 200 women at a government hospital in South Africa. The average cost is different depending on whether they were diagnosed at an early (56%) or late (44%) stage [25].

15. Sensitivity Analysis

Parameter	Central estimate	Alternative plausible values	Rationale	Results
Price elasticities	-0.53 moderate Q1, Q2 -0.31 moderate Q3, Q4, Q5 -0.29 occasional binge Q1, Q2 -0.17 occasional binge Q3, Q4, Q5 -0.24 heavy Q1, Q2 -0.14 heavy Q3, Q4, Q5			Central estimates Consumption - 4.40% Spend 18.09 % Lives saved 20,585 Cases saved 900,332
		Scenario 1 -0.40 moderate -0.22 occasional binge -0.18 heavy	Scenario 1 Applies estimates based only on drinker type, removing any wealth gradient.	Scenario 1 Consumption - 4.50% Spend 17.86% Lives saved 18,717 Cases saved 825,935
		Scenario 2 -0.5 for high income drinkers (applied to quintiles 3, 4, 5) -0.86 for low income drinkers (applied to quintiles 1,2 to be conservative)	Scenario 2 Estimates using NIDs data for two subsets of the population, the top 50% and bottom 50% of households by total household expenditure [10].	Scenario 2 Consumption - 14.16% Spend 5.4% Lives saved 52,419 Cases saved 2,331,362
		Scenario 3 -0.8	Scenario 3 Van Walbeek and Blecher [10] literature review of South African specific price elasticities found Selvanathan and Selvanathan [26] estimated -0.8 which corresponds closely to price elasticity estimates for beer (-0.8), wine (-0.9) and spirits (-0.9) produced by SALBA (2010).	Scenario 3 Consumption - 17.96% Spend 0.1 % Lives saved 64,494 Cases saved 2,891,284

Proportion of abstainers in the population	82% female non-drinkers 45% male non-drinkers	67% female non-drinkers 36% male non-drinkers	Stakeholders have indicated scepticism about the prevalence of non-drinking reported in SADHS (and all alcohol studies). Currently the model only adjusts the consumption of those who report anything at all. We will increase the survey weightings of drinkers in the SADHS so that 67% of females do not drink and 36% of males. Based on a South African study which used both surveys and biomarkers [27].	Central estimates Consumption - 4.40% Spend 18.09 % Lives saved 20,585 Cases saved 900,332 Alternative scenario Consumption - 4.48% Spend 17.77% Lives saved 15,616 Cases saved 678,929
HIV baseline estimates	iHME 2018 estimates female 77,499 deaths 4,772,473 cases male 70,186 deaths 2,799,754 cases	Thembisa 2018 estimates female 35,487 deaths 4,542,677 cases male 36,345 deaths 2,578,747 cases	Stakeholders highlighted the difference between GBD estimates and local estimates for HIV deaths. The Thembisa model was built by local academics and is used by UNAIDs [28].	Central estimates Lives saved 20,858 Cases saved 900,332 HIV lives saved 10,229 HIV cases averted 429,205 Alternative scenario Lives saved 16,086 Cases saved 907,930 HIV lives saved 5,486 HIV cases averted 423,850
Socioeconomic gradients of ill health	HIV Q1 (poorest) – 20% Q2 – 36% Q3 – 32% Q4 – 9% Q5 – 3% Intentional Injury/Road Injury/Liver Cirrhosis Q1 – 9% Q2 – 29%	Scenario 1 Changing the liver cirrhosis gradient to match the one used for breast cancer	Scenario 1 Stakeholders indicated that for long-term conditions like cirrhosis wealthier groups could well be over-represented in SA. They suggested sensitivity analysis by applying values for a condition that is less concentrated amongst the poor.	Central estimates Liver cirrhosis lives saved/cases averted Q1 133 / 3,528 Q2 432 / 11,298 Q3 295 / 7,801 Q4 288 / 7,639 Q5 82 / 2,158 Scenario 1

	Q3 – 26% Q4 – 26% Q5 – 10% Breast cancer Q1 – 7% Q2 – 7% Q3 – 22% Q4 – 18% Q5 – 47%	Scenario 2 HIV Q1 (poorest) – 25% Q2 – 22% Q3 – 20% Q4 – 18% Q5 – 14% Intentional injury/ Road injury/Liver cirrhosis Q1 – 20% Q2 – 20% Q3 – 19% Q4 – 20% Q5 – 22% Breast cancer Q1 (poorest) – 21% Q2 – 21% Q3 – 20% Q4 – 19% Q5 – 18%	Scenario 2 Recent data from another South African survey is used to provide plausible alternative socioeconomic gradients across all the conditions used in the model [29].	Liver cirrhosis lives saved/cases averted Q1 95 / 2509 Q2 104 / 2722 Q3 235 / 6203 Q4 200 / 5316 Q5 359 / 9563 Central estimates aggregate lives saved / cases averted Q1 4,088 / 176,663 Q2 7,375 / 313,360 Q3 4000 / 177,604 Q4 3,759 / 167,934 Q5 1,364 / 64,771 Scenario 2 aggregate lives saved / cases averted Q1 2,858 / 127,516 Q2 5,246 / 225,067 Q3 5,758 / 255,667 Q4 3,153 / 139,2253 Q5 3,969 / 197,191
Discount rates for costs	5% discount rate	Scenario 1 0% discount rate	Discount rate was changed to 0%	Central estimate Health costs saved R6.88 billion Scenario 1 Health costs saved

				R11.10 billion
Homebrew switching	30%	Scenario 1 0% Scenario 2 100%	The assumption that drinkers will make up 30% of the reduction in drinking recorded alcohol with homebrew comes from consultation with the stakeholders at workshop two. To test the importance of this assumption on the results a null impact and a 100% impact are introduced. 100% would mean that any homebrew drinkers will not receive any positive health impacts from the policy as all of their reduction in recorded alcohol will be replaced with homebrew alcohol.	Central estimate Consumption - 4.40% Lives saved 20,585 Cases saved 900,332 Scenario 1 Consumption - 4.56% Lives saved 21,479 Cases saved 937,507 Scenario 2 Consumption - 4.03 % Lives saved 19,156 Cases saved 844,471

16. Healthcare cost savings by quintile

Table 16: Health care costs for each of the three policy scenarios split by wealth quintile

	Q1	Q2	Q3	Q4	Q5
R5 MUP					
HIV	-R0.01	-R0.07	-R0.04	-R0.03	-R0.01
Intentional injury	R1.41	R5.22	R5.42	R12.8	R7.72
Road injury	R0.71	R2.73	R2.80	R6.39	R3.82
Liver cirrhosis	R0.02	R0.12	R0.11	R0.27	R0.14
cancer	R0.00	R0.00	R0.01	R0.05	R0.15
R10 MUP					
HIV	R162.00	R291.00	R71.10	R8.72	R33.3
Intentional injury	R495.57	R801.23	R1150.94	R1487.35	R369.03
Road injury	R232.98	R399.34	R520.70	R658.80	R163.64
Liver cirrhosis	R3.03	R9.64	R6.62	R6.45	R1.86
cancer	R0.30	R0.22	R0.80	R0.93	R1.75
R15 MUP					
HIV	R403.19	R618.29	R190.50	R79.85	R64.67
Intentional injury	R1136.23	R2029.50	R2558.09	R2350.20	R1014.96
Road injury	R536.83	R1013.46	R1173.35	R1080.17	R4618.76
Liver cirrhosis	R7.42	R23.50	R17.60	R15.20	R4.51
cancer	R0.76	R0.65	R2.24	R2.30	R4.65

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Contents

Supplementary Material

Price to consumption

Our model starts by estimating mean and peak alcohol consumption at current alcohol prices at the individual level. The proportion of alcohol consumption which is homebrew is also estimated. This process utilised both alcohol frequency questions and seven day recall questions asked in the same survey. As survey data significantly underreports consumption we calibrate these estimates to market research data using statistical methods established in the literature [1-3]. Following the shift of mean consumption, peak consumption is re-estimated using a simple regression model created at baseline. We categorise drinkers into three exhaustive and mutually exclusive groups; moderate (less than 15 standard drinks per week); occasional binge (less than 15 drinks per week but more than 5 on one occasion); and heavy (15 or more drinks per week). A standard drink in South Africa is currently 15ml or 12 grams of pure ethanol. We compute a regression model for wealth quintiles using the South African Demographic and Health Survey (SADHS) data and use it to predict wealth quintiles in the International Alcohol Control (IAC) dataset to generate price distributions for wealth and drinker groups. Alcohol is treated as one commodity due to data constraints.

1. Estimating baseline consumption using South African Demographic and Health Survey (SADHS)

The SADHS survey asked the following questions:

Table 1: Survey questions

Survey	Alcohol questions [answers]
SADHS 2016	Have you ever consumed a drink that contains alcohol such as beer, wine, ciders, spirits, or sorghum beer? Probe: Even one drink? [yes, no] Was this within the last 12 months? [yes, no] In the last 12 months, how frequently have you had at least one drink? [5 or more days a week, 1-4 days per week, 1-3 days a month, less often than once a month] During each of the last 7 days, how many standard drinks did you have? [use showcard, record total number of drinks consumed each day starting with the day before the day of the interview and proceeding backwards] During the last 7 days, how many standard home-made beers or other homemade alcohol did you have? [use showcard, record number] In the past 30 days, have you consumed five or more standard drinks on at least one occasion? [yes, no]

Process of adjusting the SADHS estimates

Drinkers were categorised by their drinking frequency and by whether or not they had reported any drinking in the last seven days.

Table 2: Frequency of alcohol consumption responses

Drinking occasion frequency	count	Reported drinks in last 7 days	Reported zero drinks in last 7 days
5 or more days a week	293	266	27 (6 binge, 21 drinker)
1-4 days per week	668	565	103 (29 binge, 74 drinker)
1-3 days per month	1163	799	364 (all drinkers)
less often than once a month	1187	404	783 (all drinkers)
NA	7025		

Readjusting those with a seven day drinking pattern (pink numbers)

The pink numbers are respondents who say they only drink 1 -3 days per month or less often than once a month but have drunk in the last 7 days. If this were multiplied by 52 it would be an overestimate. Therefore, we assumed for those that drink 1-3 days per month we have captured their one drinking week in the month and multiply by 12 to get their annual consumption. There are 799 people in this category. We assumed for those who drink less often than once a month but who did drink in the last week we have caught their one drinking week that occurs every two months. We multiplied by six, to get the annual figure. There are 404 people in this category. The yellow numbers do not require adjustment as respondents report drinking every week and have a seven day drinking pattern.

Readjusting those without a seven day drinking pattern but who say they drink (blue and red numbers)

For those with a drink frequency of five or more days per week we used the mean standard drinks for drinkers who reported the same frequency but who do have a seven day pattern, there are 27 people that this applies to (blue).

For those with a drink frequency of 1 – 4 days per week we used the mean standard drinks for drinkers who report the same frequency but who do have a seven day pattern, there are 103 people in this group (blue).

For those with a drink frequency of 1 – 3 days per month we used the mean adjusted annual drinks (adjusted in 2.2.1.3.1) of the equivalent frequency group who did report a drinking pattern. There are 364 drinkers in this group (red).

All of the above estimates were computed for sex and binge drinking subgroups.

For those with a drink frequency of less than once per month we used the mean adjusted annual drinks (adjusted in 2.2.1.3.1) of the equivalent frequency group who did report a drinking pattern. This is computed for subgroups based on sex and binge drinking. There are 783 people in this group (red)

Process of adjusting peak drinks

Using the same process as above we applied a peak drink to those observations without one. As an additional check we validated that all those reporting binge drinking had a peak drink at minimum of 5.

Comparing the adjusted SADHS data with the estimates using only 7 day recall as expected prevalence of drinking increases and per capita estimates reduce (Table 6). The prevalence estimates are now broadly similar to the NiDs and GISAH estimates (Table 3).

Table 3: Comparing adjusted with unadjusted statistics

	Prevalence of drinking		**Sample size: drinkers**	**Annual litres of alcohol - per capita**			**Annual litres of alcohol - Just drinkers**		
	Female	Male		Total	Female	Male	Total	Female	Male
SADHS (7 day recall only) Population weights applied	9.3%	32.7%	n = 1949 (report drinks in the 7 day recall) females = 571 males = 1378	2.2	0.65	4.5	10.6	6.54	12.2
SADHS adjusted (7 day recall plus adjustments based on frequency questions) Population weights applied	18%	54%	n = 3311 females = 1125 males = 2186	1.65	0.50	3.4	5.0	2.59	6.25

Figure 1: Density plot of female drinkers before and after the shift

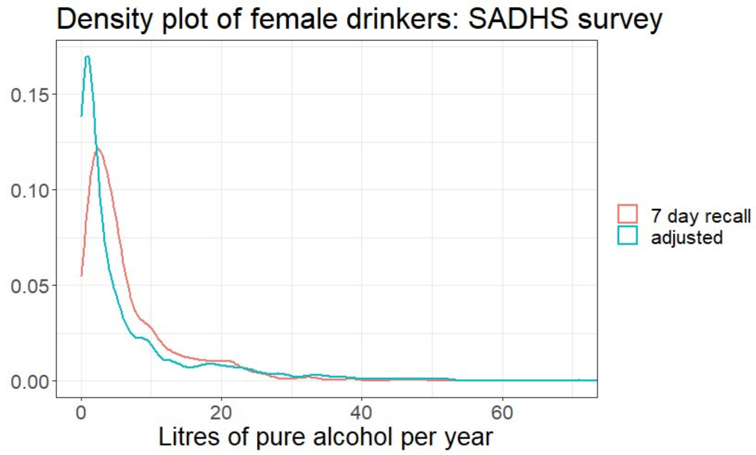
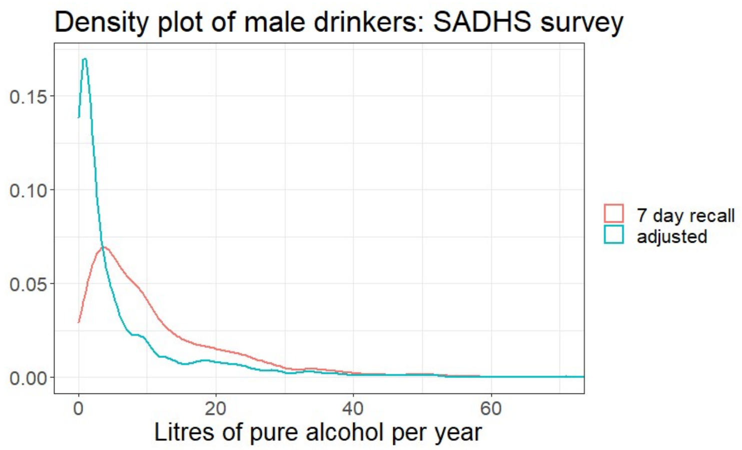


Figure 2: Density plot of male drinkers before and after the shift



Incorporating the frequency data into the seven day recall moves the distribution towards the left (Figures 1 and 2). This is logical as the sample will now include those drinkers who stated that they drink but did not record any for the last seven days, it also adjusted down those who claim to drink less than weekly but who did recall drinks for the last seven days. This pattern gives some confidence in the dataset and utilises the strengths of capturing heavy drinking well and including occasional drinkers.

2. Uplifting consumption

Surveys provide important data about drinking patterns within the population but total consumption estimates are far smaller than that indicated by administrative sources [4]. As this is a global phenomenon there are established statistical calibration methods in the academic literature. The steps are broadly as follows:

- compute the ratio between survey and sales per capita consumption (known as coverage)
- use this ratio to adjust the mean for each subpopulation of interest
- use the new mean to estimate an associated standard deviation based on a published relationship, estimated using regression on a large global dataset [2]

$$\hat{\sigma}_{shifted} = 1.174 \times \hat{\mu}_{shifted} + 1.003 \times female$$

- use the new mean and standard deviation to generate the shape and rate parameters and fit a gamma distribution

This method relies on three assumptions. Firstly that the sales data accurately reflects per capita consumption. Secondly, that the true proportion of abstainers has been captured by the survey, and finally that under-estimation of consumption is the same across all population groups.

Two additional key limitations have been identified with regards to this method. Firstly, there is no empirical evidence that under-coverage is distributed as implied by the shifts needed to fit the adjusted consumption to the gamma. Secondly, that shifting consumption to a gamma can artificially reduce the long tail of heavy drinkers [3]. To address the second point a proposed method is to fit a gamma distribution to the survey and for each percentile of the distribution calculate the percentage consumption increase and apply these percentage shifts to the corresponding percentile of the survey data.

The following steps outline, in detail, how we calibrated the SADHS dataset to Euromonitor figures:

- First a cap was applied to all drinkers of 68 litres of alcohol per year or 150 grams of alcohol per day. As the model includes long term effects (20 years) the cap is needed as a higher level of alcohol cannot be sustained in the long term [5]. This cap impacted one woman and ten men. Of this small group only two men drunk both homebrew and recorded alcohol and so their total consumption was reduced to 68 litres and then split into recorded and homebrew using their previous percentage split.

- Survey coverage level was calculated as the difference between total per capita consumption recorded in the SADHS survey and per capita consumption using Euromonitor recorded sales data for 2018. 80% of the sales data is used to account for spillage, stockpiling and tourist consumption. This sales figure was then increased to take account of the 4.15% of total alcohol consumed in the SADHS survey reported as homebrew (representing unrecorded alcohol in the model). The comparison of total consumption according to the survey and the adjusted official sales data was used to calculate a coverage of 27%.

- For female and male subgroups the mean litres of alcohol was adjusted by the multiplication factor. This adjusted mean was used to estimate an associated standard deviation based on a previously established relationship between the two. These were then used to fit a "shifted" gamma distribution (maintaining the cap of 68 litres), calculated for male and females separately.

- A gamma distribution was fitted to the original sample of drinkers, by sex, and percentiles were taken across this and the shifted distribution. Percentage differences in consumption were calculated. These increases were then applied to the percentiles of the original survey sample.

- Each individual's total consumption was split into homebrew and recorded alcohol using the original percentage split (this assumes underreporting is equal across homebrew and recorded alcohol).

- Results were compared visually and via a table (Table 7 and Figures 8 and 9). There is a small difference between the two methods, more visible for males than females. It appears adjusting by percentiles only makes a difference at the extremes, lowering the left hand peak slightly but also falling below the Gamma shifted distribution after 60 litres of alcohol per year for men meaning there is a smaller number of the very high drinkers.

The percentile adjusted distribution was used for the main model base on expert opinion.

Table 4: Comparing pre and post shift data

Females – litres of alcohol per year	Mean	Min	Max
SADHS Survey data (weighted mean and capped)	2.57	0.09	68
Gamma fitted to survey (difference due to weights)	2.50	0.09	68
Gamma shift	10.78	1	68
Adjusting each percentile (weighted mean)	10.74	0.5	68
Males – litres of alcohol per year			
SADHS Survey data (weighted mean and capped)	6.13	0.09	68
Gamma fitted to survey (difference due to weights)	5.6	0.09	68
Gamma distribution shifted	18.55	1	68
Adjusting each percentile (weighted mean)	19.2	0.5	68

Figure 3: Comparing distributions pre and post shift females

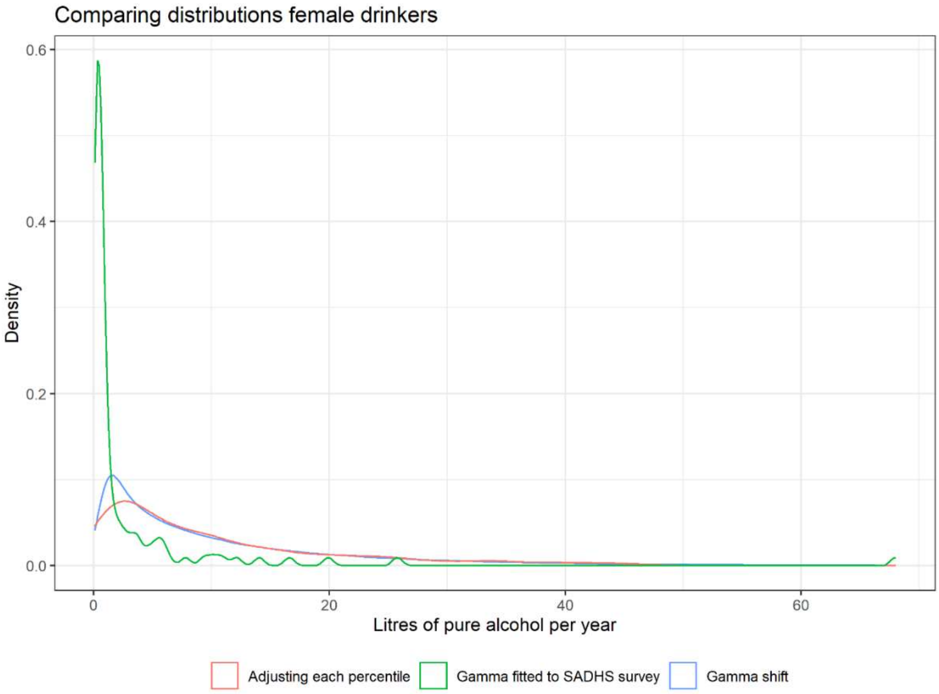
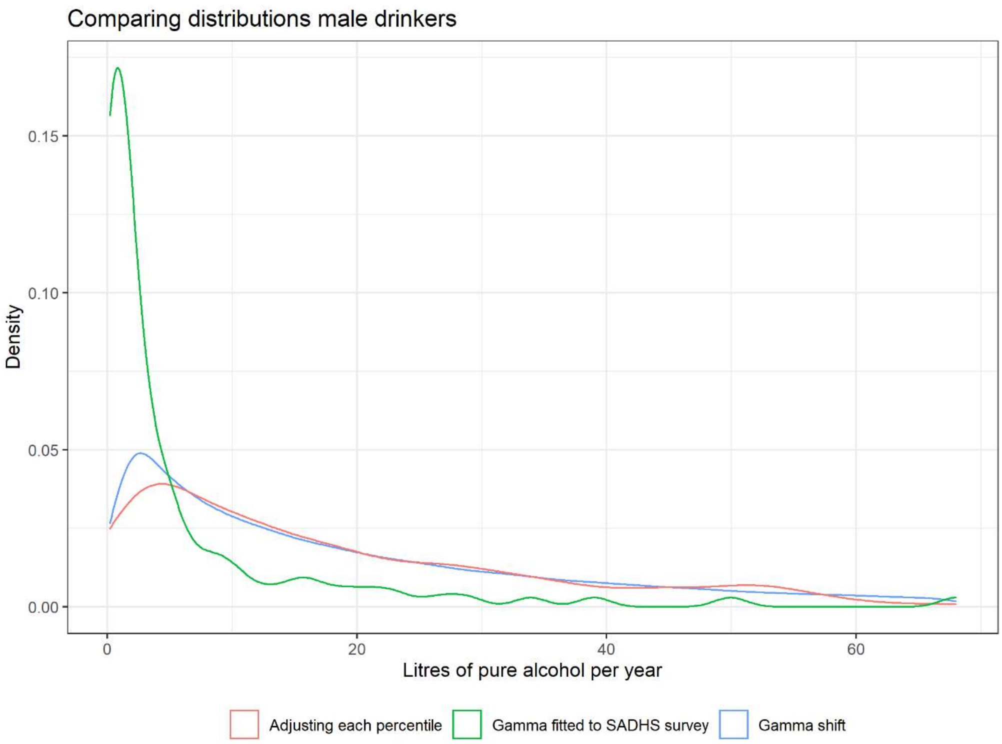


Figure 4: Comparing distributions pre and post shift males



3. Uplifting peak consumption

Peak drinking measures the highest number of drinks consumed on a single drinking occasion and therefore relates to intoxication which is associated with harms such as road injury, interpersonal violence and self-harm. Following the method used in the Sheffield Alcohol Policy Model [6], the following linear regression model was fitted, for all drinkers, to the non-shifted SADHS data, relating peak drinking to mean consumption, age and sex.

$$peak_{\,ij}(SADHS) = \beta_0 + \beta_1 \times ageband + \beta_2 \times sex$$

The model was used to compute fitted values for the non-shifted data. The model assumes there is a linear relationship between peak and mean consumption, the magnitude of which is allowed to vary by age and sex.

After the mean consumption was shifted as above the corresponding new peak consumption was computed using the following formula:

$$peak_{\,ij}(shifted) = \mathrm{peak}_{ij}\,(SADHS) \times \left(\frac{E(peak_{ij}(shifted))}{E(peak_{ij}(SADHS))}\right)$$

The linear relationship between mean and peak estimated from the SADHS survey is maintained for the shifted mean and peak consumption, this assumes individuals under reported peak and mean consumption by the same magnitude. The method also assumes the prediction error for the model is of the same magnitude for all levels of consumption.

The predictions were checked to ensure that peak estimates were not below mean daily drinking. There were 88 people (out of the 3311 drinkers) for whom this was true. These people had their peak drinking increased to match their mean daily drinking.

4. Wealth quintiles

In order to match wealth groups between the two datasets an ordered choice model was created using SADHS data with wealth quintile (1 – 5) as the dependent variable, using the MASS package in R [7]. Wealth groups were chosen as the best available measure to capture socioeconomic status that allowed us to match between the SADHS and IAC dataset. Although income was asked in the IAC dataset many of the respondents refused to answer resulting in a very small sample.

All the variables that were common across the two datasets were included in the initial model, these were not just asset ownership but also age, sex, educational level and population group (race). Stepwise regression was performed using the step.AIC function. This chooses the best variables to include by running the regression with all variables in and then taking one out and computing a goodness of fit measure (the AIC). If the goodness of fit measure is improved then that model is preferred, it runs this for many models until it finds the model with the highest AIC. This method resulted in the selection of the following variables: age, sex, population group, education level, car, landline, electricity, fridge, computer, radio, tv. The only variable it removed was mobile phone which fitted anecdotally with conversations we had with stakeholders in South Africa regarding how much poorer people prioritise mobile phones.

The goodness of fit matrix evaluates the success of the model, comparing the closeness of the predicted and observed outcome (Table 5). The model never predicts the poorest as the richest or the richest as the poorest.

Table 5: Goodness of fit matrix

		Prediction				
		Poorest	Poorer	Middle	Richer	Richest
Actual	Poorest	1300	593	196	9	0
	Poorer	299	975	744	192	17
	Middle	62	612	1042	595	26
	Richer	5	236	763	818	244
	Richest	0	10	108	422	1068

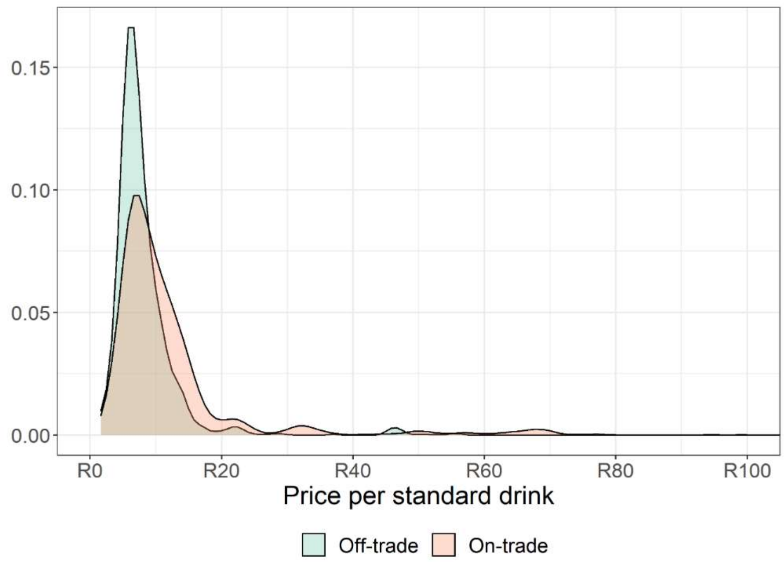
5. International Alcohol Control Study 2014 for prices

The IAC dataset provides prices by drinking location by beverage, by container size and also asks whether the individual binge drinks, demographic data is also collected. The survey asked for the price in Rands by location, for example they ask for the price of a beer paid at a pub for each container size. There are 17 drinking locations (12 on trade and 5 off trade) and 12 drink types. On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).

Prices were disaggregated by population subgroups rather than by drink type (wine/beer/spirits etc). This was consistent with the South Africa specific price elasticities which were calculated for drinker groups whilst treating alcohol as a single commodity. The IAC respondents were categorised into drinker groups using the definitions above. Each price was weighted by the number of units (e.g. bottles, glasses, cans) sold, the container size of those units and the number of drinking occasions in 6 months (Figure 5). Every price observation was validated using data from the South African Consumer Price Index. Prices were increased to 2018 to account for inflation.

Figure 5: Distribution of off-trade and on-trade prices, standard drink is 15ml or 12grams of pure ethanol.

On-trade is where the alcohol is consumed on the premises it is purchased (e.g. hotels, restaurants, pubs), off-trade is where the alcohol is consumed off the premises it was purchased at (e.g. supermarket or bottle store).



The off-trade wine prices were adjusted using data from the South Africa Wine Industry Statistics [8] who report the proportions of still wine sold (which makes up 93% of total volume of wine sold) in the off-trade in 2018 that falls within different price bands, this data was used to adjust downwards the off-trade wine (Table 6). The price observations were sorted in ascending order and a cumulative volume variable created. The price closest to the 49th percentile was then adjusted down to R3.74 and all prices below adjusted using the same proportion. The prices at the very bottom were adjusted so they could not go below R2.50. The same adjustment process was applied to each of the four groups.

Table 6: Price distribution for off-trade wine

Retail price per litre of wine for 2018	Price per standard drink (15ml) assuming 12% abv	Cumulative percentage of total still wine sold at price SAWIS data	Cumulative percentage of IAC data for off-trade wine pre-adjustment	Cumulative percentage of IAC data for off-trade wine post-adjustment
Less than R30	Less than R3.75	49%	33%	51%
> R30 – R48	> R3.75 – R6	82%	60%	83%
> R48 - R72	> R6 – R9	89%	77%	89%
> R72 - 108	> R9 – R13.5	95%	89%	95%
> R108	> R13.5	100%	100%	100%

As the Tschwane prices were collected in one locality, they were validated against national data sources. Beer is by far the most popular drink, accounting for over 50% of the alcohol sold so beer prices are critical. We accessed data from the South Africa Consumer Price Index for January 2020 to compare the Gauteng province (where Tshwane is located) with other provinces. Beer, which accounts for over 50% of alcohol sold in South Africa, Guateng is at R13.76 for a 330ml can. The average across the eight prices listed above is R13.66 which is very close to Guateng's price, therefore we assume the same price distributions across the whole of South Africa.

Finally, prices were validated with all stakeholders including individuals resident in townships who could provide anecdotal evidence relating to cheap alcohol available at shebeens.

6. Base prices by subgroup

All IAC drinkers were now categorised by drinker type and by wealth quintile (Table 7). Wealth quintile was predicted using the ordered choice model created using the SADHS data. Drinkers in the lowest wealth quintile appear the least likely to drink in moderation leaving a very small sample size (this is not weighted by number of drinks). It is therefore not possible to create price distributions for all 15 categories.

Table 7: Count of IAC price observations and respondents within each category

	Moderate obs (individuals)	Occasional Binge obs (individuals)	Heavy obs (individuals)
Poorest	2 (2)	29 (23)	35 (24)
Poorer	8 (8)	23 (18)	28 (20)
Middle	11 (11)	132 (90)	88 (40)
Richer	23 (20)	95 (59)	60 (30)
Richest	93 (68)	135 (93)	101 (50)

The mean price for each of these drinker categories demonstrates there is wealth gradient (Table 8).

Table 8 Mean price of standard alcoholic drink (15ml of pure alcohol) for each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R6.79	R7.97	R7.78
Poorer	R9.43	R10.0	R9.65
Middle	R10.2	R10.1	R9.23
Richer	R11.3	R13.4	R10.6
Richest	R11.7	R11.1	R12.8

In order to ensure adequate sample size the poorest/poorer/middle and richer/richest categories were aggregated for moderate drinkers (Table 9). This represents the final group of prices used in the model.

Table 9 Mean price of standard alcoholic drink (15ml of pure alcohol) within each subgroup

	Moderate	Occasional Binge	Heavy
Poorest	R9.13	R7.97	R7.78
Poorer	R9.13	R10.0	R9.65
Middle	R9.13	R10.1	R9.23
Richer	R11.6	R13.4	R10.6
Richest	R11.6	R11.1	R12.8

7. Adjusting the elasticities

The starting point for elasticities -0.4, -0.22 and -0.18 for moderate, occasional binge and heavy drinkers respectively [9]. We adjusted these elasticities to incorporate an income gradient using -0.86 and -0.5 elasticity for low and high socioeconomic status [10]. To remain on the conservative side we will count the bottom two quintiles as low SES and the top three as high.

Table 10: Elasticities by wealth and drinker group

Drinker type	Q1	Q2	Q3	Q4	Q5
Moderate	-0.53	-0.53	-0.31	-0.31	-0.31
Occasional binge	-0.29	-0.29	-0.17	-0.17	-0.17
Heavy drinkers	-0.24	-0.24	-0.14	-0.14	-0.14

8. Individual spend, tax and retail revenue

Alcohol consumption expenditure
The total retail spend at baseline, and each scenario, was computed by adding up all the individual spends multiplied by their population weights. When the SADHS consumption estimates were shifted to calibrate to market research data only 80% of the consumption figure was used to take account of spillage, stockpiling and tourism, but the 20% of alcohol remains in the headline sales revenue. Therefore to make it comparable we estimate the total sales revenue by increasing the modelled alcohol consumption revenue by 1.25 (100/80).

Government revenue, VAT, excise tax and retail revenue
The following steps outline how we computed government and retail revenue:

1. Calculate VAT by assuming 15% of the base retail spend is VAT
2. Import 2018 base excise tax from Treasury Budget Report [11]
3. Calculate total volume consumed of alcohol at all four scenarios (baseline/R5/R10/R15)
4. Calculate the percentage change in volume from baseline for each of the three policies
5. Apply the percentage change in volume to base excise tax (we assume a fixed ratio between volume and excise tax)
6. Calculate retail revenue by: spend - vat - excise tax

It is likely this is a conservative approach to modelling excise tax revenue as generally the cheaper alcohol, which this policy targets, generates a lower proportion of excise tax than the more expensive, so we can consider this a lower band on the excise tax revenue.

Consumption to harm

9. Relative risks

Relative risks were calculated for each of the health outcomes of interest at baseline, and each policy scenario using published relative risk equations [12,13]. The same relative risk equations are used for morbidity (or prevalence) and mortality. HIV risk is derived from a stepped function for mean drinking differing by socioeconomic status, intentional injuries and road injury from a continuous function of mean drinking differing by whether the individual binge drinks, liver cirrhosis and breast cancer from a continuous function of mean drinking, for breast cancer this is only for females (Table 10).

Table 11: Relative risk equations used

Health Condition	Relative risk Current drinkers	Relative risk former drinkers	ICD-10 codes
HIV	Low SES $RR = 2.99$ if x > 61/49 grams per day (males/females) $RR = 1.94$ if x > 0 $RR = 1$ otherwise Higher SES $RR = 1.54$ if x > 61/49 grams per day (males/females) $RR = 1$ otherwise	RR = 1	B20-24
Intentional Injuries **(self-harm and interpersonal violence)**	Drinkers $RR = \exp(00199800266267306 . x)$ Heavy episodic drinkers (HED) $RR = \exp(00199800266267306 . x + 0.647103242058538)$	RR = 1	ICD-10 codes: X60 – Y09 Y35 –36 Y870 Y871
Road Injury **(pedestrian, cyclist, motorcyclist, motor vehicle, other road)**	Drinkers $RR = \exp(0.00299550897979837 . x)$ Heavy episodic drinking $RR = \exp(0.00299550897979837 . x + 0.959350221334602)$	RR = 1	V01–04, V06, V09–80, V87, V89, V99
Breast Cancer	Females only $RR = \exp(0.01018 . x)$	RR = 1	C50
Liver	if x <= 1 $1 + x.\exp((\beta_1 + \beta_2) . \sqrt{\frac{1 + 0.1699981689453125}{100}})$ If x > 1 $\exp((\beta_1 + \beta_2) . \sqrt{\frac{x + 0.1699981689453125}{100}})$	RR = 3.26 for both females and males	K70, K74

	Female b1 = 2.351821 b2 = 0.9002139 Male b1 = 1.687111 b2 = 1.106413		
x = grams of alcohol consumed per day among current drinkers HED = drinking 60 grams or more on one drinking occasion			

10. Potential impact fractions

Potential impact fractions (PIFs) were calculated by dividing relative risk under each policy by relative risk at baseline. These incorporated population weights and were computed by sex *(i)*, wealth group *(j)* and drinker group *(k)*.

$$PIF_{ijk} = \frac{\text{relative risk}_{ijk}\ \text{(policy)}}{\text{relative risk}_{ijk}\ \text{(baseline)}}$$

11. Socioeconomic gradients of ill health

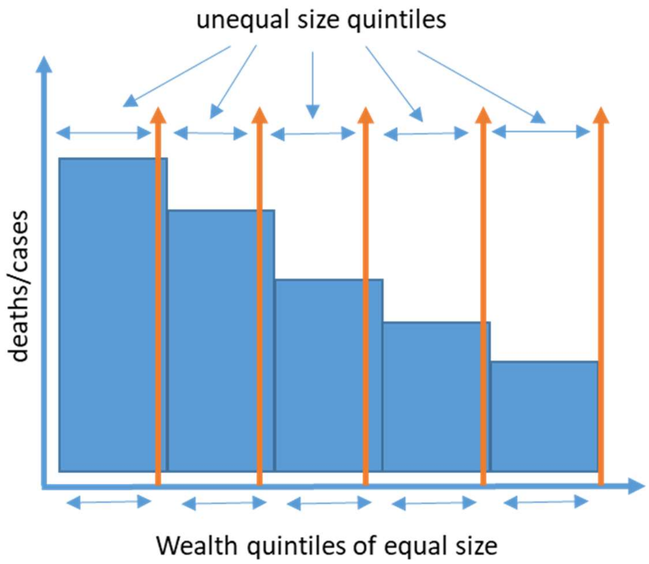
Health outcomes in South Africa are not evenly distributed throughout the population, with the poor often bearing a higher burden of disease, depending on the illness. Data analysis was carried out using General Household Survey (GHS) data for 2018. The ordered choice regression model computed previously, using SADHS data, was applied to the GHS data to split the survey population into wealth quintiles compatible with the foundational dataset (SADHS). Percentage within each wealth quintile with the disease was computed (Table 11). Liver cirrhosis was not one of the health conditions included in the survey and breast cancer was not specifically included although the broader category of cancer was. Sensitivity analysis was carried out using alternative gradients.

Table 12: Raw count of General Household Survey data 2018

	poorest	**poorer**	**middle**	**richer**	**richest**
15+ raw count (648 NAs)	4966	11462	14396	9633	7630
HIV raw count percentage	395 0.08	684 0.06	614 0.04	155 0.02	41 0.005
Intentional injuries* raw count percentage	11 0.002	30 0.0027	24 0.0018	11 0.0012	3 0.0002
Road injuries** raw count percentage	7 0.0016	26 0.0022	22 0.0016	32 0.0033	13 0.00015
Cancer raw count percentage	2 0.00038	27 0.0012	41 0.0026	27 0.0029	68 0.008
nb: percentages within each quintile were calculated incorporating the survey weights * gunshot wounds; severe trauma due to violence, assault, beating; intentional poisoning; accidental poisoning; fire and burn; crime related injury – left out sports related, disability related and other ** motor vehicle -occupant, motor vehicle – pedestrian, bicycle related					

12. Distributing baseline deaths and cases and calculating probabilities

The deaths/cases (which come disaggregated by sex) at baseline is split between the five wealth quintiles using the GHS data to account for the socioeconomic gradient, as explained above. However, a preparatory step was necessary as the proportions of the population (using the SADHS proportions) in each quintile were not perfectly equal, for example for Q1, Q2, Q3, Q4, Q5 corresponded to 0.19, 0.19, 0.20, 0.21, 0.21 for females and 0.19, 0.20, 0.21, 0.20, 0.21 for males. The probability of death was calculated for each quintile first by assuming the population was split into quintiles of equal size. The total deaths/cases for each quintile using the SADHS proportions was then calculated by applying the relevant probability of death/cases for that part of the quintile which overlapped with the underlying equally sized quintile. This concept can be best illustrated on a graph.



$$Number_{cases}(SADHS_{Q1}) = Pop_{SADHS} \quad \times Prob_{Equal}$$

$$Number_{cases}(SADHS_{Q2}) = (Pop_{EqualQ1} - Pop_{SADHSQ1}) \times Prob_{EqualQ1} + (Pop_{SADHSQ1} + Pop_{SADHS} \quad - Pop_{Equal} \quad) \times Prob_{Equal}$$

$\ldots .\, and\ so\ on$

The existence of relative risk equations implies that the baseline mortality/morbidity will also not be distributed equally between drinker groups, one would expect a higher proportion of the baseline cases to exist amongst heavy drinkers, followed by occasional binge, moderate then abstainers. In order for the baseline mortality/morbidity to vary by drinker group the total risk, for each disease, is calculated for each drinker group group, by sex and wealth quintile. The proportional share of risk between drinker groups is then calculated and used to distribute the mortality/morbidity, which has already been assigned to each quintile, between each drinker group within that quintile.

The model uses iHME data for deaths and cases of disease and population statistics (Statistics South Africa) from 2018. Life tables to get the probability of death by single year of age were only available for 2017 from iHME so these were used. The 2018 population is split proportionally into the sex/wealth/drinker groups using the SADHS proportions.

The probability of death for each disease is calculated for the baseline scenario and taken away from overall probability of death for each single year of age given in the life table to give a probability of death from non-modelled causes. This probability of death from non-modelled causes remains constant at every policy scenario. The probability of death from the five diseases of interest then vary according to the policy level and the corresponding potential impact fraction.

We model counterfactual population structure (i.e. in the absence of the policy) over 20 years, starting from 2018 using current population estimates from Statistics South Africa, plus birth projections for 2020 to 2023 and assume current age-, sex- and wealth-specific mortality rates remain constant [14]. Birth cohorts for years beyond 2023 are not modelled as they would not have reached the age at which we model alcohol consumption (15+) within the time horizon.

We create multistate life tables in which the population faces a probability of mortality for each of the five disease/injury conditions and for other cause mortality each year. This approach allows us to simulate prevalence of and mortality from multiple diseases simultaneously, assuming diseases are independent of one another. The model generates alternative population impact fractions (as above) for baseline and for each policy scenario. Using the relevant population impact fraction and rerunning the multistate life table enables a calculation of the difference between baseline and the policy.

13. Baseline health and lagged health impact

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking immediately whereas the health impact on liver cirrhosis and breast cancer are subject to lags in the effect, meaning the reduced drinking does not translate to a reduced health risk immediately [15]. Breast cancer starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Appendix part 9).

The life tables for the 20 year time horizon are saved for each of the policy scenarios. They are then used in combination with the probability of having the disease and the potential impact fraction under each policy, to estimate the number of cases.

HIV, road injuries and intentional injuries realise the full impact of the reduction in drinking from the first year of the drinking reduction whereas liver cirrhosis and breast cancer are subject to lags in the effect. Breast cancer only starts to see an impact at year 11 and it is 20 years until full effect, liver cirrhosis sees some impact from year one but does not realise the full effect until year 20 (Table 12).

Table 13: Modelled time-lags by condition – proportion of overall change in risk experienced in each year following a change in consumption (Holmes et al., 2012)

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Breast cancer	0	0	0	0	0	0	0	0	0	0	10	20	30	40	50	60	70	80	90	100
Liver Cirrhosis	21	34	43	50	56	61	65	69	73	76	79	82	85	88	90	92	94	96	98	100

14. Hospital multipliers and costs

The prevalence of disease/injury at each policy scenario for each year of the 20 year time horizon was multiplied by the proportion who would then go on to receive hospital treatment (Table 13) and the relevant hospital cost applied (Table 14). The costs taken from the literature were increased by inflation where necessary to reach the baseline year of 2018. Future costs were discounted at 5% as recommended by the Department of Health in the guidelines for pharmacoeconomic submissions [16]. All sources were sense checked with a South African stakeholder with health economics expertise.

Table 14: Estimated multiplier from population prevalence to hospital admission

Condition	Multiplier (cases in population who go on to receive healthcare treatment)	Source
HIV	0.62	UNAIDS estimates that 62% of people living with HIV in 2018 in South Africa were on treatment [17]
Intentional Injury	0.41	Survey estimating trauma admissions [18] combined with iHME data from the same year to predict multipliers.
Road injury	0.19	Survey estimating trauma admissions [18] combined with iHME data from the same year to predict multipliers.
Liver Cirrhosis	0.5	Paper on liver cirrhosis in sub-Saharan Africa suggests 50% of patients are admitted to hospital with end-stage liver disease [19].
Breast Cancer	0.75	All studies found estimate what proportion present with late stage breast cancer (51%) but not what proportion never receive hospital treatment [20]. Therefore an estimate of 0.75 is used.

Table 15: Hospital costs and sources

Condition	Cost per patient	Source
HIV	R 3,318.62 (2017/18)	This is the annual cost. Taken from a systematic literature review of per patient costs of HIV services in South Africa [21]. There are many different levels of treatment, this cost is only for first-line treatment, so this is conservative.
Intentional Injury	R58,928 (2013)	This retrospective case note review included 143 violence related emergency hospital admissions from January to March 2013. Average inpatient stay was 9.8 days with treatments including emergency surgery, intensive care and resuscitation beds on admission [22].
Road injury	R56,592.17 (2012)	A prospective cohort study followed 100 patients admitted following a Road traffic injury between late 2011 and early 2012 at Edendale Hospital Pietermartizburg [23].
Liver Cirrhosis	R2,967 (2018)	50% multiplier used above comes from paper suggesting 50% of liver cirrhosis patients get admitted to hospital with end stage liver disease. Treatment for end stage liver disease includes A specific study on liver cirrhosis was not found so general costs have been used from the district health baromenter. Expenditure per patient day equivalent (district hospitals) was R2967 (average taken from

		across the 9 provinces). This assumes just one patient day. Conservative. [24]
Breast Cancer	Early stage R14,915 Late stage R16,869 (2015)	This retrospective case review included 200 women at a government hospital in South Africa. The average cost is different depending on whether they were diagnosed at an early (56%) or late (44%) stage [25].

15. Sensitivity Analysis

Parameter	Central estimate	Alternative plausible values	Rationale	Results
Price elasticicities	-0.53 moderate Q1, Q2 -0.31 moderate Q3, Q4, Q5 -0.29 occasional binge Q1, Q2 -0.17 occasional binge Q3, Q4, Q5 -0.24 heavy Q1, Q2 -0.14 heavy Q3, Q4, Q5			Central estimates Consumption - 4.40% Spend 18.09 % Lives saved 20,585 Cases saved 900,332
		Scenario 1 -0.40 moderate -0.22 occasional binge -0.18 heavy	Scenario 1 Applies estimates based only on drinker type, removing any wealth gradient.	Scenario 1 Consumption - 4.50% Spend 17.86% Lives saved 18,717 Cases saved 825,935
		Scenario 2 -0.5 for high income drinkers (applied to quintiles 3, 4, 5) -0.86 for low income drinkers (applied to quintiles 1,2 to be conservative)	Scenario 2 Estimates using NIDs data for two subsets of the population, the top 50% and bottom 50% of households by total household expenditure [10].	Scenario 2 Consumption - 14.16% Spend 5.4% Lives saved 52,419 Cases saved 2,331,362
		Scenario 3 -0.8	Scenario 3 Van Walbeek and Blecher [10] literature review of South African specific price elasticicities found Selvanathan and Selvanathan [26] estimated -0.8 which corresponds closely to price elasticity estimates for beer (-0.8), wine (-0.9) and spirits (-0.9) produced by SALBA (2010).	Scenario 3 Consumption - 17.96% Spend 0.1 % Lives saved 64,494 Cases saved 2,891,284

Proportion of abstainers in the population	82% female non-drinkers 45% male non-drinkers	67% female non-drinkers 36% male non-drinkers	Stakeholders have indicated scepticism about the prevalence of non-drinking reported in SADHS (and all alcohol studies). Currently the model only adjusts the consumption of those who report anything at all. We will increase the survey weightings of drinkers in the SADHS so that 67% of females do not drink and 36% of males. Based on a South African study which used both surveys and biomarkers [27].	Central estimates Consumption - 4.40% Spend 18.09 % Lives saved 20,585 Cases saved 900,332 Alternative scenario Consumption - 4.48% Spend 17.77% Lives saved 15,616 Cases saved 678,929
HIV baseline estimates	iHME 2018 estimates female 77,499 deaths 4,772,473 cases male 70,186 deaths 2,799,754 cases	Thembisa 2018 estimates female 35,487 deaths 4,542,677 cases male 36,345 deaths 2,578,747 cases	Stakeholders highlighted the difference between GBD estimates and local estimates for HIV deaths. The Thembisa model was built by local academics and is used by UNAIDs [28].	Central estimates Lives saved 20,858 Cases saved 900,332 HIV lives saved 10,229 HIV cases averted 429,205 Alternative scenario Lives saved 16,086 Cases saved 907,930 HIV lives saved 5,486 HIV cases averted 423,850
Socioeconomic gradients of ill health	HIV Q1 (poorest) – 20% Q2 – 36% Q3 – 32% Q4 – 9% Q5 – 3% Intentional Injury/Road Injury/Liver Cirrhosis Q1 – 9% Q2 – 29%	Scenario 1 Changing the liver cirrhosis gradient to match the one used for breast cancer	Scenario 1 Stakeholders indicated that for long-term conditions like cirrhosis wealthier groups could well be over-represented in SA. They suggested sensitivity analysis by applying values for a condition that is less concentrated amongst the poor.	Central estimates Liver cirrhosis lives saved/cases averted Q1 133 / 3,528 Q2 432 / 11,298 Q3 295 / 7,801 Q4 288 / 7,639 Q5 82 / 2,158 Scenario 1

	Q3 – 26% Q4 – 26% Q5 – 10% Breast cancer Q1 – 7% Q2 – 7% Q3 – 22% Q4 – 18% Q5 – 47%	Scenario 2 HIV Q1 (poorest) – 25% Q2 – 22% Q3 – 20% Q4 – 18% Q5 – 14% Intentional injury/ Road injury/Liver cirrhosis Q1 – 20% Q2 – 20% Q3 – 19% Q4 – 20% Q5 – 22% Breast cancer Q1 (poorest) – 21% Q2 – 21% Q3 – 20% Q4 – 19% Q5 – 18%	Scenario 2 Recent data from another South African survey is used to provide plausible alternative socioeconomic gradients across all the conditions used in the model [29].	Liver cirrhosis lives saved/cases averted Q1 95 / 2509 Q2 104 / 2722 Q3 235 / 6203 Q4 200 / 5316 Q5 359 / 9563 Central estimates aggregate lives saved / cases averted Q1 4,088 / 176,663 Q2 7,375 / 313,360 Q3 4000 / 177,604 Q4 3,759 / 167,934 Q5 1,364 / 64,771 Scenario 2 aggregate lives saved / cases averted Q1 2,858 / 127,516 Q2 5,246 / 225,067 Q3 5,758 / 255,667 Q4 3,153 / 139,2253 Q5 3,969 / 197,191
Discount rates for costs	5% discount rate	Scenario 1 0% discount rate	Discount rate was changed to 0%	Central estimate Health costs saved R6.88 billion Scenario 1 Health costs saved

				R11.10 billion
Homebrew switching	30%	Scenario 1 0% Scenario 2 100%	The assumption that drinkers will make up 30% of the reduction in drinking recorded alcohol with homebrew comes from consultation with the stakeholders at workshop two. To test the importance of this assumption on the results a null impact and a 100% impact are introduced. 100% would mean that any homebrew drinkers will not receive any positive health impacts from the policy as all of their reduction in recorded alcohol will be replaced with homebrew alcohol.	Central estimate Consumption - 4.40% Lives saved 20,585 Cases saved 900,332 Scenario 1 Consumption - 4.56% Lives saved 21,479 Cases saved 937,507 Scenario 2 Consumption - 4.03 % Lives saved 19,156 Cases saved 844,471

16. Healthcare cost savings by quintile

Table 16: Health care costs for each of the three policy scenarios split by wealth quintile

	Q1	Q2	Q3	Q4	Q5
R5 MUP					
HIV	-R0.01	-R0.07	-R0.04	-R0.03	-R0.01
Intentional injury	R1.41	R5.22	R5.42	R12.8	R7.72
Road injury	R0.71	R2.73	R2.80	R6.39	R3.82
Liver cirrhosis	R0.02	R0.12	R0.11	R0.27	R0.14
cancer	R0.00	R0.00	R0.01	R0.05	R0.15
R10 MUP					
HIV	R162.00	R291.00	R71.10	R8.72	R33.3
Intentional injury	R495.57	R801.23	R1150.94	R1487.35	R369.03
Road injury	R232.98	R399.34	R520.70	R658.80	R163.64
Liver cirrhosis	R3.03	R9.64	R6.62	R6.45	R1.86
cancer	R0.30	R0.22	R0.80	R0.93	R1.75
R15 MUP					
HIV	R403.19	R618.29	R190.50	R79.85	R64.67
Intentional injury	R1136.23	R2029.50	R2558.09	R2350.20	R1014.96
Road injury	R536.83	R1013.46	R1173.35	R1080.17	R4618.76
Liver cirrhosis	R7.42	R23.50	R17.60	R15.20	R4.51
cancer	R0.76	R0.65	R2.24	R2.30	R4.65

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