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COMMENTARY

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How can agent-based modelling provide new insights into the impact of minimum unit pricing in Scotland?

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Abstract

In recent years we have gained insight into the impact of minimum unit pricing (MUP)—a legal floor price below which a given volume of alcohol cannot be sold—on population-level reductions in alcohol sales, consumption and harm. However, several questions remain unanswered including how individual-level purchasing changes impact the local economy (e.g., balance between on-licence and off-licence outlets), lead to long-term population-level trends (e.g., youth drinking) and social harms (e.g., violence). Agent-based modelling captures heterogeneity, emergence, feedback loops and adaptive and dynamic features, which provides an opportunity to understand the nuanced effects of MUP. Agent-based models (ABM) simulate heterogeneous agents (e.g., individuals, organisations) often situated in space and time that interact with other agents and/or with their environment, allowing us to identify the mechanisms underlying social phenomena. ABMs are particularly useful for theory development, and testing and simulating the impacts of policies and interventions. We illustrate how ABMs could be applied to generate novel insights and provide best estimates of social network effects, and changes in purchasing behaviour and social harms, due to the implementation of MUP. ABMs like other modelling approaches can simulate alternative implementations of MUP (e.g., policy intensity [£0.50, £0.60] or spatial scales [local, national]) but can also provide an understanding of the potential impact of MUP on different population groups (e.g., alcohol exposure of young people who are not yet drinking). Using ABMs to understand the impact of MUP would provide new insights to complement those from traditional epidemiological and other modelling methods.

KEYWORDS
agent-based modelling, alcohol consumption, alcohol harm, minimum unit pricing

1 | INTRODUCTION

Alcohol consumption is a leading cause of death, disease and disability globally [1, 2]. Targeted price-based interventions, for instance, minimum unit pricing (MUP), can reduce alcohol consumption, and as a result alcohol-related morbidity and mortality [3–6]. MUP sets a legal 'floor price' below which retailers cannot sell a particular volume of pure alcohol to consumers [3]. In Scotland, the introduction of MUP means that alcohol must cost at least £0.50 per unit (1 UK unit is equivalent to 8 g of ethanol) [7]. The purpose of this policy is to reduce harm from alcohol by increasing

the price of cheap and higher-strength products that are disproportionately purchased by the highest-risk drinkers, namely those consuming at harmful levels and with lower incomes [8].

Evaluations of MUP to date have examined changes in outcomes across the alcohol retail, purchasing and consumption 'system', including analyses of subgroup effects and detailed qualitative examination of vulnerable populations [4, 9]. However, these evaluations are largely informed by an individual-oriented economic rationalist framework that considers only direct relationships between price changes, purchasing and consumption behaviour. Studies have given less attention to alternative theoretical perspectives offered by the behavioural and social sciences. No studies to date have examined the mediating role of psychological antecedents of behaviour change (e.g., intentions, motivations), the spread of behaviour change across social networks, or the dynamic processes that may amplify or diminish any changes over time. Drawing on these perspectives, there are several aspects of MUP that could be explored further including impacts on local economies through changes to retailer and consumer behaviours, whether changes to drinking behaviour reach those not directly impacted by the policy through social networks and changes in social harms due to changes in alcohol consumption. A further example is how the dramatic increase in inflation since the implementation of MUP might, on the one hand, diminish the effect of MUP by eroding the price threshold in real terms while, on the other hand, increasing its impact by heightening consumer sensitivity to prices.

Agent-based models (ABM) provide a methodological framework that can support and complement more established methods for examining the impact of policies such as MUP. Unlike traditional epidemiological models that aggregate data collected at the individual level, ABMs are individual-level models that simulate agents (e.g., individuals, institutions) situated in space and time. The agents interact with other agents in the simulated environment with the environment itself [10, 11]. Typically, agents have heterogeneous characteristics, possess autonomy to make decisions and engage in behaviours [12]. Interaction with other agents and the environment happens at a local level (i.e., the agent's immediate surroundings) and agents can adapt their behaviour based on their interactions. In ABMs, the behaviours at the individual level give rise to behaviours at the population level [10]. The interplay of heterogeneous agents, interactions between agents, and agents' interactions with their environment means that social dynamics and complex behavioural processes can be explored explicitly. ABMs allow researchers, in silico, to identify and test whether different types of causal mechanisms generate emergent social phenomena, including providing best estimates of the effects of public health interventions, such as population-level changes to alcohol consumption [13].

ABMs have become increasingly popular in recent years for studying the complex and dynamic nature of alcohol-related behaviour. A relatively recent scoping review identified 29 papers published since the year 2000 that describe developing or developed ABMs on the topic of alcohol consumption and/or alcohol harm [14]. The rising popularity of these models may be attributed to the fact that they are a flexible and versatile tool for simulating the interactions between individuals, social networks and environmental factors that influence alcohol-related behaviours. ABMs offer a flexible modelling approach, which can be grounded in a broad spectrum of evidence that includes simple heuristics, qualitative data and fully quantitative data-driven models. ABMs have been used to explore underlying explanations for alcohol consumption (e.g., social norms) [15, 16], and to assess the impact of alcohol policies (e.g., alcohol taxation) on alcohol use and violence [17, 18]. Existing models have used socio-demographic microsynthesis to populate agents in the model [15, 16], and quantitative data from a variety of national, state and community-level sources in the United States to inform model parameters [17, 18].

However, like other modelling methods, this means ABMs are subject to the 'garbage-in-garbage-out' problem if the data used to inform the model is inappropriate or of poor quality [19]. Other common limitations of ABMs include the difficulty of obtaining real-world data to validate models, which often leads to researchers imposing substantial assumptions on the model, and that models may demand a high level of skill among users and computational power depending on their complexity [20].

To the best of our knowledge ABMs have not yet been used to explore the impacts of MUP. This paper therefore aims to illustrate how ABMs could provide valuable insights in three areas: (i) changes to alcohol purchasing behaviour; (ii) social network effects; and (iii) how social harm reductions 'spread' from consumption reductions.

2 | PURCHASING BEHAVIOUR

MUP evaluation studies have investigated changes to alcohol purchasing at the population [21] and household level [22, 23], indicating a reduction in purchasing in Scotland post-implementation. ABM could be used to understand how MUP has had an impact individual-level shopping habits with several potential consequences that extend beyond consumer behavioural outcomes and merit further investigation.

As a method, ABM can capture interactions between individuals and entities (e.g., retailers) often in geographical space. This is relevant because of a tension within local

economies as to whether alcohol is purchased at supermarkets or smaller retailers, which offer different types of cheap products. Supermarkets are less expensive overall, and this is partly because they can offer large discounts for buying in bulk, in addition to being able to make large overall profits on very small profit margins per product. Small retailers are more expensive but sell cheap, high-strength products that supermarkets often do not stock—however, research indicates that prior to the implementation of MUP the heaviest drinkers in Scotland purchased most of their alcohol from small retailers [24]. Given the increase in the cost of alcohol due to MUP, heavy drinkers may opt to buy less alcohol and therefore consume less. Alternatively, they may decide to shop in supermarkets rather than smaller off-trade retailers, and this provides new opportunities to buy in bulk to offset the increased cost. Whether people take up this opportunity may be dependent on the income available to them and the accessibility of supermarkets in their local area [24]. However, either outcome may have knock-on effects for retailers in terms of the products they choose to stock, whether they close or move location, and the knock-on effects for employment and the economy in the local area. Changes in purchasing among harmful drinkers shape product availability and potentially the pricing of other products and thus have knock-on effects for other drinkers and the population-level impact of MUP.

Agent-based modelling could be used to further explore how price changes arising from MUP impact the processes described above. Specifically, we could use an ABM to explore factors which may determine an individual's choice of where to purchase alcohol such as accessibility to retailers and available income to spend on alcohol. We could also provide evidence to inform concerns regarding the impacts of MUP on local economies—and the trade-off between economic losses from reduced sales versus economic gains from a healthier workforce or displaced spending [25, 26]. Other topical issues surrounding MUP such as cross-border trading and the impact of sales promotions could also be examined using ABMs [27]. The main advantage of using ABMs in this context is that we could gain insights into whether the same purchasing behaviour occurs across groups; and critically the response of alcohol retailers to the policy and knock-on effects for the local economy as a whole.

3 | SOCIAL NETWORK EFFECTS

ABMs could also be used to explore social network effects in response to MUP as the method can capture interactions between individuals. We know little about how social networks, particularly drinking networks, are impacted by MUP.

An ABM could be developed to explore how proximal social norms (the typically accepted behaviour of peers individuals often spend time with—e.g., 'drinking buddies') may influence changes to drinking behaviour after the introduction of MUP. Research has shown that social norms are more influential when perceived in those we have close relationships with (e.g., family and friends) [28, 29]. In such a model it would be possible to test whether individual-level changes to drinking behaviour could influence the drinking behaviour of others through social networks, and as a result help to explain population-level changes to drinking behaviour. To the extent that the overall effects of MUP arise from changes in heavier drinkers spreading to lighter drinkers, changes in lighter drinkers spreading to heavier drinkers, or a mixture of both.

An ABM developed to simulate the mechanisms associated with the influence of proximal norms on individuals' drinking behaviour could lead to best estimates of the longer-term effects of MUP on drinking behaviour. For example, social network effects may mean that people who do not change their purchasing behaviour in response to MUP may still drink less because other individuals in their network are drinking less due to the price increases. Alternatively, social networks could result in waning effects of the policy if people revert to drinking at the same level, either by emulating the purchasing behaviour of individuals in their social network or if individuals in their social network provide them with the additional resources to purchase alcohol or provide the alcohol directly.

4 | SOCIAL HARMS

The changes to the price of alcohol as a result of MUP, and the implications for changing how much people drink and where they drink, could also result in a change to social harm (e.g., crime, violence). It has been posited that the implementation of MUP in Scotland will positively impact social harms by reducing alcohol consumption [30]. However, the evaluation of MUP in Scotland did not find evidence of a positive or negative impact on crime for heavy drinkers [9]. Social harms from alcohol consumption have been thought to have worsened over time with the increasing availability of cheap alcohol [31].

ABMs are ideally placed to investigate the impact of behaviour changes on others in the local and social environment. There are existing ABMs which attempt to understand the relationship between alcohol consumption and violence, and specifically how alcohol policy could impact alcohol-related violence [17, 18]. Therefore, it is possible to draw on these existing models and use them to test the impact of introducing varying levels of MUP on rates of violence and victimisation.

Given that ABMs can capture heterogeneity they could be used to understand how social harm reductions 'spread' from consumption reductions occurring in different groups (e.g., for heavy drinkers, low-income groups, younger people and women). In other words, an ABM would tie together the characteristics of people changing their drinking, the characteristics of potential victims and perpetrators for different harms, and the interactions between victims and perpetrators at particular times and places. The change in where people consume alcohol, how much they consume and who they consume alcohol with due to MUP could result in positive or negative consequences for harm to others which could be explored using ABMs.

5 | CONCLUSION

ABMs provide a unique opportunity to explore a wider range of nuanced behavioural responses and social impacts of MUP. They have the potential to substantially contribute to a more nuanced understanding of the effects of public health policies, adding to the information provided by traditional epidemiological research methods. They can simulate interactions prior to implementation of interventions, allowing us to understand plausible effects of a policy early in the development process, and can also be used to evaluate policy retrospectively and then predict what could happen in subsequent years.

AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST STATEMENT

No interests to declare.

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