Accepted Manuscript

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PII: S0168-8510(17)30094-5
DOI: http://dx.doi.org/doi:10.1016/j.healthpol.2017.04.001
Reference: HEAP 3724

To appear in: *Health Policy*

Received date: 2-7-2016
Revised date: 27-3-2017
Accepted date: 1-4-2017

Please cite this article as: Nomaguchi Takeshi, Cunich Michelle, Zapata-Diomedi Belen, Veerman J.Lennert.The impact on productivity of a hypothetical tax on sugar-sweetened beverages.*Health Policy* http://dx.doi.org/10.1016/j.healthpol.2017.04.001

Title: The impact on productivity of a hypothetical tax on sugar-sweetened beverages

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Research Highlights

- A 20% tax on sugared sweetened drinks results in large productivity benefits.
- Productivity gains reached 1.9 % of total annual health expenditure in 2010.
- Lifetime productivity gains in the paid sector amount to AU$751 million.
- Lifetime productivity gains in the unpaid sector amounted to AU$1,172 million.
- We used an adapted multi-state lifetable Markov model

Abstract: Objectives: To quantify the potential impact of an additional 20% tax on sugar-sweetened beverages (SSBs) on productivity in Australia.
Methods: We used a multi-state lifetable Markov model to examine the potential impact of an additional 20% tax on SSBs on total lifetime productivity in the paid and unpaid sectors of the economy. The study population consisted of Australians aged 20 years or older in 2010, whose health and other relevant outcomes were modelled over their remaining lifetime.
Results: The SSBs tax was estimated to reduce the number of people with obesity by 1.96% of the entire population (437,000 fewer persons with obesity), and reduce the number of employees with obesity by 317,000 persons. These effects translated into productivity gains in the paid sector of AU$751 million for the working-age population (95% confidence interval: AU$565 million to AU$954 million), using the human capital approach. In the unpaid sector, the potential productivity gains amounted to AU$1,172 million (AU$929 million to AU$1,435 million) using the replacement cost method. These productivity benefits are in addition to the health benefits of 35,000 life years gained and a reduction in healthcare costs of AU$425 million.
Conclusions: An additional 20% tax on SSBs not only improves health outcomes and reduces healthcare costs, but provides productivity gains in both the paid and unpaid sectors of the economy.

Keywords: Health policy; Markov Model; Productivity; obesity; taxes

1. INTRODUCTION

Globally, the prevalence of obesity (body mass index (BMI) ≥30 kg/m^2) in adults has increased from 3.2% to 10.8% in men and from 6.4% to 14.9% in women over the period from 1975 to 2014 (1). The combined number of individuals with overweight (BMI ≥25 to <30 kg/m^2) and obesity has more than doubled over the last 20 years, from 857 million in 1980 to 2·1 billion in 2013 globally (2). Overweight and obesity increase the risk of many chronic diseases such as type 2 diabetes, stroke, ischemic heart disease, hypertensive heart disease, osteoarthritis and cancers of the breast, colon, endometrium and kidney (3). Overweight and obesity also increase mortality from various diseases (4). According to the Global Burden of Disease Study (5), 4.9% of disability-adjusted life years (DALYs) lost worldwide in 2015 were attributable to overweight and obesity.

Given that individual-level interventions have not been able to dampen or reverse the rise in body mass, more ‘upstream’ interventions at the national-level have been put forward (6, 7). Several leading public health authorities suggest implementing health policies that influence the individual consumer’s choices to help reduce overweight and obesity at the population-level. For example, the World Health Organization (WHO) has recommended the use of fiscal policy levers to encourage healthy lifestyles, i.e., taxation of unhealthy products (8). Fiscal policies to influence consumer choices and thus obesity have been implemented in Mexico, where a modest tax (approximately 10%) on sugar-sweetened beverages (SSBs) has reduced the amount purchased by

6% in the first year (9). Denmark, Finland, France and Hungary have also implemented additional taxes on SSBs to address the obesity epidemic (10).

The prevalence of high BMI (overweight and obesity) is also a major public health concern in Australia where the combined prevalence of overweight and obesity in adults rose by 4 percentage points from 57% in 1995 to 61% in 2012, and the prevalence of obesity in adults increased significantly from 19% to 27% over the same period (11, 12). The social and economic losses due to people being overweight and obese are tremendous. For example, Colagiuri et al. (13) estimated that the total direct healthcare expenses of overweight and obesity were AU$10.2 billion in 2005. However, in order to establish the cost of overweight and obesity from a societal perspective, the indirect costs (mainly productivity losses) also need to be considered. Indirect costs have been described as wealth losses to society resulting from diseases and reduced productivity (14). As a component of indirect costs, the productivity losses are classified either as productivity losses due to premature death or reduced productivity due to people living with disease. Cadilhac et al. (15) estimated that (paid) productivity losses due to high BMI (overweight and obesity) in Australia were approximately AU$877 million over the lifetime. However, overweight and obesity is not only associated with losses in paid work but also in unpaid work. A substantial proportion of human necessities (such as caring, housework, and meal preparation) are satisfied through unpaid labour (16). In 2006, the Australian Bureau of Statistics (ABS) reported the value of total unpaid household work to be 39.2% of Gross Domestic Product (GDP) and the value of total volunteer and community work to be 4.3% of GDP (17). These types of unpaid economic activities are important to include when calculating the 'true' costs of diseases from the societal perspective because they represent real welfare losses to citizens, even if they are not directly participating in the paid sector of the economy.

Numerous international studies have highlighted the substantial productivity losses due to obesity. In the United States (US), the total indirect costs of obesity were approximately US$37 billion in 2007 (18). For the European Union, estimates were around € 33 billion (or US$32 billion) for the annual direct and indirect costs due to obesity in 2002 (19). In Asia, several studies have measured productivity changes due to obesity. The cost of productivity losses due to obesity was estimated to be approximately 7 billion Baht (US$390 million) in Thailand in 2009 (20). In New Zealand, the productivity losses due to obesity were equivalent to 1.6% of the total healthcare expenditure in 2005 (21).

The aim of this study is to estimate the gains in productivity (paid and unpaid work) that would result from an additional 20% tax on SSBs in Australia.

2. METHODS

In this section, we describe the theoretical framework for the study. Following this, we describe the epidemiological model and methods used in this study, including data and analytical approach.

To quantify the far-reaching impacts of the policy, we took a societal perspective where both the paid and unpaid sectors of the economy were considered. The societal perspective is the most inclusive perspective and generally favoured by economists because it enables societal decision-making (efficiency considerations) (22, 23). The implication of this for our study is that it provides the opportunity to test productivity effects.

This study focuses on the impact of a hypothetical 20% additional specific tax on SSBs. Several studies have estimated and modeled this relatively high increase in taxes on SSBs, justified on the basis that such a rate is needed to achieve a measurable impact on obesity (24). It also provides consumers and industry with a clear message that governments recognize the health damage caused by SSBs and they are willing to take action to reduce this burden. In this study, we build on the work of Veerman et al. (24) who estimated that a 20% tax on SSBs in Australia would reduce the prevalence of obesity by about 2.7% among males, and 1.2% among females. Other studies have reported similar-sized effects. Briggs et al. (25) estimated that a hypothetical 20% valoric tax (flat sales tax) on SSBs would reduce the prevalence of obese adults by 1.3% in the United Kingdom (UK). Similarly, Manyema et al.(26) estimated that a hypothetical 20% tax on SSBs in South Africa would reduce potential adult obesity prevalence by 3.8% in males and 2.4% in females.

2.1 The theoretical model

The strong positive correlation between health status and labour productivity is well established by Bhattacharya et al. (27). Basically, poor health status leads to a reduction in productive time which, in turn, results in losses of income or time in unpaid activity. Bhattacharya et al. (27) proposed the following equation for the association of productivity with health status based on the original Grossman (28) model, which provides an intuitive link between health and productivity:

$$T^P \equiv \Theta - T^S = T^W + T^Z + T^H \quad (1)$$

where T^P is productive time, Θ is units of time spent in each period, T^S is time spent on being sick, T^W is time spent on working, T^Z is time spent on other activity, and T^H is time spent on improving health. The healthier the individual is, the less time they spend sick at a given time and the more productive time T^P they have available. Grossman (28) defined the role of health as a unique input into production. Thus, health policy can be used to reduce the time people spent in a sick state (T^S). The reduced sick time could then be used to generate additional productivity (29, 30). Reducing overweight and obesity could contribute to that goal as a result of the decrease in high BMI (overweight and obesity) related mortality and morbidity. As a health policy, the tax on SSBs is likely to lead to a reduction in obesity, which will bring about a reduction in the amount of time people spent in a state of ill health, T^S, with the potential to generate additional productivity (31, 32).

2.2 Overview of the model

The epidemiological model used in this study is an adaptation of the published multi-state life table Markov model developed by Veerman et al.(24). The analysis by Veerman et al. involved comparing the health outcomes of a 'status quo' scenario to those in an alternative scenario in which there are changes in BMI due to the introduction of the 20% tax on SBBs based on the 2010 Australian population. The novel aspect of this study is that we have extended the model by incorporating the effects of a reduction in the prevalence of obesity on productivity. As overweight was not related to productivity in our data, we did not include any effect of a reduction in the prevalence of being overweight. A further, minor difference between our analysis and Veerman et al. is that we set up the base case at 3% discount rate, because this rate is widely applied in economic evaluations (22).

In the model, the tax leads to higher prices of SSBs and a decrease in the purchases and consumption of SSBs (mean own-price elasticity = -0.63) (33) and thus to lower total calorie consumption. This translates into a reduction in BMI across the Australian adult population, which is modelled as lognormal distributions in 5-year age groups by sex, over the lifetime (34). Energy balance calculations were used to predict the impact on BMI based on those in Hall et al. (35).

The decrease in BMI translates into improvements in various health outcomes and reductions in healthcare costs. A multi-state life table Markov model was used to estimate the health outcomes (36). We used potential impact fraction (PIF) calculations (37) to estimate the reduction in the incidence of obesity-related diseases. The incidence, prevalence and mortality of diabetes mellitus, stroke, ischemic heart disease, hypertensive heart disease, osteoarthritis, post-menopausal breast cancer, endometrial cancer, colon cancer, and kidney cancer were explicitly modeled. Changes in disease related quality of life and mortality were integrated in life tables, where impacts in terms of disability-adjusted life years (DALYs) were calculated. All health outcomes are modeled through changes in body mass resulting from a change in energy consumption, and no direct effects of SSBs consumption on health outcomes are estimated. Similar analytical models of the cost-effectiveness of taxes on SSBs have been constructed for the UK and South Africa (25, 26).

The direct healthcare costs were calculated using the same methodology as that used in Veerman et al. (24) and in the Assessing Cost-Effectiveness Prevention project (38). The costs in 2003 were converted to 2010 Australian (real) values, using national health price inflation estimates based on the Australian Institute of Health and Welfare report (39).

Under this framework, the impact of an additional 20% tax on SSBs on productivity, healthcare costs (savings) and health outcomes (such as Life Years (LYs) and DALYs) were assessed. Similar to the previous study (24), changes in disease-related quality of life at every age were captured using DALYs (40). Disease-specific changes in mortality and disease-specific quality of life losses fed into a life table to calculate the number of DALYs (36). Similar to the previous studies (7, 24, 40), the calculation of DALYs in this study was also based on the assessment from the 2003 Australian Burden of Disease study (41). The disability weights were derived from the original Global Burden Diseases (GBD) study (42) and the Netherlands disability weights study (43).

For the present study, productivity effects were added by using the lognormal BMI distributions to determine the proportions of people in the obese BMI range (BMI ≥30 kg/m^2) and normal BMI range (BMI ≥18.5 to <25.0 kg/m^2) by 5-year age group and sex. These percentages were multiplied by the average productivity for the BMI categories.

2.3 Method for estimating productivity gains

We estimated the productivity gains of a reduction in the prevalence of obesity as result of the implementation of a hypothetical 20% valoric tax on SSBs for both the paid and the unpaid sectors.

We used both the Human Capital Approach (HCA) and the Friction Cost Approach (FCA) to estimate productivity gains in the paid sector (and we adjusted for age and sex; see Supplementary Figures 1 and 2). The HCA was used in the main analysis because it better reflects the impact of an increase in SSBs taxation from a societal perspective. The sensitivity of results was tested by applying the FCA, where we used 3 month and 6 month friction periods as proposed by Koopsmanschap et al.(44) and the friction periods commonly used in economic evaluations (22). As for the unpaid sector, the study incorporated the value of household work and volunteer and community work at the replacement cost. These activities are commonly valued by assigning a shadow price based on the opportunity cost method or the replacement cost method (45). All estimates of productivity gains were based on LYs or the number of fewer deceased individuals (and not on DALYs).

Because the main focus of the study is on calculating the potential productivity gains due to the tax on SSBs from the societal perspective, we describe the HCA approach (most appropriate costing method) below. A schematic representation for the productivity estimates in the unpaid work is provided in Figure 3. The FCA and unpaid work sectors are described in sections 1.1 and 1.2 of the Supplementary material.

2.3.1 Human capital approach

In this study, the HCA was used to measure three types of productivity changes due to obesity-related diseases. Firstly, productivity gains resulting from reduced mortality are estimated from the age of premature death until the age of traditional retirement. Due to obesity-related disease, individuals lose productive life and thus income. Secondly, productivity due to obesity-related absenteeism is assessed. This is measured in terms of the individual taking days off because of their obesity-related diseases. Thirdly, lower employment due to obesity-related morbidity is calculated.

2.3.1.1 Productivity due to a reduction in obesity-related mortality

Applying the HCA to our model, productivity changes are quantified as described in equation (2). People obtain additional life years (LYs) due to the health policy with the potential to earn higher incomes as follows:

$$P^M = \sum_{i=1}^{n} LY_i W^A \qquad (2)$$

where P^M is productivity changes due to obesity-related reduced premature mortality, LY_i is the number of added years lived in employed populations due to the health policy (a 20 % SSB tax), and W^A is the average annual wage rate in age based groups.

2.3.1.2 Productivity due to obesity-related absenteeism

This measure involves quantifying the sick leave associated with obesity-related diseases. This absenteeism will generate additional workloads for other workers as they try to compensate the sick-leave worker's workload. Missing work due to a sickness decreases a worker's contribution to a company's output. In addition, since many jobs are not performed in isolation in modern society, the absence may affect teamwork or the performance of other workers. Nicholson and colleagues (46) term this effect the "wage multiplier". This study incorporates the multiplier so as not to underestimate the effects on productivity. Equation (3) calculates productivity due to obesity-related absenteeism:

$$P^A = m\sum_{i=1}^{n} D_i W \quad (3)$$

where, P^A is productivity due to the obesity-related absenteeism, m is wage multiplier, D_i is the number of working weeks, which is added due to the effect of the SSBs tax on the health of the working population and W is the average weekly wage rate for specific age groups.

2.3.1.3 Productivity due to obesity-related lower employment

As a consequence of the reduction in obesity-related morbidity, the employment rate will be higher. Due to obesity-related diseases, people exit the labour force prematurely, and often permanently. The new tax policy on SSBs will reduce these losses. The calculation is performed as follows:

$$P^L = \sum_{i=1}^{n} N_i W^A \quad (4)$$

where P^L is productivity due to obesity-related lower employment and N_i is the number of people who no longer have obesity in the labour force due to the health policy.

These three aspects of productivity have been calculated under the HCA. This method for evaluation is consistent with previous obesity studies in Australia (15, 47).

2.4 Data

Table 1 summarizes the data used to construct the productivity components of the model. Firstly, based on the National Health Survey (NHS) (29, 48), we estimated the number of days sacrificed due to obesity. Then, wage and employment data from the ABS were used to quantify the lost days i.e. monetarize the productivity losses.

Employment status, absenteeism and reduced activity of people with obesity compared to people with normal BMI (BMI ≥18.5 to <25.0 kg/m^2) were obtained from the 2004-2005 NHS Confidential Unit Record Files (CURF) and the 2011-12 NHS CURF reported by the ABS (29, 48). The NHS consists of self-reported information about the health status of Australians, use of health services, and other health-related dimensions of lifestyle. This study identified absenteeism and reduced activity using a jackknife resampling strategy based on the NHS CURF data. The reduced activity variable measured the reduced number of days due to illnesses. The jackknife strategy is usually applied in order to correct biases and estimate standard error and parameters from samples (49). The data sources for wages were employee earnings, benefits and trade union membership in

Australia reported by the ABS (50). In the HCA and the FCA, the productivity calculation targeted people who were under 65 years since the traditional retirement age is 65 years in Australia.

2.5 Sensitivity analysis

We applied a 3% discount rate and tested the sensitivity of results to alternative discount rates (0% and 5%) for health and economic outcomes (productivity and healthcare costs) as recommended by Drummond et al. (22). Analysis under the 3 month and 6 month FCA was performed, and we estimated the effect of a later retirement age (70 years old).

Probabilistic sensitivity analysis of parameter uncertainty was performed using Monte Carlo simulation. The analysis involved repeatedly sampling random values from specific statistical distributions for the input parameters. In this model, uncertainty analysis for the decrease in BMI and the incidence of disease were incorporated. The parameter estimate for productivity is provided in Table 1. The output values from the simulation indicated the degree of certainty with respect to the parameters of which the value was varied. The uncertainty modeling was undertaken in Microsoft Excel 2013 (Microsoft Corp., Redmond, WA, USA). Ninety-five percent confidence intervals were determined for all outcome measures by Monte Carlo simulation (2,000 iterations), using the Excel add-in tool Ersatz (51).

3. RESULTS

In the following sections, we present the potential productivity gains, health gains, and healthcare costs (savings) due to the additional 20% tax on SSBs. As previously mentioned, the potential health gains and healthcare costs are consistent with the previous study (24). The novel contributions in our study are estimates of the productivity gains due to the tax.

3.1 The impact on obesity and productivity

Table 2 presents the impacts on obesity, productivity savings in the paid and unpaid sectors and the (direct) healthcare cost.

The SSB tax was estimated to reduce the number of people with obesity by 437,000 persons (95% CI: 400,000 persons to 473,000 persons) which was 1.96% of the entire population, and to reduce the number of workers with obesity by 317,000 persons (95% CI: 290,000 workers to 343,000 workers). The total additional weeks in the paid and unpaid sectors due to the tax on SSBs were 363,000 weeks (95% CI: 275,000 weeks to 453,000 weeks). The additional hours of paid work as a proportion of the total hours worked per year by the Australian population in 2010 is 0.04% (52). The total productivity gains in the working-age population due to the tax on SSBs was estimated to be AU$751 million (95% CI: AU$565 million to AU$954 million), using the HCA. The FCA results were all lower than the HCA results; the detail is given in the Supplementary material.

Figure 1a shows that the annual productivity gains using the HCA were sustained over the first 5 years, reaching around AU$23 million per year (95% CI: AU$16 million to AU$30 million), and then decreased over time. This is because the participation in paid work decreases rapidly around the retirement age (65 years). The productivity results using the FCA show a similar pattern but the gains decreased at faster rate.

3.2 The impact on productivity in the unpaid sector

Figure 2 shows that the annual total productivity gains in the unpaid sector increased to around AU$25 million per year (95% CI: AU$20 million to AU$31 million) after the first 25 years. Similar patterns are evident in household work gains, and volunteer and community work gains (See Figure 2b and 2c). In contrast to the gains in the paid sector, the productivity gains in the unpaid sector increased over the first 25 years of the tax on SSBs, because productivity remained high after retirement.

Table 2 also presents the significant potential productivity gains in the unpaid sector due to the tax, with most of the potential gains related to household work. The total productivity gain of household work that could be achieved was AU$1,042 million (95% CI: AU$826 million to AU$1,276 million) over the lifetime. In addition, the total productivity gain in volunteer and community work was AU$129 million (95% CI: AU$103 million to AU$159 million) over the lifetime.

The productivity gains (including those in the paid sector using the HCA and those in the unpaid sector) that could potentially be achieved summed to AU$1,922 million (95% CI: AU$1,494 million to AU$2,389 million).

3.3 Health outcomes and healthcare costs

The health outcomes and healthcare cost savings are consistent with the previous analysis (24) except the base case has a discount rate of 3%. As previously reported (24), the tax would also result in 25,000 extra life years (LYs) for men (95% CI: 18,000 – 32,000 LYs) and 10,000 LYs gained for women (95% CI: 8,000 – 14,000 LYs). Over the lifetime, 43,000 DALYs could be gained for men (95% CI: 28,000 – 60,000 DALYs) and 20,000 for women (95% CI: 14,000 – 28,000 DALYs). The reduction in the healthcare costs (savings) over the lifetime of the 2010 population aged 20 years or older was AU$427 million (95% CI: AU$305 million to AU$554 million) (Table 2). If we add healthcare cost savings to those in paid and unpaid sectors, the overall potential economic gain due to the hypothetical tax of 20% on SSBs was estimated to be AU$2,347 million (95% CI: AU$1,802 million to AU$2,935 million) over the lifetime (Table 2). This productivity gain is equivalent to AU$5,375 over the lifetime per person whose obesity is prevented or cured by the intervention.

3.4 Sensitivity analysis

Results of the sensitivity analysis are consistent with the results using the base case, because unpaid work continued to make a substantial contribution to the total gains of the health policy at different discount rates and towards the health outcomes.

The results under the FCA 3 months and 6 months are presented in the Appendix. Supplementary Figures 1 and 2 show that estimates of productivity gains in the unpaid sector differ depending on the discount rate applied. Because the productivity gains in the unpaid sector are occurring at older ages and further into the future, they are significantly reduced at higher discount rates. In contrast, the productivity gains in the FCA (Supplementary Figure 1) are barely impacted by variations in the discount rate, because these tend to materialize closer to the present.

As a one-way sensitivity analysis, we explored the effect of a retirement age of 70 years. Several national governments have raised the eligibility age for the Aged Pension and/or the traditional retirement age in recent years in an effort to improve labour force participation among older workers and thus secure additional tax revenue from which to fund the increasing costs of healthcare, social security and other essential services mainly due to the ageing population. In Australia, the Government announced in its 2015 budget that, in addition to increasing the age of eligibility for the Aged Pension to 67 years by 2023, it plans to further increase the age of eligibility to 70 years by 2035 (53). Many people choose to retire when they become eligible for the Age Pension in Australia and thus the two changes often occur at the same age. The increase in retirement age to age 70 would result in an increase in the production in the paid sector and a slight decrease in the unpaid sector. The Supplementary Figure 3 and 4 show these results.

4. DISCUSSION

This study has demonstrated that a hypothetical 20% tax on SSBs leads to potential economic benefits of AU$751 million in productivity gains in the paid sector and AU$1,172 million in the unpaid sector over the lifetime of the 2010 population of adult Australians. In 2010, Australia's health expenditure totaled AU$121.4 billion, which was 9.4% of GDP (39). The total productivity gain over the lifetime due to the modeled SSB tax was equal to 1.9% of total annual health expenditure or 0.2% of GDP in 2010.

The health outcomes reported in this study are consistent with the Veerman et al. (24) study even though there are some differences in magnitude. The difference in the outcomes is attributable to the discount rate setting. In the Veerman et al. (24) study Table 1 "Results of Sensitivity Analysis", a discount rate of 3% was applied to both the health gains and the costs which resulted in DALYs of 63,167 and health care cost savings of AU$423,214,932. This is very similar to our baseline results. Moreover, our results at a 0% discount rate scenario have the healthcare cost savings from the tax at AU$606 million and an additional drop of 112,000 DALYs for men and 56,000 DALYs for women. There is no significant difference in the outcomes between our paper and the Veerman et al. (24) study.

Our model and results are comparable to other studies showing the effect of a tax on SSBs on obesity. Briggs et al (25) estimated the reduction in people in the UK who are obese to be 180,000 people (1.3% of the obese population) due to a 20% SSBs tax. Manyema et al. (26) estimated that a 20% SSBs tax in South Africa would reduce obesity by 3.8% in adult males and 2.4% in females. The extent of the estimated decrease in obesity is mainly due to the BMI distribution for the specific population and the country-specific own price elasticity estimates on the purchase/consumption of SSBs. Cadilhac et al. estimated the total potential productivity gains to be AU$877 million over the lifetime if high BMI (overweight and obesity) was to be eliminated (15). Compared to our study, there are some differences in the results due to the costing approach and estimation methods used. Cadilhac et al. (15) estimated the decrease in high BMI (including the overweight population) and used population attributable fractions for the estimation of the impact on high BMI-related diseases. Despite differences in methods and data, similar to these previous studies, our study showed that a tax on SSBs significantly decreases the burden of obesity and leads to productivity benefits.

4.1 Study strengths and limitations

This study has two major strengths. One is that it took a societal perspective to estimate the impacts of the tax on SSBs, which was not adopted in the previous study (24). The results from this study provide a comprehensive picture of the benefits, by estimating the health status and economic impacts of the hypothetical tax on SSBs and thus extending the previous analysis which only estimated the direct healthcare cost savings (24). Secondly, the study used the best available data (NHS 2011-12) and a novel multi-state lifetable Markov model (24) to provide a rigorous evaluation of the benefits that can be derived from the proposed tax on SSBs.

The study has some limitations. It relies on self-reported cross-sectional data to identify (and quantify) the association between the risk of obesity and productivity. There is a lack of reliable Australian longitudinal data for the relationship between obesity and productivity outcomes (54). There is the potential for bias because the study relies on NHS respondents' self-reported labour force participation. However, self-reported unpaid activities, paid and unpaid work, and health status (overweight, obesity) are regarded as valid measures for such studies (55). Furthermore, there are no studies measuring the accuracy of the survey responses in the NHS. Other limitations include that our population level model assumes that co-morbidities are random rather than clustered in high-risk individuals, that epidemiologic parameters and health care costs (in net present values) remain stable into the future, and that it does not allow us to examine differences in the impacts on socio-economic and other subgroups. Our analysis also implicitly makes the assumption that wages remain unaffected by changes in labour supply, population health and population numbers. We note that these assumptions may be relaxed using an Australian Computable General Equilibrium (CGE) model where shocks to the labour market, health care market and beverage market could be consecutively analyzed. The Lock et al. model is one study that has examined the health, agricultural and economic impacts of people taking up healthy diet recommendations in the United Kingdom and Brazil using CGE modeling (56). Additionally, the productivity effects of obesity were estimated by age group and sex, but were not adjusted for potential confounders such as education and income level. To the extent that obesity is associated with a lower income, these confounders may have led to an overestimation of the impact of the tax. In contrast, the dichotomisation of body mass may have led to a downward bias (57). Co-morbidity would partly be a consequence of obesity, and hence adjusting for it risks resulting in over-adjustment. Additionally, we did not include any effect of reductions in the prevalence overweight. This may have led us to underestimate the impact of the tax, given that overweight is associated with increased risk of disease (58). For disease frequency, we have used data from the Australian Burden of Disease 2003 study (41), with trends extrapolating to 2010. The use of more recent estimates, such as those from the Global Burden of Disease study, may alter the size of the effect estimates but is unlikely to change the overall conclusions of our study.

4.2 Further research

Further research may involve estimating other scenarios for the design and implementation of health policy and interventions. This study provides a novel approach to modeling the productivity gains of a health policy, which may be incorporated into further policy/economic evaluation studies. The model may be extended to estimate the long-term societal effects of different food taxes at different rates, and taxes targeted at different food categories in Australia. The current study focused on a tax on SSBs only. It would also be valuable to perform similar analyses in other settings for obesity interventions. The results are consistent with similar modelling work in other countries (25, 26). If similar data are available, the methodology used in this paper for estimating productivity gains due to a tax on SSBs may also be applied to other countries.

Furthermore, the model may be extended to include children and adolescents because obesity in childhood tends to increase the risk of obesity in adulthood, morbidity, and mortality (59, 60). Increased soft drink consumption is associated with obesity in childhood and increased risk of type 2 diabetes (61, 62). Further research may also involve expanding the model to include the impact on children's education, activity, social/community involvement and health due to the hypothetical tax on SSBs. Effects on wages may be examined with, for example, CGE Models that enable to estimate the effects of changes to the labour market, healthcare market and beverage market (63, 64).

5. CONCLUSIONS

Developing effective health policy to reduce obesity and improve labour participation is a major concern for policymakers in Australia and elsewhere, because of the need to avoid unnecessary economic losses as the population ages. This study added a productivity component to an existing multi-state lifetable Markov model to provide information about the potential productivity impacts of an additional 20% tax on SSBs in Australia, and found that it could generate a significant benefit to society in terms of improved productivity and health gains.

CONFLICT OF INTEREST:

The authors have declared that no competing interests exist.

Acknowledgements

Dr Veerman is supported by funding from the NHMRC Centre for Research Excellence in Obesity Policy and Food Systems (APP1041020).

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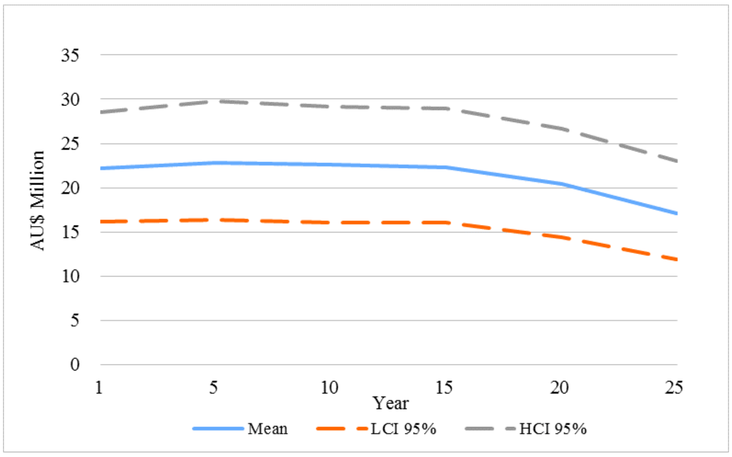
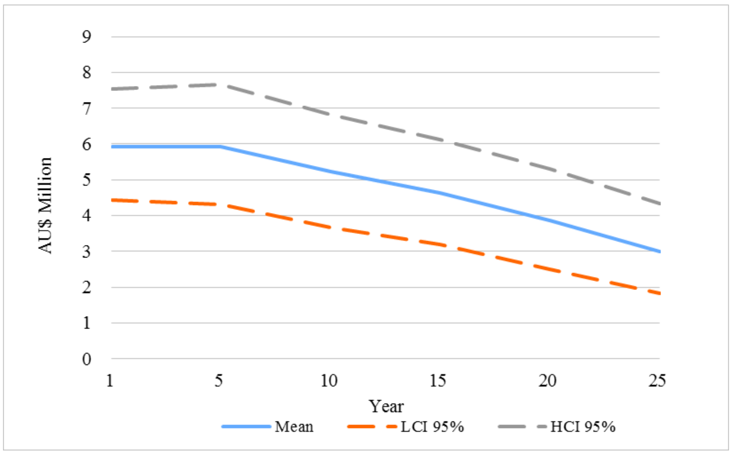
Figure 1: The annual productivity gains in the paid sector from 2010-2035 after implementing a 20% tax on sugar-sweetened beverages (SSBs) in Australia in 2010

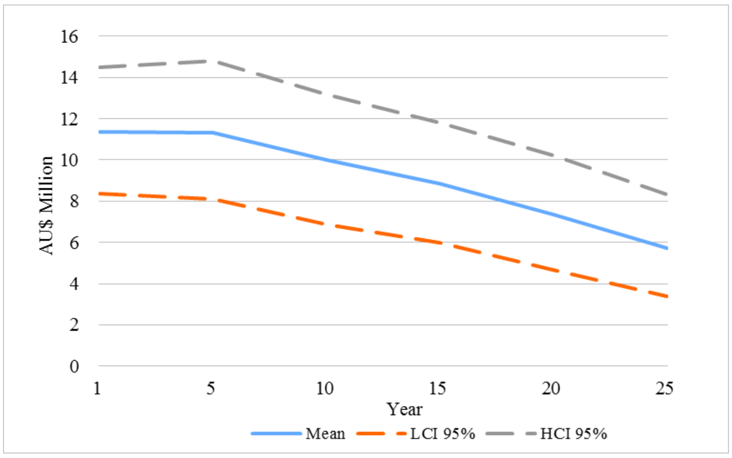
(a) Productivity gains using Human Capital Approach (HCA), by 25 years since introduction of the tax on SSBs



(b) Productivity gains using Friction Cost Approach (FCA) 3 months, by 25 years since introduction of the tax



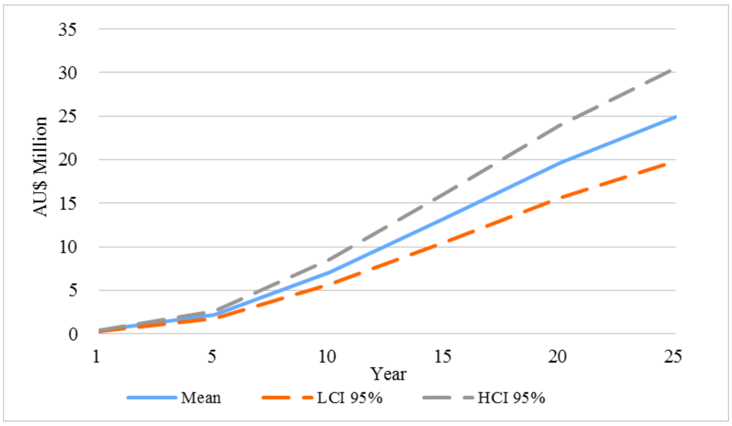
(c) Productivity gains using FCA 6 months, by 25 years since introduction of the tax



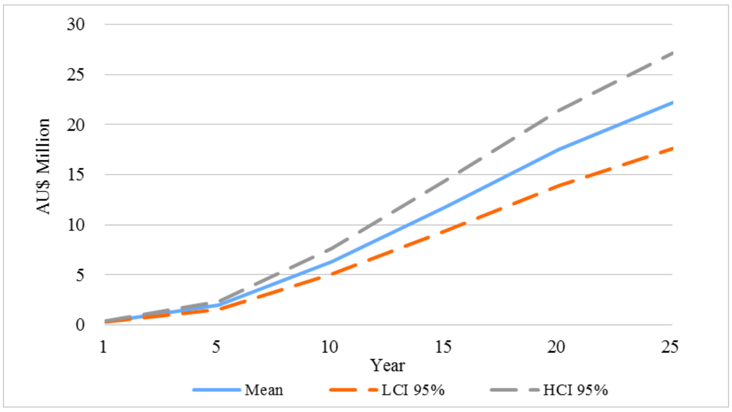
LCI: Lower Confidence Interval, HCI: Higher Confidence Interval

Figure 2: The annual productivity gains in the unpaid sector over the first 25 years after implementing a 20% tax on sugar-sweetened beverages(SSBs) in 2010 in Australia

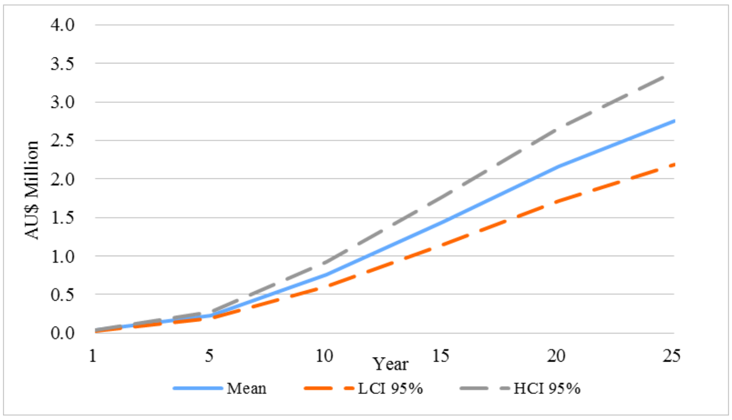
(a) Productivity gains in the unpaid sector



(b) Household work gains



(c) Volunteer and community work gains



LCI: Lower Confidence Interval, HCI: Higher Confidence Interval

Figure 3: Schematic overview of the method for estimating household productivity and volunteer and community work productivity

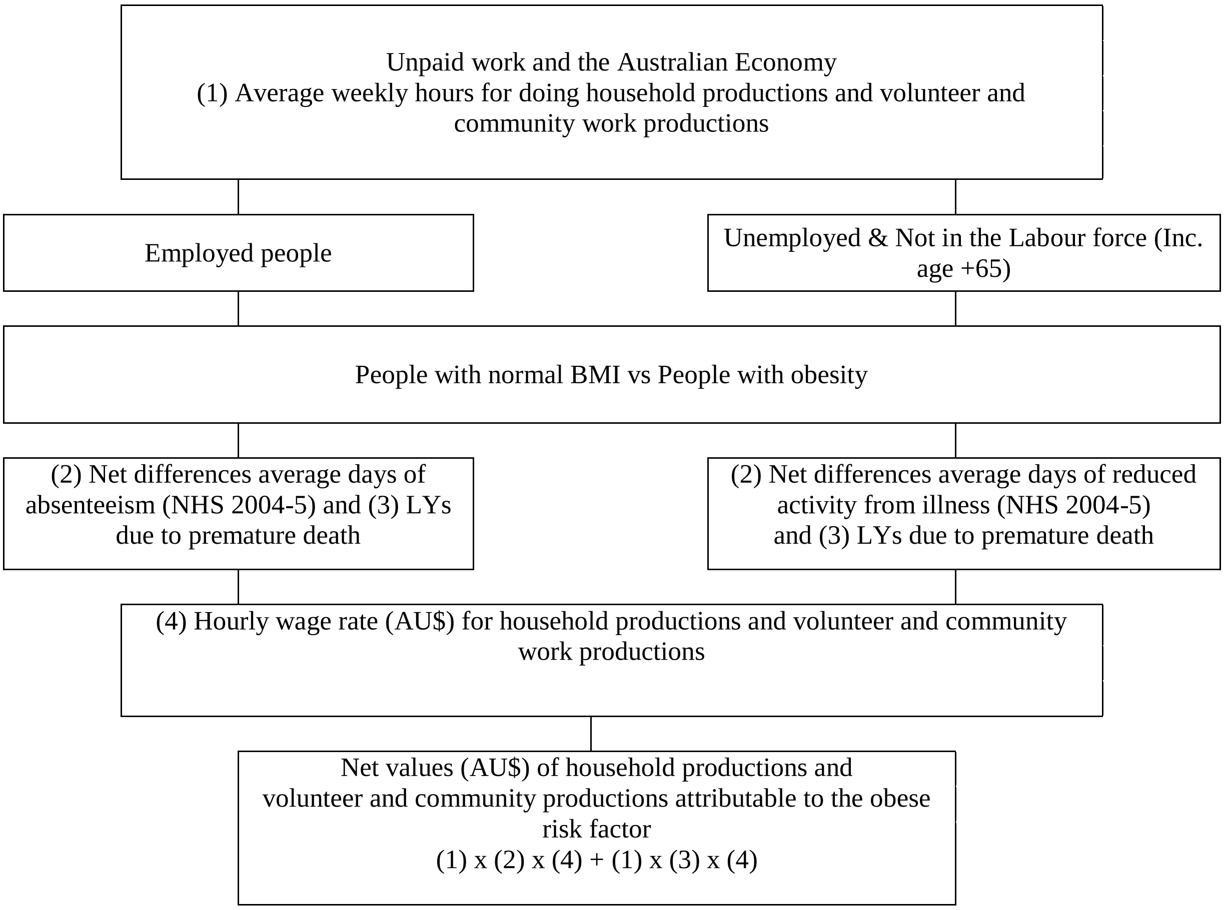


Table 1: Technical parameters, data sources and distribution of the productivity components of the model

Data item	Source	Values	Parameter*	Distribution	Comments
The estimated change in BMI	Haby MM et al. (34) and Sharma A et al. (33)	Mean, SE		Lognormal	By age and sex
The incidence of obesity-related disease	Begg S et al. (41)	Mortality and Prevalence rate of 9 obesity-related diseases			By age and sex
The Australian average weekly earnings in main jobs	ABS 6310.0 May 2013(50)	Mean SE	1-1	N/A	By 5 age groups Assumed SE as 10% of Mean value
Wage growth rates	ABS 6345.0 Sep 2016 (65)	2.88 (0.14)		Normal	From 2010 to 2016
Friction periods	Koopmanschap et al. (44)	3,6 months		N/A	Varied in sensitivity analyses
Training costs	ABS 6362.0 Apr 2003(66) ABS 6310.0 May 2013(50)	Mean SE		Normal	Average % per person Assumed SE as 10% of Mean value
Retirement age		65 years/70 years		N/A	Assumed
Wage multiplier	Nicholson et al. (46)	1.61 (0.006)		Normal	Median
Average weekly hours for doing household work and community & social work	ABS 5202.0 May 2014 (17)	Mean, SE	1-2	N/A	By employment status
Hourly wage rate (AU$) for household work and community & social work	ABS 5202.0 May 2014 (17)	Mean, SE	1-2	N/A	Replacement cost by sex
Employment status of people with normal BMI	NHS 2011-12(29)	Mean, SE	1-3	Normal	By age and sex
Employment status of obese people	NHS 2011-12 (29)	Mean, SE	1-4	Normal	By age and sex
Employment rate in Australian population	ABS 6202.0 Aug 2015 (52)	Mean, SE	1-4	Normal	By age and sex
The number of days off due to long term sickness in people with normal BMI	NHS 2011-12(29)	Mean, SE	1-5	Gamma	By sex
The number of days off due to long term sickness in obese people	NHS 2011-12 (29)	Mean, SE	1-5	Gamma	By sex
The number of days of reduced activity due to long term sickness in people with normal BMI	NHS 2004-5 (48)	Mean, SE	1-5	Gamma	By sex
The number of days of reduced activity due to long term sickness in obese people	NHS 2004-5 (48)	Mean, SE	1-5	Gamma	By sex

Further details about the parameters used to estimate the productivity gains due to the tax is provided in the supplementary tables.

*The numbers in column indicate the supplementary table's numbers.

ABS: Australian Bureau of Statistics, NHS: National Health Survey, BMI: Body Mass Index, SE: Standard Error

Note details of data source were provided in the references of the manuscript

Table 2: Summary of the productivity gains due to the extra 20% tax on SSBs

Outcome	Unit	Mean	Lower 95% CI	Higher 95% CI
Reduced number of individuals with obesity	Persons	437,000	400,000	473,000
Reduced number of employees with obesity	Persons	317,000	290,000	343,000
The working additional weeks in the paid sectors		183,000	139,000	228,000
The additional weeks in the unpaid sectors	Weeks	180,000	136,000	225,000
The additional paid and unpaid weeks		363,000	275,000	453,000
Productivity HCA (a)		$751	$565	$954
Productivity FCA 3 months (b)		$151	$109	$198
Productivity FCA 6 months (c)		$290	$205	$383
The unpaid sector's Productivity (d)	AU$ million	$1,172	$929	$1,435
- Household Work Productivity		$1,042	$826	$1,276
- Volunteer and community work productivity		$129	$103	$159
Direct health care cost savings (e)		$425	$308	$547
Total productivity gains in the HCA (a+d)		$1,922	$1,494	$2,389
Total productivity gains in the FCA 3 months (b+d)	AU$ million	$1,323	$1,037	$1,633
Total productivity gains in the FCA 6 months (c+d)		$1,461	$1,133	$1,818
Total benefit in the the paid sector (a+e)		$1,175	$873	$1,500
Total benefit in the the paid sector (b+e)	AU$ million	$576	$417	$745
Total benefit in the the paid sector (c+e)		$714	$513	$929
Overall economic gains (a+d+e)		$2,347	$1,802	$2,935
Overall economic gains (b+d+e)	AU$ million	$1,748	$1,345	$2,180
Overall economic gains (c+d+e)		$1,886	$1,441	$2,364

Results based on 2,000 iterations for the Monte Carlo simulation. The result shows the lifetime savings for the total population

HCA: Human Capital Approach, FCA: Friction Cost Approach