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Informing investment to reduce health inequalities (III) in Scotland: a commentary

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Executive summary

Aim

Reducing health inequalities is an important policy objective. Although broad principles of inequalities reduction are understood, there is a lack of quantitative evidence about the relative impact of specific interventions. This project aimed to provide modelled estimates of the impact of a range of interventions on health and health inequalities.

Project outline/methodology

A range of interventions across the determinants of health (including ‘upstream’, ‘downstream’, individually-focused and population-wide) were selected for modelling in consultation with an advisory group. We reviewed the literature to identify the highest quality and most generalisable evidence linking the interventions to changes in mortality and hospital admissions. For some determinants of health, we examined the impact of changes in risk factor exposure resulting from an unspecified intervention. We developed models to estimate cumulative mortality and years of life lost (YLL) in intervention and comparison populations over a 20-year time period for a single year of intervention. We estimated changes in inequalities using the relative index of inequality (RII). We developed a Microsoft Excel-based tool that allows users to vary interventions, targeting and other assumptions to examine realistic scenarios for intervention impact over the short, medium and long term for Scotland overall and for Health Boards and local authority areas individually.

Results

Eleven interventions were modelled based on the available literature. Introduction of a ‘living wage’ generated the largest beneficial impact on health, and led to a modest reduction in health inequalities. Increases to benefits had modest beneficial impacts on health and health inequalities. Income tax increases had a negative impact on population health but reduced inequalities, while council tax increases worsened both health and health inequalities (as the model looked only at the taxation increases and not the potential for redistribution or changes to expenditure that this might facilitate). Increases in active travel (defined as a modal shift from driving to walking/cycling for those commuting to work) had minimally positive effects on population health but widened health inequalities. Increases in employment reduced inequalities only when targeted to the most deprived groups. Tobacco taxation had modestly positive impacts on health but little impact on health inequalities. Alcohol brief interventions had modestly positive impacts on health and health inequalities only when socially targeted, while smoking cessation and ‘Counterweight’ weight-reduction programmes had only minimal impacts on health and health inequalities even when socially targeted.

The results are generally sensitive to assumptions contained within the models. These include effect sizes drawn from observational data and populations at risk drawn from self-reported survey data; the impacts of which are likely to over- and underestimate the reduction in inequality of the health behaviour interventions respectively.

Conclusions

We developed modelling approaches that used the best available data and evidence at the time to estimate reductions in hospitalisations, YLL and health inequalities associated with a range of public health interventions. We were able to develop a transparent and usable interactive tool that allows users to model a range of interventions designed to reduce health inequalities.

Interventions have markedly different effects on mortality, hospitalisations and inequalities. The most effective (and likely cost-effective) interventions for reducing inequalities were regulatory and tax options which affect income. Interventions focused on individual agency were much less likely to impact on inequalities, even when targeted at those in the most deprived communities.

Introduction

Health inequalities in Scotland are wider than in the rest of west and central Europe and increasing on many measures.[1] The Scottish Government has stated that 'reducing inequalities in health is critical to achieving the Scottish Government's aim of making Scotland a better, healthier place for everyone'.[2] There is demand from the Scottish Government, territorial Health Boards, local authorities and Community Planning Partnerships (CPPs) for support in deciding which interventions are the most effective and cost-effective in reducing health inequalities. This reflects a gap in current scientific knowledge with important practical implications; although the broad principles about what works to reduce health inequalities have been articulated,[3,4] the evidence on specific interventions and the likely magnitude of impact remains limited. This project seeks to assist decision-makers by quantifying the likely impacts of a range of interventions using the best available data and evidence.

The aims of the project were:

1. To quantify and model the capacity for a range of public health interventions to reduce health inequalities in Scotland, based on realistic scenarios for the delivery of downstream interventions to individuals in deprived groups.
2. To compare such downstream interventions with universal, population-level approaches in terms of their potential impact on health inequalities.
3. To augment an existing suite of practical tools for informing decisions about how to reduce health inequalities in Scotland through the addition of further interventions and outcomes.
4. To provide decision-makers with comparisons of the effectiveness of differing strategies to tackle health inequalities.

This commentary includes an overview of the approach used in creating the models for the Informing Investment to reduce health Inequalities (henceforth 'III') project, some illustrative results and a discussion of the broader learning about how best to reduce health inequalities.

Methods

Selection of interventions for modelling

We aimed to select interventions which varied across the range of ‘upstream’ and ‘downstream’, and in the degree to which they required individuals to ‘opt in’ (i.e. the degree of individual agency required). To do this we created a matrix using the determinants of health framework development by Dahlgren and Whitehead[5] against a dichotomous ‘population-wide’ or ‘individual’ axis. The project team identified exemplar interventions for each layer and the project advisory group (PAG) was consulted on these and whether there were further interventions that could be added to ensure relevance to current Scottish policy and practice in public health decision-making. A rapid literature review was carried out for each suggested intervention to ascertain whether effect sizes for mortality and hospitalisation were available from reasonably valid and relevant studies. The PAG was then asked to approve a prioritised list of interventions on the basis of the desired spread of intervention type, and the availability and quality of evidence of impact. Some interventions were prioritised by the PAG even though there was an absence of a single defined intervention generating impacts along a theoretical causal chain (for employment, housing and active travel). This process resulted in the following interventions being included:

(1) Changes to taxation (1p on the Scottish rate of Income Tax, a 10% rise Council Tax).
(2) Changes to benefits (a 10% increase in the value of Jobseeker’s Allowance and Income Support, a 10% increase in basic and 30-hour Working Tax Credits).
(3) Introduction of a ‘living wage’).
(4) An increase in the level of tobacco tax.
(5) Greater provision of smoking cessation services.
(6) Greater provision of alcohol brief interventions (ABIs).
(7) Greater provision of a Counterweight weight-management service.
(8) Changes in levels of employment.
(9) Changes in the extent of active travel (walking and cycling).

The III tools are designed to inform decision-makers about the likely impact of a change in either the number of interventions, or the socio-economic composition of the populations which are targeted, and which take up, the interventions. They do this by comparing the impact of modelled scenarios to the counterfactual scenario of no intervention (for those interventions not currently being implemented) or of the current level of intervention.

As noted above, we did not identify discrete interventions for employment or active travel, and so we instead modelled the impact on admissions and mortality of specified changes in levels of employment and in levels of active travel occurring as a result of unspecified interventions. We were not able to include a housing intervention as originally planned because of the absence of evidence about impacts of housing improvements on mortality or hospitalisations, which made modelling even from an intermediate step impossible.[6]

Overall approach to modelling

We created a non-stochastic model of the impact of a range of interventions on health and health inequalities. This supersedes the previously published Health Inequalities Tools for Scotland (HITS) (2009 and 2012).

We compared the impact of the selected interventions on all-cause mortality and all-cause hospitalisations (and on inequalities in mortality and hospitalisations) to the counterfactual scenario of no intervention (for those interventions not currently being implemented) or of the current level of intervention. This was examined for the current cohort of adults aged 16 years or more for the smoking, tobacco tax, ABI and counterweight models, aged 15–69 years for the employment model, aged 15–64 years for the active travel model and the whole population for the income models. We took a fixed (closed) cohort approach, and so we did not model the impact on populations not included in the original baseline cohort (i.e. immigrants and those born in the future or reaching adulthood in the future (for the adult-only models)).

We obtained data from National Records of Scotland (NRS) on the current age, sex and Scottish Index of Multiple Deprivation (SIMD) quintile distribution of the population and quantified the number of people within each stratum who were exposed or unexposed to the relevant risk factor (e.g. smoking or unemployment) from the most appropriate data source.

We used mathematical functions to describe total mortality and hospitalisations according to age, sex, SIMD quintile and calendar time for hospitalisation and mortality. Historical data were used to estimate mortality and hospitalisation rates by age, sex, SIMD and calendar time. Projected mortality rates obtained from NRS were used to estimate mortality rates by age, sex and calendar time. The final mortality function combined projected rates for age, sex and calendar time from the projected data, with rates for SIMD from the historical data. The hospitalisation rate function was based on historical data. Mathematical functions were also used to describe the change in the rate ratio (i.e. the risk of mortality/hospitalisation for those exposed compared to those not exposed) for each specific intervention over time or (in the income model only) by SIMD (for mortality and hospitalisation separately). For each year of follow-up, we multiplied the mortality and hospitalisation rate by the rate ratio (between 0 and 1) for each intervention to provide an estimate of the effect of the intervention (delivered at time zero) during each year of follow-up. If, for example, the effect of an intervention on the mortality rate is believed to attenuate over time, the rate ratio tends to one over time. The calculations used to obtain the mathematical functions describing mortality rates, hospitalisation rates and rate ratios were performed in R (www.r-project.org/. All subsequent calculations were performed within Microsoft Excel software. In order to perform these calculations, functions were created within Visual Basic for Applications (VBA) in Excel to allow calculation of the cumulative incidence, years of life lost (YLL) and hospitalisation count for each age, sex, and SIMD stratum for each follow-up period of interest – under both the intervention and counterfactual scenarios. The difference between the two scenarios was used to generate the estimated effect of the intervention. The difference in years of life lost has, for simplicity, been called years of life gained (YLG). The stratum-specific estimates were then aggregated as appropriate to calculate the impact of the policy on the whole Scottish population, each Health Boards (as at April 2014) and local authority area, where there were sufficiently large populations to facilitate modelling, and each SIMD quintile. The results were presented as the difference in the relative index of inequality (RII) (of YLL and hospitalisation) in the population which is modelled to have received the intervention compared to that in the population model without an intervention.

The Excel spreadsheets form a toolkit that allows users to determine the intervention and population of interest; and for individual-level interventions the number of interventions, the number of years over which the intervention is delivered (set to one year for interventions delivered on an individual basis, but able to be varied) and the distribution across Scottish SIMD quintiles. It also allows users to model the impact of the intervention for Health Boards and local authorities individually.

For two outcomes (YLL and hospitalisation) we illustrate absolute change and changes in relative inequalities accumulated over 10 and 20 years for the Scottish population. For interventions with a fixed delivery cost per intervention, we model an investment of £5m; for active travel the population affected is set at 100,000; for employment we model 20,000 new jobs.

A key feature of the tools is that they allow users to specify whether they wish to target the intervention by deprivation, and to which Scottish Index of Multiple Deprivation (SIMD)[7] quintiles. The targeting strategy within the model is crude and assumes full delivery of the intervention(s) to quintile 1 (the most deprived) or quintiles 1 and 2. In addition, the tool facilitates targeting according to distribution of need (e.g. if 30% of smokers live in SIMD1 then they will receive 30% of the interventions delivered) as well as an option for ‘even’ distribution (i.e. 20% of interventions delivered across each of the five SIMD quintiles). It is also possible for users who are comfortable manipulating Microsoft Excel spreadsheets to create bespoke reach patterns.

Further details of the methods are contained within appendix D. The VBA and R code used in the models are also available on request. We provide full details of each model specification and the sources of the assumptions we make in Tables 1 and 2. A brief summary is provided below.

Income interventions

We were limited to examining only those changes in income distribution and health resulting from tax and benefit changes modelled in the only identified publication, providing estimates of the impact of such changes on income distribution in Scotland.[8] The interventions were: a 1p increase in a Scottish rate of Income Tax (SRIT); a 10% rise in Council Tax; a 10% increase in Jobseeker's Allowance and Income Support; a 10% increase in basic and 30-hour Working Tax Credits; introduction of a living wage (defined as £7.20 per hour). The risk associated with changed income distribution was applied to the whole population. We did not identify any studies estimating the direct impact of income changes on mortality or hospitalisation independent of wider economic changes. We therefore regressed log-transformed standardised mortality and hospitalisation rates for Scotland (obtained from the Information Services Division (ISD) of NHS National Services Scotland, www.isdscotland.org/) on log transformed mean weekly equivalised household income after housing costs (data from the Institute of Fiscal Studies/Family Resources Survey) for each SIMD income domain quintile, using these coefficients to predict the effect of changing the income distribution. We did not attempt to estimate the direct costs or savings of the income interventions and the econometric model on which we were reliant did not facilitate modelling of the potential for redistribution following changes to taxation, changes to public spending nor variation in the underlying assumptions.

Tobacco tax

We modelled a 10% increase in tobacco product prices as a result of tobacco taxation. The population at risk (PAR) was defined as all Scottish residents aged ≥16 years who smoke (data from the 2012 Scottish Household Survey) and exposure risk ratio based on the risk of all-cause mortality/hospitalisation in individuals who currently smoke compared with those who have never smoked.

Smoking cessation

The intervention was defined as an increase in the number of people offered the current mix of smoking cessation services provided by the Scottish NHS. The PAR, exposure risk ratio, likelihood of relapse and projected decline in smoking prevalence in the absence of an additional intervention were equivalent to those used in the tobacco tax model. The cost per smoking cessation intervention was estimated at £98 in 2011[9] – this was updated to 2012 prices.

Alcohol brief interventions (ABI)

The intervention was defined as an increase in the number of people offered the current Scottish ABI service. The PAR was defined as Scottish residents aged $\geq$16 years drinking hazardously or harmfully (Scottish Health Survey (SHeS) 2008–11 combined), assuming the non-intervention group would experience no change over time. The exposure risk ratio was based on the risk of all-cause mortality/ hospitalisation in individuals who drink at hazardous and harmful levels in comparison to those who drink moderately.

The cost of an ABI was estimated at £25 in 2011[10] and remained unchanged when inflated to 2012 prices after rounding.

Counterweight

The Counterweight intervention was defined as an increase in the number of people offered the Counterweight weight management service. The PAR was defined as Scottish residents aged $\geq$16 years with BMI $\geq$30 kg/m^2 (SHeS 2008–11 combined). The exposure risk ratio was based on the risk of all-cause mortality/hospitalisation in individuals who are obese compared to those who are not obese. The cost of a Counterweight intervention was estimated at £72 in 2011[11] – this was updated to 2012 prices.

Employment

We identified no robust evidence on the impact of specific interventions on employment that were generalisable. We therefore defined this model in terms of changes in employment levels rather than a specific intervention. We defined the population at risk (PAR) as Scottish residents aged 15–24 years not in full-time education, training or employment, or aged 25–69 years and not in employment (data from the Scottish Government Annual Population Survey, 2012). The exposure risk ratio was based on the risk of all-cause mortality/hospitalisation in individuals who are employed compared to those who are not in employment. The cost per job created is assumed to be the £4,400 cited in Beatty and Fothergill (2011),[12] adjusted to 2012 prices.

Active travel

The active travel intervention was defined as changes in commuting by walking and cycling rather than as a specific intervention. This choice was enforced by a lack of robust evidence on the impact of specific interventions on active travel. We assumed that the intervention would be structural (e.g. changing the physical environment or providing new infrastructure) and that changes in behaviour for the affected cohort would be sustained over time. We defined those at risk as the working population aged 16–64 years who commute to work in a car or van over distances of three miles or less (determined from the Scottish Household Survey (SHoS) 2008–12 combined dataset), assuming that this would not change in the absence of an intervention.

Again, the PAR is based on a fixed cohort approach; we did not consider the impact of any new people coming into the eligible group over the period being modelled. The exposure risk ratio was based on the risk of all-cause mortality in individuals who are physically active (i.e. engage in at least 30 minutes of moderate intensity physical activity on most days of the week) compared to those who are inactive. We also did not attempt to estimate the direct cost of the active travel intervention. Estimates of the impact of increased physical activity on all-cause hospitalisations are unavailable.

Table 1: Exposure risk ratios and proportion of PAR eligible for treatment for each model

	Exposure risk ratio		**Percentage of the PAR eligible for the intervention**	
	Mortality	**Hospitalisation**	**%**	**Rationale**
Tobacco tax	2.27[13,14]	1.52[15]	80%	Assume 20% of the PAR (i.e. aged 16 years or more) unaffected due to increases in illegal sources of

				tobacco, and that this applies equally across SIMD quintiles.[16]
Smoking cessation	2.27[17,18]	1.52[19]	74%	74% of the PAR eligible for the intervention (i.e. aged 16 years or more) using data on quit motivation.[20]
ABIs	1.25[21]	1.10.[22]	39%	KAM module indicates 39% of hazardous/harmful drinkers aged 16 years or more want to reduce alcohol consumption.[23]
Counterweight	1.39[24]	1.18[25]	71%	KAM module data on motivation to lose weight among obese population aged 16 years or more.[23]
Employment	1.63[26]	1.02[27]	34%	Assume all unemployed (i.e. aged 15–69) and 30% of those aged 15–24 years who are economically inactive and not in full-time education are eligible.
Active travel	1.30[28]	No evidence identified for modelling	33%	Intervention only relevant to those aged 16–64 who commute <3 miles by car or van (2001 Census).

Hospitalisation costs

Geue et al.[29] estimated the average cost of a continuous inpatient stay between 2001 and 2007 at £2,113 based on a mean (SD) number of admissions of 15,576 (34.1) - this has been adjusted to 2012/13 prices.

Sensitivity analysis

To reflect the uncertainty surrounding some of the assumptions on which the models are based, a number of sensitivity analyses were undertaken. A brief summary of each sensitivity analysis is given below.

Income

For income models, the estimated changes in income resulting from each specific intervention was drawn from published results that were based on a household level model of the Scottish economy which included a behavioural response element.[30] It was not possible to identify appropriate parameters from published results to enable sensitivity analysis of the impact of the policy levers concerned on income inequality**.** Sensitivity analysis was therefore confined to the assumption that the relationship between income and mortality was not confounded. For illustrative purposes, it was arbitrarily assumed that confounding attenuated the impact of income changes on mortality by 25% and 50%, giving more conservative estimates of the impact of the interventions.

Tobacco tax/smoking cessation

Using base population data ‘elements’ of smoking prevalence; leavers (i.e. people who’ve quit between 1–2 years ago[31]), starters (including those ≥16 years and occasional/regular smoking 15-year-olds) and population estimates, the Scottish Government has produced projections of smoking prevalence to 2045. Two projected smoking prevalence models are presented; a basic model where none of the elements changes from baseline, and an enhanced model where assumptions are made regarding changes in each element (e.g. decreases in prevalence among 15-year-olds and those aged ≥16 years and increasing proportions of successful quitters). The tobacco models use the basic smoking prevalence projection estimates. A sensitivity analysis was carried out using the enhanced model estimates of prevalence change between 2012 and 2032.[32]

ABIs

Given the complexities in estimating how prevalence of hazardous and harmful drinking may change in future, the ABI model assumes that the PAR in the untreated group will remain static over the 20-year period. A sensitivity analysis was carried out assuming either an increase or decrease (e.g. +/- 10%) in the untreated PAR over the 20-year period.

The suggested 65% compliance rate used in the ABI model from the review by Kaner[33] and colleagues is likely to be optimistic in the Scottish context. In Scotland, the implementation of ABIs has been different to that in the original trials, taking place in other settings and for other population groups. We have therefore provided a range of sensitivity analyses to illustrate the impact of much more conservative (15%) or more extreme (100%) compliance with the intervention.

Counterweight

USA trend data on obesity levels amongst adults suggest that Scotland is around 10–15 years behind the USA in its obesity trends.[34] The prevalence of obesity in Scotland in 2003 (22.9%) was similar to USA levels in 1991 (23.2%). The data suggest that obesity levels in the USA will reach 52% by 2030. If the trend in Scotland followed that in the US (applying a 12-year time lag alongside obesity prevalence data from SHeS), and assuming no additional effective obesity prevention in Scotland, obesity levels for the 16–64 year age group could reach 41% by 2030, an increase of 58% over 2008 levels. When adjusted to reflect levels in the population aged 16 years and above, the projected prevalence becomes 43%. This estimate equates to an increase in the prevalence of obesity in Scotland of around 14.5% over the next 20 years, a figure which is used in the Counterweight model. Given the uncertainty surrounding this estimate, we have therefore provided a range of sensitivity analyses to illustrate the impact of more conservative increases in obesity prevalence (half of this, or 7.25%) or a scenario where the projected obesity prevalence increases return to null over a five-year period.

The compliance rate is defined as the proportion of individuals enrolled into Counterweight who attended a 12-month follow-up appointment: approximately 40%. The average weight loss figure of 3.7kg (or 1.36 kg/m^2) is applicable to this group only. This is an estimated figure based on experience from Counterweight implementation. Although the published figure for compliance is 28%, this included a large number of participants from a Health Board where follow-up was done outside general practice and follow-up rates were particularly low; excluding this Health

Board generates an estimate of about 40% and this is considered more in line with what is achievable in general practice in Scotland. We have therefore provided a range of sensitivity analyses to illustrate the impact of more conservative (28%) or more extreme (100%) compliance with the intervention.

Results

Years of life lost

Most of the modelled interventions reduce both YLL and relative inequalities after 10 years, but with varying effects (Figure 1). Introduction of a living wage generated the largest beneficial impact on YLL, and led to a modest reduction in health inequalities (with a gain of 77,000 years of life and a decrease of 0.32 percentage points in the RII over 10 years). A 10% increase in JSA/IS has a less prominent beneficial impact on YLL, but a greater impact on health inequalities (a reduction of 26,000 of YLL and decrease of 0.88 percentage points in the RII over 10 years). Increases in employment had a more modest impact on YLL and only reduced inequalities when targeted to the most deprived groups, while tobacco taxation and a 10% increase in working tax credit improved YLL but had minimal impact on health inequalities. In contrast, increases in active travel had minimally positive effects on YLL but marginally widened health inequalities. Increasing council tax worsens both YLL and health inequalities as the model looked only at the taxation increases and not the potential for redistribution or changes to expenditure that this might facilitate. For the same reason, a 1p increase in the SRIT reduces inequalities modestly but worsens YLL. The more downstream focused interventions (i.e. ABIs, smoking cessation and Counterweight) had only minimal impacts on YLL and health inequalities, even when targeted to the most deprived areas.

After 20 years the protective impact of most of the interventions on YLL and inequalities continue to accumulate, although there are some notable exceptions. For example, in both the Counterweight and the ABI models, the protective impact of the interventions appears to regress over time.

Hospitalisations

Most interventions achieve an absolute reduction in the number of hospitalisations and in inequalities after 10 years, again with differing effects (Figure 2). Introduction of a living wage again generated the largest beneficial health impact, and led to a modest reduction in health inequalities (with more than 56,000 hospitalisations prevented and a decrease of 0.35 percentage points in RII over 10 years). Paralleling YLL results, a 10% JSA/IS increase has a less prominent beneficial impact on hospitalisations, but an increased impact on health inequalities (17,000 hospitalisations prevented/decrease of 0.66 percentage points in RII over 10 years). Alcohol brief interventions had modestly positive impacts on hospitalisations and health inequalities only when socially targeted, while tobacco taxation and a 10% rise in working tax credit also modestly reduced hospitalisations but had minimal impact on health inequalities. Again, like the results from the YLL model, increasing council tax negatively impacts on hospitalisations and health inequalities and a 1p increase in the SRIT reduces inequalities modestly but increases hospitalisations (again, this is because the econometric modelling does not facilitate redistribution or increases in public spending as a result of the changes). The remaining interventions have small beneficial impacts on both outcomes or make no difference.

After 20 years, the protective impact of most of the interventions on hospitalisations and inequalities continues to accumulate, although there are again some notable exceptions. A similar regression of impact over time is observed within the Counterweight and ABI models. In addition, the protective impact of gaining employment also declines over time to the point where, after 20 years, hospitalisations begin to increase for the cohort involved.

Table 2: Summary of evidence and assumptions used for intervention impact

Intervention	Assumed intervention effectiveness	Assumed change in intervention risk ratio over time	Other assumptions
Income	Varies by income intervention; dependent on the percentage change in mean household income experienced by each SIMD quintile.	Intervention risk ratio is assumed constant over time.	Standardised mortality and hospitalisation rates by SIMD income domain quintile can be applied to income quintile and overall SIMD quintile; mean income by SIMD quintile matches mean income by income quintile; the income/health relationship is not confounded.
Tobacco tax	The reduction in smoking prevalence falls to 1.4% after 2 years before stabilising (based on a price elasticity of demand for tobacco in high income countries (including the UK) of between -0.2 and -0.6[35] and a relapse rate derived from studies of nicotine replacement[36]).	Smoking cessation risk ratios increase from 0.99 to 0.72 (mortality) and from 0.99 to 0.83 (hospitalisation) and do not vary across population strata.[37,38,39]	11.5% of the PAR (>16 years) will stop smoking without the intervention in a linear fashion over 20 years.[40]

Intervention	Assumed intervention effectiveness	Assumed change in intervention risk ratio over time	Other assumptions
Smoking cessation	7% of the treated group abstinent after one year, falling to 4.9% after two years then stabilising (based on five-year averages from the Scottish smoking cessation database).	As for tobacco tax.	As for tobacco tax.
ABIs	65% of those receiving the intervention (>15 years) comply and have a successful outcome, (based on a loss-to-follow up estimate from similar interventions[41] - those lost to follow-up derive no benefit) defined as a decrease of 3.66 units of alcohol per week.[42]	Intervention risk ratios for successful interventions of 0.97 for mortality and 0.95 for hospitalisation were used,[43] returning linearly to 1.00 over seven years (and the same across all population strata).[44]	The PAR in the untreated group will remain static over the 20-year period.

Intervention	Assumed intervention effectiveness	Assumed change in intervention risk ratio over time	Other assumptions
Counterweight	40% of those receiving the intervention (>15 years) comply and have a successful outcome (those lost to follow-up derive no benefit) defined as a mean loss of 3.7 kg (1.36 kg/m^2) at 12 months.[45]	The population experiencing a successful intervention have a risk ratio of 0.91 for mortality[46] and 0.93[47] for hospitalisation, returning linearly to 1.00 over five years (and the same across all population strata).	It was assumed that the PAR in the untreated group will increase linearly by 14.5% over the 20-year period, based on obesity projections by the Scottish Government (2010).[48] In the absence of intervention obese individuals increase weight by 1 kg per year.[49]
Employment	75% of the ‘treated’ group will remain in employment after one year; 67% after 20 years.[50]	The intervention risk ratio on mortality decreases (0.56 after one year, 0.90 after 20 years).[51] Similar assumptions for hospitalisations had a negligible impact.	Each year, 1.6% of the non-intervention group (16–69 years) move into employment (34% of the population at risk over 20 years) (Office for National Statistics (ONS) UK labour market flow data.[52])

Intervention	Assumed intervention effectiveness	Assumed change in intervention risk ratio over time	Other assumptions
Active travel	One-third of eligible commuters (aged 16–64 years, 11% of the PAR) increase PA by 120 minutes per week (iConnect study[53]). Every additional 15 minutes PA beyond the first 15 per day reduces mortality by 4%; the effect the same for all population strata.[54]	Intervention risk ratio is assumed to stay constant over time.	The impact of increased injuries or health impacts of air pollution are insignificant compared to the impacts of changes in PA.[55,56]

Financial impact

The model facilitates estimation of direct NHS savings, in a notional sense, from prevented hospitalisations; i.e. the value of inpatient days potentially freed up rather than actual savings (Table 3). For example, over 10 years, introduction of a living wage would save £138m, a 10% JSA/IS would save £41m and a 1p increase in prices as a result of tobacco taxation would save £17m. Conversely, a 10p rise in council tax and adding 1p on to the standard rate of income tax would incur additional costs of £29m and £45m respectively (this does not include the money raised with the increases in tax which would offset this, nor the impacts of using that money for redistribution or increases in public spending).

Table 3: Estimated direct financial savings from prevented hospitalisations 10-years after implementation, proportionate to need

	Reduced continuous inpatient stays	
Intervention	**(£m) whole population**	**(£m) most deprived quintile**
Introduction of a living wage	138.0	32.4
10% rise in JSA/IS	41.1	36.7
Tobacco taxation	17.0	5.8
10% rise in Working Tax Credit	14.0	4.6
ABIs (£5m investment)	11.2	2.4
Counterweight (£5m investment)	4.0	1.0
Smoking cessation (£5m investment)	3.7	1.3
Employment, 20,000 jobs	1.2	0.3
10% rise in council tax[57]	-29.2	-7.6
1p on standard rate of income tax[57]	-44.6	-3.0

Sensitivity analysis summary

Applying the enhanced model estimates of projected prevalence of smoking over the next 20 years to the tobacco models results has a minimally positive impact on reported outcomes (see appendix A). In addition, sensitivity analyses run on different prevalence projections for obesity and hazardous/harmful drinking produce only marginal changes to outcomes with scenarios where prevalence is projected to fall over the next 20 years producing the most positive results.

The largest impact on results is seen when adjustments are made to the compliance rates for the Counterweight and ABI models (see appendix A). As one might expect, higher levels of compliance with the intervention impacts positively on health outcomes in particular for preventing hospitalisations via ABIs. Moreover, increasing levels of compliance with Counterweight and ABIs only reduced health inequalities when socially targeted, although much more effectively through ABIs in the hospitalisations model than in the mortality model.

As expected, sensitivity analysis showed that if confounding attenuated the relationship between income and mortality by 50%, the estimated impact of the intervention was reduced by the equivalent extent for all outcomes. For example, the percentage change in RII as a result of introducing a living wage would be reduced from -0.32 to -0.16.

Figure 1 – Modelled changes after 10 years in the RII of cumulative years of life lost and the total number of years of life gained for all the modelled interventions (based on £5m investment where associated costs are estimated)

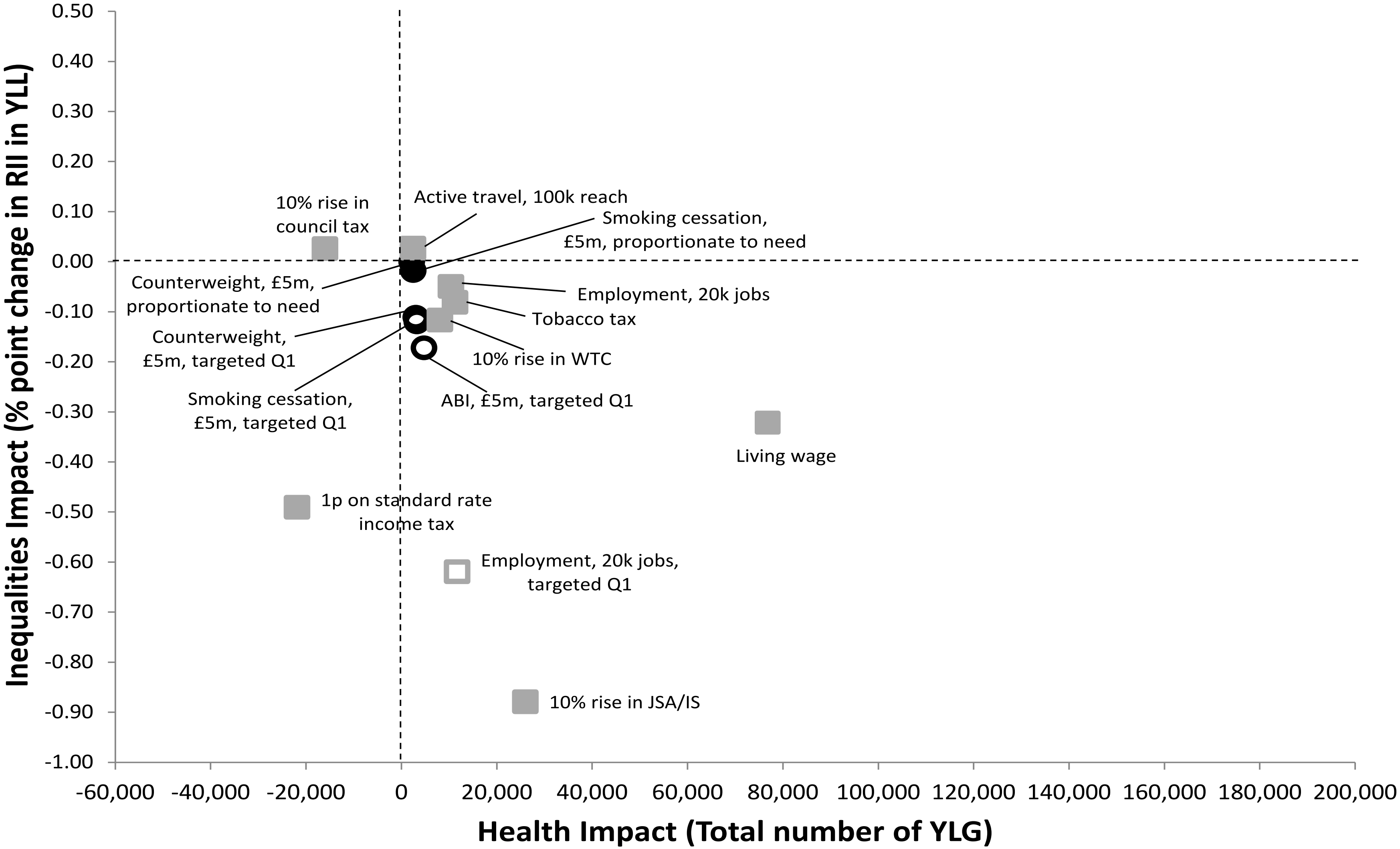


Figure 2 – Modelled changes after 20 years in the RII of cumulative years of life lost and the total number of years of life gained for all the modelled interventions (based on £5m investment where associated costs are estimated)

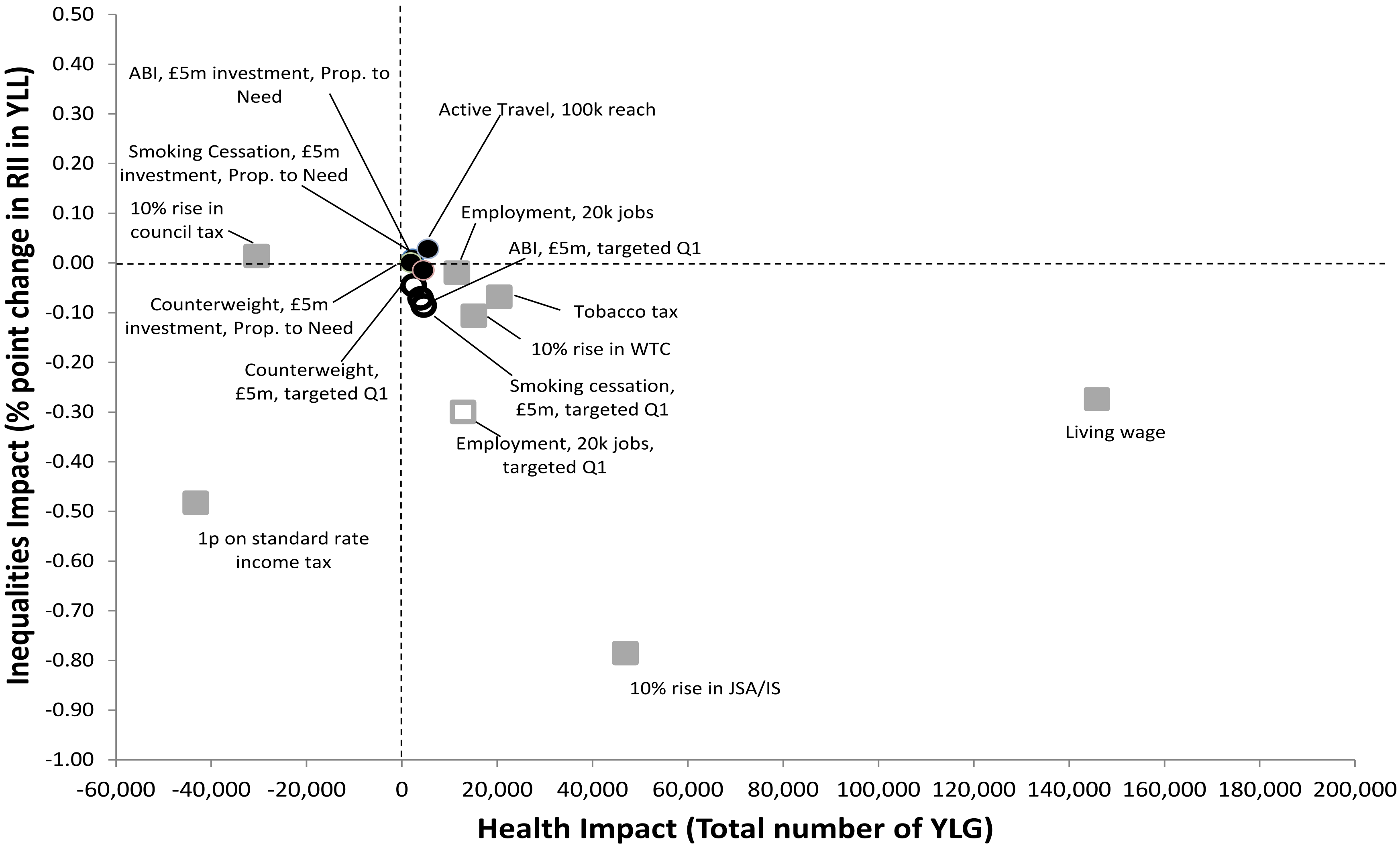


Figure 3 – Modelled changes after 10 years in the RII of cumulative continuous inpatient stays and the total number of hospitalisations prevented for all the modelled interventions (based on £5m investment where associated costs are estimated)

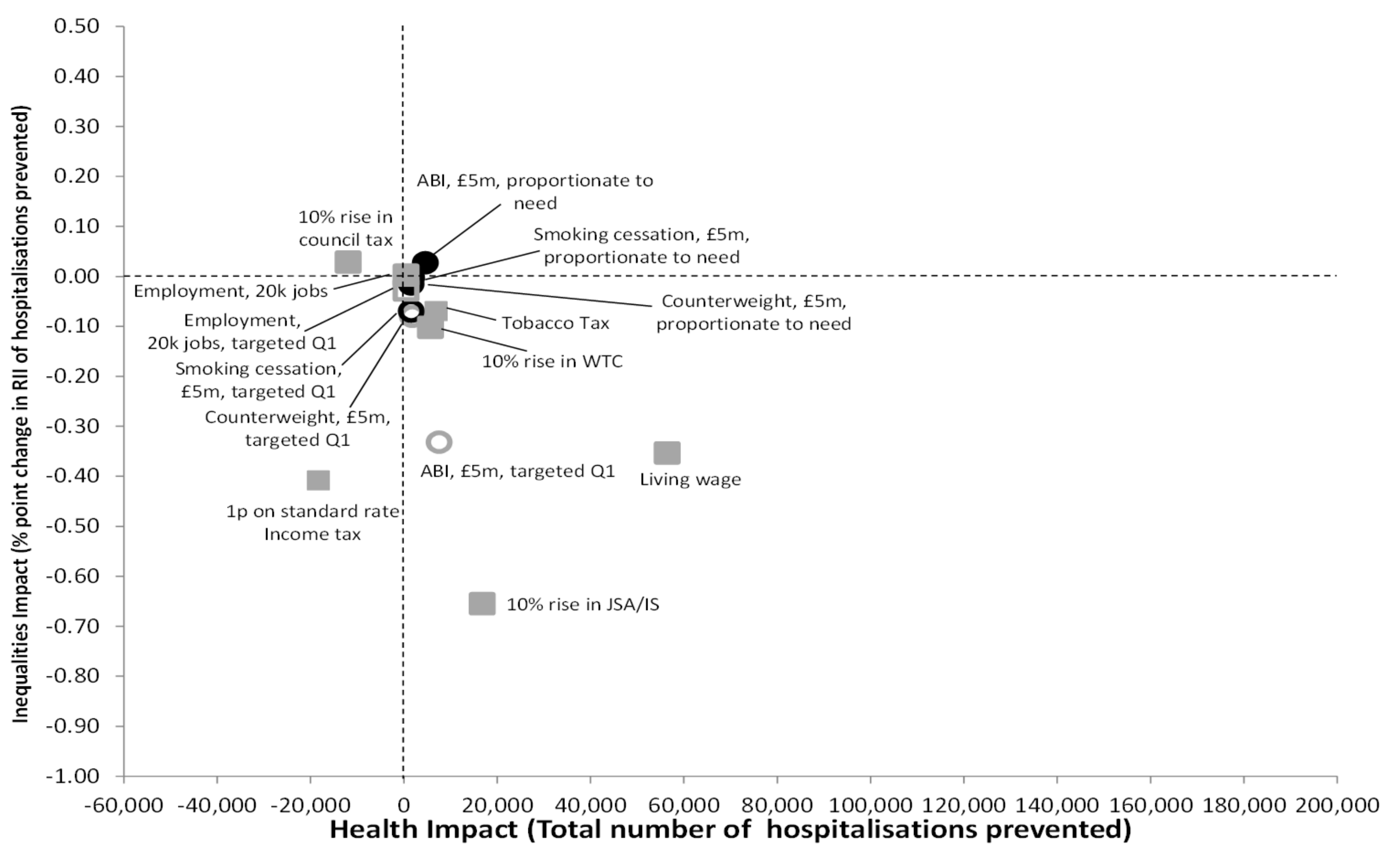
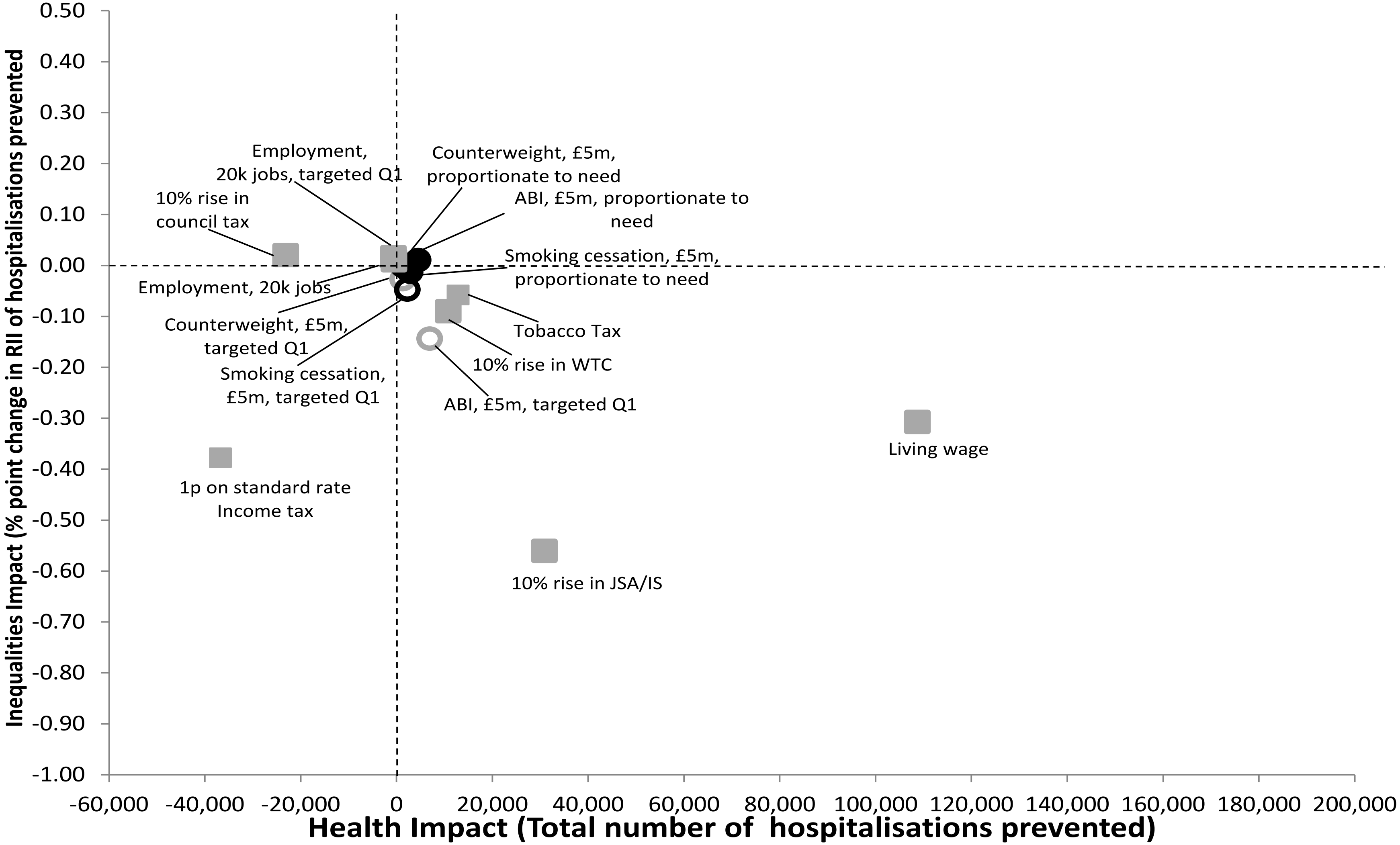


Figure 4 – Modelled changes after 20 years in the RII of cumulative continuous inpatient stays and the total number of hospitalisations prevented for all the modelled interventions (based on £5m investment where associated costs are estimated)



Discussion

Summary of the main results

Introduction of a living wage generated the largest beneficial impact on health, and led to a modest reduction in health inequalities. Increases to benefits had modest beneficial impacts on health and health inequalities. Income Tax increases actually had a negative impact on population health but reduced inequalities, while council tax increases worsened both health and health inequalities. Increases in active travel had minimally positive effects on health but widened health inequalities. Increases in employment reduced inequalities only when targeted to the most deprived groups. Tobacco taxation had modestly positive impacts on health but little impact on health inequalities. Alcohol brief interventions had modestly positive impacts on health and health inequalities only when socially targeted, while smoking cessation and Counterweight weight-reduction programmes had only minimal impacts on health and health inequalities even when socially targeted. These results reflect model specifications and need careful interpretation.

The income interventions involve modest changes to the income distribution, include a number of conservative assumptions relating to the behavioural responses of population and do not include the impacts (positive or negative) on public spending or the wider economy of the proposed changes in taxation or benefits. For example, the impact of changes in the council tax and SRIT work in opposite directions in relation to their impact on inequalities because of their respective regressive and progressive nature. However, neither improves overall health because the additional government revenue is not allocated in those models. It is plausible that tax increases could be redistributed or recycled to finance interventions which could improve population health and reduce inequalities.

The interventions which involve specific health behaviours (tobacco tax, smoking cessation, active travel, Counterweight and ABIs) are based on the assumption that a change in exposure will result in changes in outcomes derived from observational studies. This is likely to overestimate the impact of the interventions. The inequalities impact of ABIs, and to a lesser extent smoking cessation and an increase in tobacco tax, may be underestimated in the models because they rely on self-reported health behaviours which are recognised to be biased towards healthy respondents. These issues are discussed in more detail below.

Strengths and limitations of the modelling

Modelling offers a 'flexible, cost-effective, evidence-based research method with the capacity to inform public health policymakers regarding the implementation of population health interventions to reduce social inequalities in health'.[58] This III model provides a novel means of comparing the impacts of a range of interventions across the determinants of health on national and local health and health inequalities in Scotland over a period of up to 20 years. It utilises the best available evidence relevant to the Scottish context and marks an improvement in the support available to decision-makers when allocating resources and when planning interventions and policies to improve health and reduce health inequalities. Although the modelling requires a number of assumptions, these are explicit and can be varied as better evidence becomes available or as local contexts require. Users will be able to vary models published at www.scotpho.org.uk Sensitivity analyses allow uncertainty around the estimates to be made explicit.

The III model usefully models the impact of a range of interventions, 11 in total, both upstream and downstream. Despite this, the relatively small number of interventions included restricts the options that decision-makers will be able to access from the III tool (in particular, the income interventions available looked at only minor changes in the income distribution). This could inadvertently divert attention from worthwhile but under-studied interventions, biasing attention to 'downstream' lifestyle interventions that are easier and cheaper to study.[59] We could not identify specific interventions for active travel and employment which necessitated using changes in physical activity and employment as proxies.

We were only able to look at two outcomes (mortality and all-cause hospitalisations) to ensure that our measures were comparable across interventions. Ideally, we would have like a much broader range of health measures (including wellbeing and positive health), but these data were not available to us.

The models do not include impacts beyond the original cohort, which then creates an ageing cohort and a (expected) decline in mortality inequalities[60] in populations unaffected by interventions. This is compounded by the projected reduction in mortality used in the NRS analyses (which itself is uncertain[61]). The complexities of the modelling, alongside limited evidence about differential impacts across population strata, meant that we had to assume the risk ratios applied evenly across groups for all of the models except those involving income interventions (which may have biased the results of the inequalities analyses in an unknown direction).

Differences in inequalities over time are measured using SIMD2012 (based on approximately 2011 data); however it is possible that, as a result of the interventions applied, the relative position of some areas in terms of deprivation may change. This is not factored into the analysis which treats the people as a fixed cohort living in areas whose relative deprivation within Scotland is also considered fixed.

In some models (e.g. employment) we used longitudinal studies with repeated measures of exposures and health outcomes over time. In others we used comparisons of outcomes where only baseline assessments of exposure (e.g. alcohol, BMI) were available. The tobacco tax, smoking cessation, ABI and counterweight models focused on 'downstream' exposures (e.g. health behaviours), and derived effect sizes from observational studies which did not examine a change in the exposure. These models are vulnerable to overestimation of impact on inequalities because we assume that a change in exposure at that distal point in the causal chain will improve outcomes despite there being several other causal pathways through which more 'upstream' exposures such as poverty will continue to generate mortality.[62,63,64,65,66,67]

The income model is limited by the small number of interventions for which new income distributions were available. Income model impacts were considered to be immediate and constant over time and allow for changes by SIMD. The available interventions achieved only very limited reductions in income inequality and did not extend to some of the more radical options that have been proposed recently within the Scottish Parliament.[68,69,70] As noted above, the impact of income interventions is unlikely to be subject to bias because of other competing exposures and so the relative positive impact compared to the other interventions is likely to be underestimated. While there is a theoretical possibility of reverse causality in the relationship between income and health, in practice this has been shown to be minimal.[71] We also had to approximate area-based income deprivation quintiles with household income quintiles and this is likely to have underestimated the impact of the intervention because a large number of people will have been misclassified into an incorrect quintile.[72]

The impacts in the employment model are likely to be underestimated because: it assumes that some of the non-intervention group gain employment each year and that the protective impact of gaining employment declines over time. The long-run increase in hospital admissions in the employment model is due to the limited impact of employment on hospitalisation (in contrast to mortality) combined with an increasing ageing population of survivors (who accrue more admissions). It is also possible that there may be other specific employment interventions which we haven't been able to model which have differing impacts on health and health inequalities.

Over time, the impact of the tobacco interventions is assumed to increase in contrast to other interventions effects because of the long-term effects of stopping/continuing to smoke. For ABIs and Counterweight, the impact of both interventions tends towards zero because the models assume the protective impact is likely to be short-term. This creates a 'delayed mortality' effect which eventually reduces their impact on health and inequalities in the longer term (see appendix B). The time frame over which these interventions are compared is therefore crucial in determining which is more likely to be favourable.

The inequalities impact of ABIs, and to a lesser extent smoking cessation and an increase in tobacco tax, may be underestimated in the models because they rely on self-reported health behaviours which are recognised to be biased towards healthy respondents. Those included in the SHeS sample have been shown to be substantially healthier than the general population,[73] and their reported alcohol intake much lower than the amount of alcohol sold in Scotland.[74,75] The net result is that the inequality impact of the interventions which use self-reported health behaviours to estimate the PAR, is likely to be underestimated.[76,77,78] Despite these caveats, ABIs do appear to impact on inequalities more than the other downstream interventions, albeit at modest levels. This is because both excessive alcohol consumption and alcohol-related harm are strongly associated with deprivation, to a greater extent than smoking or obesity related harm. In previous versions of this toolkit, we produced an estimate for ABIs that suggested larger impacts on overall health and health inequalities. We have substantially revised this estimate down because higher-quality evidence has become available on the impact of ABIs and how long the effect of the intervention is likely to last.

Robust estimates of the prevalence of hazardous/harmful alcohol consumption and obesity were not available for nine local authorities. For these local authorities, we substituted prevalence rates based on merged local authorities with demographically similar characteristics[79] to create five new areas (Argyll & Bute and Perth & Kinross, Clackmannanshire & Falkirk, East Renfrewshire & East Dunbartonshire, East Lothian and Midlothian and Stirling and Perth & Kinross) with a large enough sample size to produce plausible estimates. This approach means that results generated from the ABI and Counterweight tools for these local authorities should be interpreted with care. The SHeS team also note that the SHeS sampling and weighting has been designed primarily for high level (national and Health Board) analyses.

The impacts of active travel are limited to impacts on commuting patterns and therefore to those already in work and who own a car or van (both more prevalent in the least deprived quintiles). This explains the modelled increase in health inequalities. In reality, the impact on health inequalities is less certain since structural changes in the environment would also impact on non-commuting travel, reduce road traffic injuries (more common in deprived areas), and improve air quality. Moreover there may be other specific active travel interventions which we haven't modelled that have differing impacts on health and health inequalities.

Targeting

The model demonstrates the importance of targeting strategies in tackling health inequalities. In simple terms, the targeting within the model provides individuals living in deprived areas with an intervention which is denied to others, thereby creating a differential health gain which contributes to a reduction in health inequalities.

The extent to which policies should be implemented universally or targeted at specific groups depends on a range of factors including the nature of the health problem, its context and the potential effectiveness and efficiency of the solution.[80] With reference to Geoffrey Rose's population health strategy (1985),[81] Benach and colleagues present a typology of four policy scenarios to address health inequalities (i.e., targeted and health gap, universal policy with additional focus on gap, 'redistributive policy', and 'proportionate universalism' or universal policy with increasing benefits through the gradient). Table 1 (below) categorises each of the seven interventions modelled in the III project in accordance with the typology of scenarios of health inequalities reduction.

Table 4: Typology of four policy scenarios of health inequalities reduction, classified by focus of reduction and extent of benefits, with examples from III modelled interventions

	Inequality reduction focus	
	Gap	**Gradient**
Benefits to social groups		
Selective	1 Targeted interventions on worst-off only - 10% ↑JSA/IS	3 Redistributive policy - 10% ↑Council Tax - 1p SRIT - Tobacco taxation
Universal	2 Universal policy with additional focus on gap - Smoking cessation - Counterweight - Employment	4 Proportionate universalism - Alcohol brief interventions - Active travel - 10% ↑ WTC - Living wage

The feasibility and desirability of targeting all interventions to the most deprived quintiles is highly debatable. In terms of feasibility it requires a mechanism for targeting that often does not exist in practice. For example, only 34% of Scottish low-income households are in the 20% most deprived areas in Scotland.[82] Targeting may also be undesirable because it can result in such services and interventions being seen as 'poor people's services'. This can create stigma, undermine quality and undermine the collectivism which is essential to support the funding of public services.[83]

One approach to avoiding the dangers of ‘means testing’ is to create services which are both universal and proportionate to need.[84] For example, in Scotland, there is a HEAT target in place to deliver universal smoking cessation services to achieve at least 80,000 successful quits (at one month post-quit) including 48,000 in the 40% most-deprived within-Board SIMD areas over the three years ending March 2014.[85]

Conclusions

The III models provide a means for decision-makers within the Scottish Government, Health Boards and local government to understand the likely impacts of a variety of interventions on health and health inequalities. Currently, resource allocation decisions are often made in the absence of such evidence. III allows the assumptions and baseline conditions of the models to be changed, the impacts of interventions to be compared, the impacts to be modelled for local authority areas and for investment and direct hospitalisation costs to be compared.

We developed modelling approaches that used the best available data and evidence at the time to estimate reductions in hospitalisations, YLL and health inequalities associated with a range of public health interventions. We were able to develop a transparent and usable interactive tool that allows users to model a range of interventions designed to reduce health inequalities.

Interventions have markedly different effects on mortality, hospitalisations and inequalities. The most effective (and likely cost-effective) interventions for reducing inequalities were regulatory and tax options which affect income. Interventions focused on individual agency were much less likely to impact on inequalities, even when targeted at those in the most deprived communities. In broad terms, these results fit with previous evidence that interventions that tackle inequalities in the socio-economic environment and regulatory interventions are more likely to reduce health inequalities, while those requiring individual agency are less effective.[86,87]

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