Using the Dynamic Microsimulation MINOS to Evidence the Effect of Energy Crisis Income Support Policy

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Abstract

Rates of anxiety and depression are increasing due to financial stress caused by energy pricing with over half of UK homes unable to afford comfortable heating. UK Government policies to address this energy crisis have been implemented with limited evidence and substantial criticism. This paper applies the dynamic microsimulation MINOS, which utilises longitudinal Understanding Society data, to evidence change in mental well-being under the Energy Price Cap Guarantee and Energy Bill Support Scheme Policies. Results demonstrate an overall improvement in Short Form 12 Mental Component Score (SF12-MCS) both on aggregate and over data zone spatial areas for the Glasgow City region compared with a baseline of no policy intervention. This is work in progress and discussion highlights potential future work in other energy policy areas, such as Net Zero.

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Supplementary Material *Software (Source Code)*: `https://github.com/Leeds-MRG/Minos/tree/244_gis`, archived at `swh:1:dir:be994021b118b5533e0d37815ce7cf198ed048c2`

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1 Introduction

United Kingdom energy prices have tripled in just five years, impacting on the cost of living via fuel, food, and other expenses [3]. Household income is being squeezed to the point that more than half of UK Homes [11] are now in energy poverty and can no longer afford

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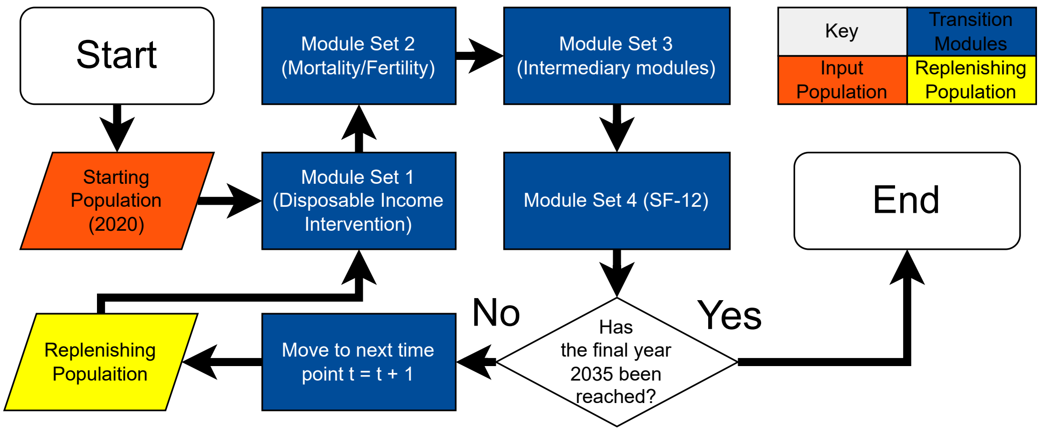


Figure 1 MINOS model flow chart. Outlines three main model stages for initialisation of 2020 population, propagation through a series of transition models and population replenishment for 15 years until 2035.

comfortable heating. Literature [2] suggests this is having a drastic effect on mental health as financial stressors increase incidence of anxiety and depression. The UK Government is implementing a number of policies to try and protect household disposable income and public health. Two well reported examples [5] are the Energy Price Cap Guarantee (EPCG) which places a temporary cap on energy prices and the Energy Bill Support Scheme (EBSS) where a flat £400 rebate is provided to all households, with more going to vulnerable subgroups such as pensioners. These policies have been widely criticised as insufficient and based on limited evidence [3, 9, 7]. Work is needed to quantify the effect of the energy crisis on mental health and any alleviating effects from both real EBSS policy and any hypothetical alternatives [9].

One methodology to synthesise policy evidence is dynamic microsimulation [10]. A population of individual households is generated, either synthetically or from survey data, and propagated forwards in time under some transition probability mechanics and policy interventions. Dynamic microsimulation can be used to quickly generate long term evidence over a suite of multiple policies repeatedly to quantify uncertainty and provide rich individual level data. This approach can be readily used by policymakers for evidence-based decision making and has seen broad application particularly in economics and health[10, 6]. This paper applies the dynamic microsimulation MINOS to estimate how the EPCG and EBSS policies have affected UK mental health using the Short Form 12 Mental Component Summary (SF12-MCS) [12] as the outcome of interest. Section 2 outlines the overall MINOS model structure, data sources, transition probability models and intervention scenarios. Section 3 presents results demonstrating change in mental well-being due to both policies at aggregate level and spatially over Data Zones (DZs) for the Glasgow City region. Finally section 4 summarises findings, limitations, and potential future work.

2 Data and Methods

MINOS is built using standard dynamic microsimulation design [10] as a first order discrete time Markov model. UK population households transition forwards one year at a time using a series of transition models that estimate new state at time $t + 1$ only using current time t information. MINOS is built using a flexible modular design allowing for associative representation of causal systems pathways between income and mental well-being [8] given available data. MINOS is completely open source and written in the R. and python languages using the vivarium framework [1]. An overview of the MINOS life cycle is given in Figure 1. The first stage initialises a population of UK households by importing either real or synthetic panel data. This population serves as initial conditions and is the same for every model run. The second stage of MINOS is a series of transition probability modules. Each module evolves some subset of individual attributes forward one year in time. The order in which these modules are run is important and done in four sets. The first set only updates household disposable income. All policy interventions are parameterised as change in household disposable income, and placing this module first allows change to propagate through the rest of the system immediately. The second set contains birth and death modules to ensure only those who are alive are intervened upon. The third set contains a number of intermediary modules that are influenced by change in disposable income and subsequently influence mental well-being. The final fourth set contains only a mental well-being module that estimates the desired health outcome given change in all other areas. After running each module set, the third stage of MINOS is population replenishment where a new batch of households is added to the model to maintain population size. Stages two and three are run indefinitely until the desired simulation horizon year 2035. At this point any post-hoc analysis can be performed to estimate life trajectories of households. A summary of the transition probability models used is given in table 1. Each model used depends primarily on outcome data type. Full module data tables, predictors, and model coefficients are available on GitHub[2]. MINOS uses the Understanding Society (US) dataset [4] as its primary data source. US provides 11 annual cohorts from 2009-2020 containing hundreds of individual and household attributes pertaining to health, employment, and demographics. US data are used both directly as input population data for MINOS and to calibrate statistical models. Preprocessing is applied to US data to correct missing data and improve readability resulting in $n = 15192$ individual observations for the 2020 starting year dataset. Additional ONS data are used to calculate mortality and fertility rates using the NEWETHPOP project [13]. Key variables in the US dataset are household disposable income and Short Form 12 Mental Component Score (SF12-MCS). Household disposable income is defined as money after taxes and bills a household can spend on other needs. It is a continuous variable that is heavily right skewed with a median income of £1300 per month. SF12-MCS is a widely used metric of mental well-being that ranges from $0 - 100$ with higher values indicating better well-being. It is approximately Gaussian distributed with mean 50 and variance 10^2. In order to produce spatially disaggregated results, we draw on a synthetic population which combines US data with Census data to derive Data Zone level estimates for Scotland [14]. Results use a 10% sample scale for the Glasgow City region with $n = 227589$ individuals over 747 data zones each containing $500 - 1000$ people and mapped in Figure 2b. Glasgow was chosen for its mixed socioeconomic demographics and an existing Scottish evidence base for comparison [3].

Three scenarios are applied to the Glasgow City region. The first baseline scenario changes nothing about the UK population. Energy prices start low at 2018 levels and never increase. This is a useful benchmark with which to compare other policies. The second policy is the Energy Price Cap Guarantee (EPCG) scenario, in which energy prices do increase and are capped by the UK government. Data suggests [11] energy prices increased by 240% from 2020 to 2023. High energy prices are sustained beyond 2023 to assess the impact to mental well-being. The final scenario implements both the EPCG and EBSS policies together to assess any further change in well-being. The EBSS provides a £400 base lump sum to all

[2] `https://github.com/Leeds-MRG/Minos/tree/244_gis`

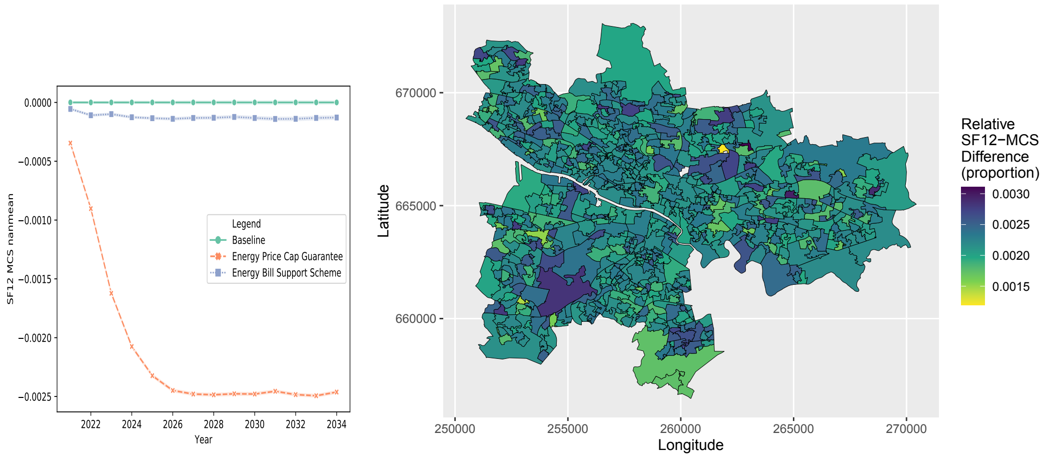
Table 1 Table of transition probability models used in MINOS.

Module Name (Module Set)	Outcome Variable	Variable Type	Model Used
Household disposable income (1)	Monthly household disposable income (£s)	Continuous	Ordinary Least Squares
Mortality (2)	Is the subject alive? (yes/no)	Binary	Rate Tables
Fertility (2)	Has subject given birth in last year? (yes/no)	Binary	Rate Tables
Housing quality (3)	Household quality composite (1-3 Likert)	Ordinal	Cumulative Link Model
Neighbourhood safety (3)	Neighbourhood composite (1-3 Likert)	Ordinal	Cumulative Link Model
Loneliness (3)	Is subject lonely? (1-3 Likert)	Ordinal	Cumulative Link Model
Nutrition (3)	How many fruit and vegetables per week? 0+	Continous	Ordinary Least Squares
Tobacco (3)	Cigarettes smoked per week 0+	Continuous	Zero Inflated Poisson
Mental Well-Being (SF12) (4)	SF12 Mental Component Summary score (0-100)	Continuous	Ordinary Least Squares

households and further income to households that include pensioners, universal credit, long term sick/disability, and council tax bands A-D. Each of these groups receives £650, £150, £300, and £150 additional monthly income respectively [5, 3]. These changes are applied directly to household disposable income and are capped at an upper limit of £0 matching real policy that only returns money if energy is used. Each of these three policies is run 100 times through MINOS.

3 Results

Results estimate changes in well-being for the Glasgow City population at an aggregate level. For each of the MINOS runs the mean SF12-MCS value is recorded giving a sample of 100 means. These are then used to estimate confidence intervals for the overall SF12-MCS mean. Values are then scaled to estimate the percentage change in well-being versus baseline for EPCG and EBSS policies in Figure 2a. The EPCG policy sees an approximate 0.25% decrease in SF12-MCS score per year for the population by 2026. EPSS policy does improve mental well-being vs EPCG alone but is not enough to bring SF12-MCS score back to pre-2018 levels. This finding matches other literature suggesting the energy crisis has been detrimental to mental well-being [3] but underestimates the effect size for reasons mentioned in final discussion. SF12-MCS values were also aggregated spatially over Scottish Data Zones. Starting with the mean by data zone for each of the 100 model/simulation runs, and taking the grand mean again results in a scalar change in SF12-MCS for each data zone that can be mapped. Figure 2b shows these values for the year 2025 comparing difference in SF12-MCS for the EPCG vs EBSS scenarios. The EBSS scenario shows an improvement in mental well-being across all areas. The areas that see the least improvement appear to be the most economically affluent. Unsurprisingly these households are largely insensitive to energy price



(a) **(b)**

Figure 2 Energy interventions for Glasgow: (a) Lineplot showing relative change in SF12-MCS score for EPSS and EPCG vs baseline. (b) Map of the Glasgow City region comparing EPCG and EBSS policies for the year 2025. Comparison with the Scottish Index of Multiple Deprivation (`https://simd.scot`) shows a strong correlation (0.61) between deprived LSOAs and greater benefit from the EBSS scheme. The Springburn (262000, 668000), Castlemilk (260000, 660000), and Pollok (254000, 662000) regions see the most benefit. Note two LSOAs are missing with white colouration as map geometry is from 2011 and they no longer exist in 2020.

increases. Lower-middle class areas of Glasgow (north east, south east) appear to benefit the most from the EBSS policy. Poorer areas see most of their disposable income lost to the energy crisis and preventing this improves mental well-being [9]. Further investigation is needed to disaggregate this map and identify vulnerable households that are seeing less improvement under the EBSS policy [9] and personalise policy strategy.

4 Discussion

This paper has applied the dynamic microsimulation framework MINOS to the Energy Bill Support Scheme policy in the UK to estimate its impact on household disposable income and mental well-being. Results show significant overall improvement in well-being when implementing EBSS policy, but not enough to return mental well-being to 2018 baseline levels. Spatial analysis suggests lower income households benefit the most from EBSS policy; however more analysis is required to determine which vulnerable households need more assistance.

This work is limited primarily due to the Understanding Society data source. Yearly interval data are not granular enough to capture mental health change that can occur at a much finer timescale (e.g. days). There is also missing data for food and vehicle fuel expenditure, this makes it difficult to accurately estimate changes in household disposable income. Comparison with other research suggests the effect sizes for the EBSS are underestimated [3].

Application of the Energy Bill Support Scheme policy demonstrates the utility of the MINOS framework. Initial future work will elaborate on the methods used in MINOS particularly for transition probabilities and validation techniques using literature and online documentation. MINOS can readily be further developed to simulate spatially distributed policies that target inequities such as prepayment meters, the influence of place (e.g. rural locations) and additional cost of living impacts such as increase in rent [3]. In combination with other Government targets [9, 5] such as social housing, energy efficiency and Net Zero, MINOS has the potential to be developed into a pragmatic tool for future crisis policy that is able to balance the preservation of economy and health as well as protecting vulnerable households.

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