Department for Energy Security & Net Zero

Interim Evaluation of Domestic Energy Affordability Support Schemes in Northern Ireland

Annex C: Supplementary Research

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Annex C1 Alternative Fund Population Estimation in NI

1.1 Background

The Energy Bills Support Scheme Alternative Funding Northern Ireland (EBSS AF NI) was designed to support households that did not receive the main EBSS AFP payment because they lacked a domestic contract with an energy supplier. This support is equivalent to the support provided automatically to households through the EBSS AFP scheme. It was estimated that around 28,000 households in NI would be eligible for this support with their energy bill costs. Those who were eligible for the EBSS AF NI needed to submit a short online form via the Government's GOV.UK webpages. To deliver the schemes, ex ante estimates of how many households were potentially eligible for this support had to be made at pace and with the data available at the time, which was limited for some population groups. London Economics (LE) was commissioned to conduct additional work to assess methods of estimating the size of the alternative funding (AF) populations in NI to understand how these estimates could be improved in the future with existing data and data that has since become available, particularly the publication of the 2021 census.

1.1.1 Scope of the Report

This report establishes methods of estimating the eligible cohort through the examination of how the ex ante estimates were established and exploring alternative methods of measurement. The scope of the study involved the following elements:

- Identification of data sources that could be used to estimate the size of the AF populations.
- Benefits and limitations of these datasets, including those used in the original estimates and any new ones.
- Identification of methodologies that could be applied to these to estimate these populations.

1.2 Findings on EBSS AF NI estimation

EBSS AF was intended to support households that either do not have a domestic electricity meter, or do not have a direct relationship to a domestic electricity supplier. The total ex ante estimated size of this cohort was based on the estimated size of each eligible population group. These groups were broadly as follows:

- care home residents and others in care facilities/sheltered accommodation (wholly or partly self-funded)

- park home residents, houseboats and caravans that can provide proof of address
- social and private tenants who pay for energy through a landlord on a nondomestic supply
- homes on a heat network/private wire
- off-grid homes
- farmhouses used for wholly domestic purposes

Note: these are similar to the groups that were finally eligible for the scheme but there was some further refinement of specific eligibility criteria as the scheme was developed. For a full description of the scheme see the main report.

1.2.1 Caravans, Houseboats, Mobile Homes and Travellers

This grouping included residents of residential park homes, those on boats with permanent residential moorings, and those on permanent gypsy and traveller sites.

Original Estimate Methodology and Sources

- DESNZ used the 2011 Census to estimate the number of people living in caravans or other mobile or temporary structures, including residents of residential park homes and those on boats with permanent residential moorings.
- DESNZ employed data published by the Northern Ireland Human Rights Commission, which noted that the NI Housing Executive recorded the wider traveller population in NI fluctuating between 1,228 and 1,486 from 2002 to 2014. Additionally, the All-Ireland Traveller Health Survey in 2010 estimated that at least 3,905 Travellers resided in NI. [1] DESNZ also used data from the Republic of Ireland's 2016 Census, which found that Irish traveller households comprising a married couple with children had an average of 5.3 persons per household. [2]
- To estimate the number of Traveller households, DESNZ averaged the pre-2015 population estimates outlined above and divided this by the average Traveller household size from the 2016 Census. To estimate the number of Travellers on unauthorised sites, further adjustments were made based on data from Great Britain regarding the percentage of Traveller caravans on unauthorised sites.

Alternative Data Sources, Methods and Considerations

The primary alternative data source for this population is the 2021 census which has since been released for Northern Ireland.

- The advantage of using the census for cross-tabulations is that it allows more recent data, and for the inclusion of Gypsy, Roma and Travellers and relies on comprehensive population data rather than secondary sources, eliminating the need for assumptions or extrapolations.

[1] https://nihrc.org/news/detail/nihrc-launches-report-out-of-sight-out-of-mind-travellers-accommodation-in
[2] https://www.cso.ie/en/releasesandpublications/ep/p-cp8iter/p8iter/p8itd/

- Original reliance on 2011 NI Census data and other sources such as the Northern Ireland Human Rights Commission, while useful at the time, may have overestimated eligibility. The main limitation of the data employed was its focus on population level data, which doesn't account for the one-payment-per-household rule. This may have led to inflated estimates of eligible households. Future estimations should rely on household-level census data to provide a clearer and more accurate picture of the eligible population.

1.2.2 Private and Social Renters with a commercial meter

Private and social renters were eligible to apply in cases where they had a commercial rather than domestic meter, or paid via a landlord with a commercial contract

Original Estimate Methodology and Sources

The total number of private and social renters were obtained from the 2011 NI Census estimates for dwellings by tenure.[3] DESNZ then applied an assumption that 3% of this population group could be eligible for the scheme.

Alternative Data Sources, Methods and Considerations

- The subnational dwelling stock from the 2021 NI Census, using the number of households rather than usual residents, resulted in a significant reduction – almost 50% - in the estimated number of eligible households in both the private and social renter cohorts. This reduction is attributable to the shift from using residents to households in the estimates, rather than to a decrease in the number of renters.
- The 2021 NI Census provides data on the number of private and social renters living in flats, maisonettes, or apartments that are part of a converted or shared house (including bed-sits) or located in commercial buildings (e.g., office buildings, hotels, or above shops). These households may be eligible if they have a shared or business energy connection.
- When comparing the number of these private and social renters to DESNZ estimates, which are based on a 3% eligibility assumption, the analysis shows that if all households in this cohort were eligible, the number of private renters may have been underestimated by 7%, while the number of social renters may have been overestimated by 64%.
- In conclusion, the 2021 Census provides a detailed breakdown of the number of households by household type. Using the number of households allows for more precise estimates, especially when identifying private and social renters who may have a shared connection or are in a commercial building. Future estimates could use the number of household or adjust for household size where household counts are unavailable.
- A potential limitation of the census is its frequency given the number of private renters increased significantly between 2011 and 2021. Depending on the timeframe, if the

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[3] https://www.nisra.gov.uk/publications/2011-census-key-statistics-tables-housing-and-accommodation

most recent census is too out of date it could still be used to inform the proportion of eligible renters.

1.2.3 Heat Networks

NI has a limited number of heat networks, estimated to be around 120, primarily consisting of communal systems. A communal heat network supplies heat within a single building to multiple occupants, such as in a block of flats. [4] The 2021 Census did not include data on the coverage of heat networks, and to the authors knowledge there is no publicly available information available on the number of households connected to heat networks in NI. In the Census, 1,362 households selected "Other" as their heating source, which did not include oil, mains gas, electric, tank or bottled gas, solid fuel, renewable heating systems, wood (e.g., logs or waste wood), or no heating. While this category may include households on heat networks, it could also encompass other heating sources.

1.2.4 Farmhouses

Households living in domestic farmhouses with a non-domestic meter were eligible for EBSS NI AF.

Original Estimate Methodology and Sources

- The Department for Environment, Food and Rural Affairs (Defra) reported to DESNZ that there are 80,000 farmhouses solely used for domestic purposes in NI and GB. It is not clear what analysis, if any, underpins this figure. Analysis undertaken by DESNZ noted that one reason for the low take-up among these farmhouses might be due to inaccurate population estimates and the isolated nature of these households. Since the government cannot identify which electricity supply a household uses, the estimate might include households with a domestic electricity supply that were not eligible for the scheme, skewing the percentage of take-up figures.

Alternative Data Sources, Methods and Considerations

- According to the Agriculture in the UK Evidence Pack produced by Defra in 2021, the UK agriculture industry comprised 216,000 farm holdings. In England, there were 105,200 farm holdings. Of these, 54% were owner-occupied, 14% were wholly tenanted, and 31% were mixed tenure (both owning and renting the land they farm). If all owner-occupied farms were eligible, there would be 56,808 eligible farms in England. England accounts for 49% of the UK's farms and 64% of its agricultural workers, suggesting that the average farm in England has a greater number of workers. This could be due to the type of farming, such as horticulture, which typically requires more labour, or generally larger farm sizes compared to NI, Wales, or Scotland. Assuming the number of employed in the agricultural sector is a proxy for the distribution of farms across the remainder of the UK and the proportion of owner-occupied homes remains constant, there would be approximately 79,000 owner-occupied farm holdings in 2021 (7,000 in NI). While this estimate closely aligns with the Department's figures, it relies on

[4] https://www.economy-ni.gov.uk/articles/heat-networks

numerous assumptions, and the number of farms with a separate domestic electricity connection remains unknown.

- Using data from the Ipsos Wave 1 nationally representative Push to Web Survey conducted in NI (the main household survey), which was undertake as part of this study, it was revealed that 30% of farmhouses surveyed had a commercial electricity contract (based in a sample size of 30 across the UK). Assuming every farm holding includes a farmhouse, this suggests that 64,000 farmhouses (12,000 in NI) would be eligible. Focusing on owner-occupied farms, the number of eligible households would be 24,000 (2,000 in NI). The household survey suggests that of those in farmhouses that knew their contract type, 33.3% were in a commercial contract, although this is based on a sample size of nine respondents.
- Another source of the number of farms in the Agricultural Census in Northern Ireland, June 2023 results found that there are 26,131 farms (72% of which are owner occupied) in NI.5 Applying the percentage of farm households with a commercial contract derived from the Ipsos Survey would suggest 5,644 eligible farmhouses. Both surveys are used to maximise the sample size.
- The census provides a breakdown of the number of farms by LA district. Assuming that the percentage of owner-occupied farms remains constant and that the data from the Ipsos Survey is representative, the number of eligible farms in each LA can be estimated. This estimation is calculated by multiplying the number of farms in each LA by the percentage that are owner-occupied and then by the percentage of farms with a commercial electricity contract.

1.2.5 Care home residents

Care home residents, or those in an assisted living facility, were eligible where they were either fully or partly self-funded, directly or through loss of pension.

Original Estimate Methodology and Sources

The estimate of the eligible care home population was based on the number of residential and nursing care packages in effect as of 2020, based on data from the Department of Health.[6]

- According to the Department of Health's website, residential and nursing care packages are the forms of care recommended through the care management process.
- It is not clear if all residential or care home residents have care packages. In June 2020 there were 5,278 beds in residential care and 10,802 in nursing homes, totalling 16,080. Whilst there were 11,808 care packages, suggesting 73% occupancy. DESNZ then distributed this 11,808, based on the share of care home residents in each

[5] https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Agricultural%20Census%202023%20Publication.pdf
[6] https://www.health-ni.gov.uk/sites/default/files/publications/health/cc-adults-ni-19-20_0.pdf

parliamentary constituency based on data from 2011.[7] The proportion which is self-funded is derived from the Nuffield trust[8].

Alternative Data Sources, Methods and Considerations

- Another potential way of estimating the number of individuals in care homes would be through the most recently available Census. The 2021 NI Census found that there were 26,300 people in 1,421 communal establishments, of which, 13,200 lived in care homes and 7,000 in educational communal establishment.[9]
- To the authors knowledge, there is no publicly available information on the proportion of individuals that pay for their own care in NI. Employing the proportion as based on English data (35.27%) gives rise to an estimated 4,656 eligible residents.[10] This is significantly greater than the number estimated by DSNEZ. However, the Alzheimer's Society in Northern Ireland noted that most people will pay some of their care home costs, with their contribution decided by the financial assessment.[11]
- Whilst the use of residential and nursing care packages based on Department of Health data ensures that the estimates are grounded in official health care records, it is unclear whether all care home residents have care packages. Some may reside in care homes without a care package, leading to underestimation of care home residents.
- The 2021 NI Census provides the recent and comprehensive data on communal establishments, including care homes. The Census lacks specific information on self-funded care home residents in Northern Ireland, leading to reliance on English data (35.27%) as a proxy, which may not fully reflect the NI situation. The assumption that the distribution of care homes mirrors all communal establishments introduces potential errors, particularly in areas with high concentrations of students or other non-care-related communal living (e.g., Belfast).The NI Census 2021 provides data on the number of people living in communal establishments by LA. Assuming that the distribution of care homes mirrors that of all communal establishments and that the proportion of self-funded residents is consistent across each LA, it is possible to estimate the number of care home residents and self-funded residents in each LA. However, this estimate may contain some error due to the concentration of students in university towns such as Belfast.

1.3 Overarching Considerations

The addition of more recent (2021) census data reduces the risk of error associated with ex ante estimates, particularly where there is a greater risk of data being out of date. However, many of the populations eligible for EBSS AF NI cannot be estimated directly from the census,

[7] https://datavis.nisra.gov.uk/dissemination/NINIS-redirect.html
[8] https://www.nuffieldtrust.org.uk/news-item/how-much-social-care-does-each-country-fund#key-points
[9] https://www.nisra.gov.uk/system/files/statistics/census-2021-main-statistics-for-northern-ireland-phase-3-statistical-bulletin-communal-establishments.pdf
[10] ONS, 'Care homes and estimating the self-funding population, England', See: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/socialcare/datasets/carehomesandestimatingtheselffundingpopulationengland
[11] https://www.alzheimers.org.uk/sites/default/files/2020-03/paying_for_care_and_support_ni532.pdf

so future estimates would still need to rely on many of the same assumptions about what proportion of a wider population would be eligible. For example, there are significant challenges in estimating the 2021 census data does not provide a detailed breakdown of households connected to heat networks in Northern Ireland, and the estimation of the number of owner-occupied farmhouses by electricity connection type remains challenging.

Annex C2 Price and income elasticity modelling

2.1 Introduction

This section presents results of additional modelling undertaken to estimate price elasticities of demand. This supplements the primary fieldwork undertaken, by providing estimates of how energy and other consumption would have changed in the absence of the energy affordability schemes and provides estimates of the schemes' impact on maintaining energy consumption, energy burden and non-energy consumption. This work uses aggregate quarterly ONS data from the Consumer Trends and Family Spending Workbook.

To provide an estimate of how the energy affordability schemes affected energy and non-energy consumption during the intervention period, Almost Ideal Demand System (AIDS/QUAIDS) models[12] of demand were used to calculate price elasticities of demand (the change of consumer demand for a product or service following a change of its price). Due to the universal nature of the schemes, more standard counterfactual impact estimation techniques were not possible. The econometric technique of estimating demand systems and demand elasticities allows us to make a counterfactual prediction from the model, however. Since the various policies contained a mix of price changes and income changes, and these are the main independent variables in consumer demand modelling, we can make a prediction from AIDS/QUAIDS models to say what would have happened without the interventions, i.e., with higher prices and lower incomes.

To model the preferences of consumers, the analysis used a structural model which estimates a system of consumer demand functions. The functions in these models take prices and income as the inputs, and output price elasticities and expenditure, generally expressed as a budget share. Price elasticities of demand are modelled as the percentage changes in energy consumption relative to the percentage changes in prices, for each household group included in the model. These models enable comparisons of the output function at varying price and income levels, such as with/without the EPG scheme.

The package of interventions in NI comprised the following schemes (see main report for full details):

- Energy Price Guarantee (EPG) lowered the unit price households paid for electricity and gas by setting a discount rate that domestic energy suppliers must apply to the unit rates and standing charges they set for households. The government then compensated energy suppliers based on the amount of discounted gas and electricity they sold. The consumer saving was based on usage, so bills and savings could be higher or lower depending on how much energy consumers use.

[12] Deaton & Muellbauer (1980), 'An almost ideal demand system', The American economic review, volume 70(3), pages 312-326

- Energy Bills Support Scheme and Alternative Fuel Payment (EBSS AFP) was available to every household with an electricity meter who received a one-off £400 payment under the EBSS NI scheme in the winter on 2022/23 only. Unlike in GB, every NI household was *also* entitled to receive a £200 payment for those using alternative fuels who would not benefit from EPG. All households received this, regardless of their home heating system, because most households in NI use oil to heat their homes and the data required to exclude households with gas or electric heating from receiving the AFP were not readily available.
- Energy Bills Support Scheme Alternative Fund (EBSS AF) which was open to applications from households that did not have a domestic energy contract with a licensed supplier and often paid for their energy through a commercial landlord or other intermediary. The EBSS AF was combined with the AFP and therefore eligible customers without a domestic electricity meter, could apply for a one-off £600 payment.

The work presented in this paper makes use of quarterly aggregate ONS Consumer Trends and Family Spending Workbooks. The modelling also required additional data on various factors such as energy performance certificate ('EPC') rating and household income. For the GB context, this was made available from the National Energy Efficiency Data-Framework ('NEED'). However, the NEED dataset does not cover NI. Instead, a dataset was scraped which contained approximately 335,000 EPC ratings and properties for NI which gave a reflection of the distribution of EPC ratings. We used the proportional spread of consumption for annual kWh by decile as estimated from the GB NEED data and applied this across deciles to create a profile of consumption, across decile and by EPC.

This use of this aggregate data imposes some limitations on the modelling undertaken, and further sensitivity testing using micro data is planned for the separate economic evaluation of the UK schemes (see below). Most importantly, there may be nonlinear effects not captured in these aggregate results for certain groups of households once they face very high energy prices. This aggregate nature of the data available also, by definition, means that the modelling captures long-term responses to price variation better than any short-term effects that might otherwise be expected.

A separate economic evaluation of the affordability schemes has been commissioned by DESNZ. This work is expected to use household level micro-data and undertake further sensitivity testing of the results presented in this paper.

2.2 Methods

The primary focus of this report is to estimate own and income elasticities and apply them to various groups or estimates of groups for the NI economy. The purpose is to give the counterfactual impact of what would have happened to energy consumption, and other goods consumption in the absence of such payments. Given the estimates of the policy changes as income and price supports, the changes in income and price, all else equal, are then modelled for different income deciles. This allows us to show estimated changes in energy usage, and impacts on fuel poverty.

The rationale for such an approach derives from empirical research in consumer economics which shows that various commodities can behave as normal, luxury, or inferior goods, in other words, consumers' consumption may change as their income changes with respect to these goods. Moreover, goods may be luxury goods at lower levels of income while inferior goods at higher levels (e.g., alcohol), which means the share of expenditure on any good may increase or decrease over a range of incomes. The models we employ allow us to test and account for different slopes and shapes of the Engel Curve, which describes the behaviour of expenditure on a good as household income changes.

The modelling is based on the Almost Ideal Demand System (AIDS) model of Deaton and Muellbauer (1980). This framework allows for consistent estimation of own and cross price elasticities for specified commodity types and bundles. This modelling framework is state of the art in terms of applying restrictions that are consistent with consumer demand, but that do not impose unnecessary restrictions such as not allowing some goods to be luxury and some to be normal goods. The AIDS model gives a first order approximation to any demand system, and aggregates perfectly over consumers. This strong theoretical underpinning, combined with its ease of estimation, makes for a good approach to estimate the impacts of certain policy scenarios on commodity usage.

We fit the AIDS model to the available data and can then predict how usage and expenditure shares change based on the different policy scenarios from the energy affordability schemes. Detailed descriptions of the models used are given in Sub-annex 1, they are demand system models in the AIDS family. We also calculate the compensating variation (CV) and equivalent variation (EV) of the EPG price change policy, which gives a monetary estimate of the value of the policy to different income groups (deciles). The definition of CV and EV are how much money would the household need to be given to achieve the same utility as a price change. The CV and EV are monetary estimates of the impact of the policy change while allowing quantities and income to vary, including a variable marginal utility of income. In short, they answer the question of how much a consumer could in theory be compensated for the impact of a price change. Estimates of fuel poverty and underheating are also investigated.

2.3 Data

The primary data source for this modelling was the ONS Consumer Trends UK quarterly timeseries (CT). This provided 156 observations from 1985Q1 through 2023Q4. For each commodity type there were data for expenditure (in current price) and a quantity index (chained volume measure). The CT quarterly time series are broken down into constant volume and expenditure measures the corresponding implicit prices. Using these values, two further variables were calculated for each commodity: price per unit quantity; and share of total expenditure. This gave us the necessary data required to fit a demand system model to the data, which will be discussed in the next section.

Data from the ONS Family Spending Workbook were used to allow us to estimate how the expenditure timeseries changes for different income deciles. The data did not need to be modified and were simply used to disaggregate the expenditure timeseries data based on the ratio of each decile's expendable income with the median. This data was also used to cross check the model predictions.

It is important to note that the data contains the actual intervention periods of the energy affordability schemes, so the effect of the actual price rises, caps and interventions is contained in the data.

Additional data on various factors such as EPC rating and household income was also made available from the National Energy Efficiency Data-Framework (NEED). The NEED data were not used in the estimation *per se*, but were subsequently used to see how expenditure shares predicted by income decile group changed by EPC rating, with and without energy affordability interventions. The NEED data were provided in the form of cross tabulations (crosstabs) giving averages of gas and electricity usage for each combination of EPC rating, floor area and income bracket, for each year available. The frequency with which each combination occurred was also provided. Combinations with fewer than 5 occurrences were replaced with NA values to make the data non-disclosive.

2.4 Modelling approach

The modelling started with the idea of demand system models to estimate income and price elasticities. The demand systems were estimated in STATA using their demand system modelling framework. The econometric framework allows for prediction that is consistent with all the system of own and cross price and income elasticities for the commodity expenditures specified. The model then enabled us to predict counterfactual scenarios of 'no intervention' for two key policies:

- **receiving a £600 income support and an EPG price reduction, capturing the majority of households in NI;**
- **receiving a £600 income support and no EPG price reduction, capturing households who are off the electricity and the gas grid.**

The relevant counterfactual scenario is the case of 'No intervention', i.e., the energy affordability schemes were not implemented to support households through the cost of living. It is important to note that there are no official data sources containing typical consumption levels for Northern Ireland, and therefore this modelling assumed typical energy bill costs for Northern Ireland based on Ofgem consumption levels for GB. Analysis of tariff data imply an annual dual fuel bill in Northern Ireland for a direct debit customer of £3,083 in Greater Belfast and West and £3,493 in the Ten Towns, compared to a GB-wide average of £3,549 (pre-EPG discounts).

The AIDS model then 'predicts' (i.e., via the predicted value from the econometric demand system) the change in expenditure given a change in price and income. It is important to note that whilst the model and approach of the predictions for % change and elasticities are the same for GB and NI, the counterfactual

The model data is for all UK aggregate quarterly time series. Thus, the elasticity estimates do not vary by GB and NI. This is consistent with the assumptions of the model, namely, exact aggregation. The specific values of income and income decile groups, and price and income changes in % terms for the GB and NI policies were implemented in the models when making predictions of the counterfactual. The first part of the section below, thus follows exactly the GB model description, as there is no difference.

To simplify the model commodities consumed by households were aggregated into five categories of broadly similar types. The fifth category is of the most interest as this is where the policies were intended to have a direct impact. The aggregated groups were:

- Food, drink, water and health (which have the ONS FS commodity numbers) (1, 4.4, 6)
- Alcohol, tobacco, narcotics, restaurants, hotels, recreation, culture and miscellaneous (2, 9, 11, 12)
- Clothing, transport, communication and education (3, 5, 7, 8, 10)
- Rent, house imputed rent and non-water non-energy utilities (4 excl. 4.4 and 4.5)
- Electricity, gas and other fuels (4.5)

The next step was to find the best models for the data. To do this, several models were fitted to the data, after which the compensated (Hicksian) and uncompensated (Marshallian) price elasticities given by each model were compared with those of the other models to find which models gave the most reasonable predictions under current economic theory (provided the results were also statistically significant. The models tested were:

- Almost Ideal Demand System (AIDS)
- Generalised AIDS
- Quadratic AIDS (QUAIDS)
- Generalised QUAIDS

The QUAIDS model expands on the AIDS model and further allows for non-linear Engel curves (curves of how expenditure varies with income). The generalised version of these models enables committed quantities, or minimum subsistence levels, which is often preferable as this ensures that a constant term is included in each demand equation. A detailed description of these models is given in Sub-annex 1.

While the generalised versions of these models have some good properties, they are not as good a fit for the data than simpler ones. Based on the rubric and process outlined earlier it was decided to proceed with the AIDS model and have the QUAIDS model as a sensitivity test (both the ungeneralised versions). In general, the AIDS model fit the data well and there wasn't much sensitivity across models. The QUAIDS models fit the data well but gave some counter intuitive predictions for shares of the higher income brackets so only the results of the AIDS model are presented here.

Below, in Table 1 we can see the expenditure elasticities derived from the estimated parameters of the AIDS model. The figures in the table are the expenditure elasticities of the goods with respect to income. Thus a % change in energy predicted by the % change in income. A positive value indicates the good is a normal good and a negative an inferior good. Values positive and greater than 1 are luxury goods. These values confirmed that the AIDS model was working as intended and giving us values that conform to economic literature—e.g., in particular a negative elasticity for energy, that is to say the share of expenditure on energy should decrease with income.

Table 1: Expenditure elasticities (AIDS model)

Expenditure	Food, drink… (1, 4.4, 6)	Alcohol, tobacco… (2, 9, 11, 12)	Clothing, transport… (3, 5, 7, 8, 10)	Rent, house (4 excl. 4.4 and 4.5)	Electricity, gas… (4.5)
Elasticity	**0.568**	**1.221**	**1.318**	**0.653**	**-0.297**

Source: London Economics analysis. **Bold: P-value < 0.05**

The next Table 2 shows the uncompensated (Marshallian) price elasticities for each of our bundles of commodities in the AIDS model. Uncompensated elasticities contain both the substitution and income effects of a price change.

The main focus here should be on the own price elasticity of electricity, gas and other fuels, which is negative and between zero and one, indicating inelastic demand. These are generally of the expected sign and size, and significant (except one, category 4, rent and housing, which is not surprising). The uncompensated elasticities include the price and income effects. Again, these values gave us confidence in the AIDS model. In particular, we paid close attention to the main diagonal of own-price elasticities of this table.

Table.2: Uncompensated (Marshallian) price elasticities (AIDS model)

	Food, drink… (1, 4.4, 6)	Alcohol, tobacco… (2, 9, 11, 12)	Clothing, transport… (3, 5, 7, 8, 10)	Rent, house… (4 excl. 4.4 and 4.5)	Electricity, gas… (4.5)
Food, drink… (1, 4.4, 6)	**-0.772**	-0.045	**-0.088**	-0.022	0.701
Alcohol, tobacco… (2, 9, 11, 12)	0.091	**-0.568**	**-0.254**	**-0.287**	**-1.010**
Clothing, transport… (3, 5, 7, 8, 10)	-0.006	**-0.169**	**-0.322**	**-0.469**	**-0.583**
Rent, house… (4 excl. 4.4 and 4.5)	-0.024	**-0.320**	**-0.553**	-0.017	**1.429**
Electricity, gas… (4.5)	**0.143**	**-0.118**	**-0.102**	**0.141**	**-0.241**

Source: London Economics analysis. **Bold: P < 0.05**

The NI modelling used data to increase the shares by decile across the estimated income deciles such that they were scaled up by the average ratio of NI/UK energy and total expenditure. NI spends on average more on energy compared to GB, and this appears to be due to higher reliance on fuels/not having such as large portion of households on the gas network. The analysis presented is for the typical 'types' of household, given these assumptions. However, it was not known exactly how many or which households benefitted from EPG, EBSS AFP or EBSS AF in NI.

Another issue was that NEED data was not available for NI but EPC rating data was. We attempted to use an 'implied EPC rating usage', and then to proportionally adjust this down by the SERL or the LE/NEED percentage actual data, but this gave counter-intuitive results, as some ratings categories and income brackets still had very large, predicted energy use while others had smaller than expected. Moreover, this did not result on predictions of near monotonic increase in use by EPC and decile or income indicator (nor decrease by floor area). Thus the initial matrix of expected usage in total energy in kWh for GB (from NEED) was used as the starting point.

2.4.1 Limitations

Lack of EPC data in NI: The EPC dataset used to compensate for the lack of an equivalent of the NEED data in NI in our analysis is based on an extract from the EPC Building Register of c. 335,000 active Energy Performance Certificates in Northern Ireland from 2013 to September 2023. This dataset represents EPC coverage in NI at 44% of all residential buildings. Using data of only households with an active Energy Performance Certificate (EPC) could lead to biased results. This is because the sample of households with active EPCs might not accurately represent the entire population of households.

Identifying off-gas grid households: The modelling attempted to assess the impact on households that would not have received EPG (i.e. were off both the gas grid and the electricity grid). However, there was no way with the data available for the evaluation at the time of writing to explicitly model on/off gas grid behaviour.

2.5 Usage under counterfactual scenarios

Once the data were modelled using the AIDS model, London Economics began the process of predicting the effects under various scenarios such as no policy using the econometric model. This has the benefits of taking account of the own-price, cross price and income effect together with a consistent set of parameters, with the restrictions on demand and expenditure functions imposed. First, we estimated the impact on the quantities of each commodity group under two policies: EPG and a £600 lump sum, a £600 lump sum only, and the counterfactual of no policy at all.

The predictions from the AIDS model indicate that the lowest income decile used 26% more energy with the £600 + EPG policy in place than they would have without it (no policy), which is consistent with the policy objectives. This is slightly smaller as a % change relative to GB, which was 28% from similar modelling. Notably the predicted percentage-change in energy usage decreases with higher income deciles until the 10th decile where there is very little difference with the counterfactual of having no policy. This is due to the negative income elasticity, but that the own price elasticity creates income and substitution effects.

Also of particular interest is the difference between the EPG plus £600 policy vs the £600 policy. The £600 income support policy has a much smaller impact on the change in energy expenditure. In NI, naturally, the £600 plus EPG policy would have a bigger impact than just £600. The AIDS model predictions for the £600 policy indicate this policy does not change energy use by more than 5% in any decile. This arises from two facets of the policy differences: one that there are no own and cross price elasticity effects in the £600 policy; and two that the overall total value of EPG is more than £200. Indeed, EPG was a circa £1000 difference for the typical household (from the typical household analysis of the ex-ante analysis from the policy) —we present values of Equivalent and Compensating variation later below.

This model also estimated that the share of expenditure going towards electricity, gas and other fuels decreased under the £600 + EPG policy relative to no policy. While the share of expenditure would also fall for the £600 policy when compared to the counterfactual of no intervention, the size of the effect is much smaller. This indicates that under the £600 + EPG policy households were likely to use more energy while also spending more on other goods and services and that the £600 policy would have mostly gone towards other household expenses.

The detailed results by income decile are found in the table below. The energy figures are converted to kWh and expenditure shares.

Table 3: Electricity, gas and other fuel (4.5) usage over 2022Q4 and 2023Q1 (kWh) with counterfactual scenarios (AIDS model)

Income Decile	Quantity [kWh]				
Group[13]	£600 + EPG	No Policy	% diff	£600 only	% diff
1st	6,599	5,096	25.8%	6,284	4.9%
2nd	7,741	6,163	22.8%	7,494	3.2%
3rd	8,058	6,572	20.4%	7,892	2.1%
4th	8,376	6,965	18.4%	8,265	1.3%
5th	8,661	7,375	16.1%	8,609	0.6%
6th	9,280	8,143	13.1%	9,292	-0.1%
7th	9,169	8,326	9.6%	9,248	-0.9%
8th	9,391	8,865	5.8%	9,538	-1.6%
9th	9,480	9,607	-1.3%	9,745	-2.8%
10th	11,536	13,882	-18.5%	12,120	-4.9%

Source: London Economics analysis

It should be noted that the above data are presented with kWh estimates. The aggregate CT time series is given with constant volume quantity measures for the aggregate economy.

[13] To note, there are nine income deciles, which divide the income distribution into 10 equal sized groups. The decile groups are estimated on disposable household income from ONS data.

Notably, quantities are generally in arbitrary units with implicit prices and expenditures. The estimates are consistent for a typical household, and subsequent typical households with incomes in the different deciles of the income distribution, so the EPC ratings dataset was utilised to estimate winter kWh usage for the typical household by Decile. To do this, first the income deciles were interpolated from the data, for each of electricity and gas, as the income categories were not exactly matching deciles. Next the total electricity and gas kWh per household per year were summed for the interpolated deciles. Then, from the seasonal quarterly consumer trends time series, for the 2022-23 winter, the proportion of annual expenditure that was on the winter intervention period was calculated. London Economics then created a proportional factor, for each quarter. These proportional factors were then used to give the baseline kWh for the winter quarters of the intervention period and thus scaled the data (which was annual) to the winter period only. The percentage changes for the quantity were then applied for the policy and no policy scenarios as the changes are all proportional.

Also of particular interest was how the policy scenarios affected other spending categories. The modelling framework developed enabled the prediction of changes in expenditure, quantity and share for all commodity bundles specified. For presentational purposes food and drink and water and health are provided because the way in which the policies impacted other ‘necessities’ is of particular interest. The category of food, (non-alcoholic) drink, water and health (1, 4.4, 6) is of obvious importance, so we discuss it here.

We followed the same procedure to generate the predictions by decile, and the two policies, for the food, drink, water and health categories. The table below shows that the price change for energy was predicted to have had a small effect decreasing expenditure on food, drink, water and health, under the AIDS model. This is consistent with the expectations of the Engel curve for these goods and is consistent with substitution of expenditure towards the lower priced energy product. This effect is more pronounced for higher income deciles. The expenditure shares on this category do not change by a large amount for any decile.

Table 4: Food, drink, water and health (1, 4.4, 6) usage over 2022Q4 and 2023Q1 with counterfactual scenarios (AIDS model)

Income Decile	Quantity (Constant Volume measure ONS)					Share		
	£600 + EPG	No Policy	% diff	£600 only	% diff	£600 + EPG	No Policy	£600 only
1st	46,032	44,179	4.1%	42,827	7.2%	15.7%	16.8%	16.3%
2nd	54,621	53,414	2.2%	51,637	5.6%	14.5%	15.4%	14.9%
3rd	61,147	60,667	0.8%	58,519	4.4%	13.6%	14.5%	14.0%
4th	66,588	66,720	-0.2%	64,234	3.6%	13.0%	13.8%	13.3%
5th	73,062	73,900	-1.1%	70,978	2.9%	12.2%	13.0%	12.5%
6th	80,650	82,023	-1.7%	78,554	2.6%	11.4%	12.1%	11.6%
7th	87,385	89,501	-2.4%	85,470	2.2%	10.7%	11.4%	10.9%
8th	93,385	96,289	-3.1%	91,690	1.8%	10.0%	10.7%	10.2%
9th	101,052	104,985	-3.8%	99,559	1.5%	9.3%	9.9%	9.4%
10th	110,685	116,385	-5.0%	109,645	0.9%	8.2%	8.9%	8.3%

Source: London Economics analysis

2.5.1 Compensating and Equivalent Variation of the Policy

Equivalent variation (EV) and compensation variation (CV) are two measures based on the indirect utility function approach of the economic ‘value’ seen by a household under a price change. A comprehensive description of these concepts and how they are calculated is given in Sub-annex 2. In essence, the two measures estimate how much income would have to be given to the household in question to give the same utility as a price change. These measures allow us to compare the ‘value’ or welfare impact of say the £400 + EPG with the £600 direct income support.

To find the EV and CV seen by each household under the intervention we first used its AIDS model to estimate them on a national level then divided by the number of households (29 million[14]). In STATA, EV and CV calculations only account for price changes so the £600 lump sum needs to be added to the result of the calculation. The % change estimates for price and the income level estimates for NI for the decile groups were used in the predictions. Nonetheless the numbers are not far off the GB estimates. The results are detailed in the table below.

Table 5: Compensating and equivalent variation of policy (£ per household) (AIDS model)

Income Decile Group	Compensating Variation (CV) per household	Equivalent Variation (EV) per household
1st	842.14	839.82
2nd	870.59	868.71
3rd	888.20	886.71
4th	899.94	898.80
5th	909.98	909.31
6th	915.51	915.38
7th	913.67	914.01
8th	905.47	906.20
9th	883.42	884.58
10th	829.00	830.44

Source: London Economics analysis

The NI estimates are not qualitatively different than GB. Small differences arise as to the fact that the price changes in NI were as a % slightly smaller, the EBSS AFP or EBSS AF value was somewhat higher, but then the income levels for NI are slightly lower for all deciles. Qualitatively, same pattern is evident, that the predicted benefits of the price change are not very sensitive to the income decile group, nor to the choice of CV or EV.

The results of the EV and CV are interesting. Middle income deciles saw the largest economic benefit from the policy according to both models. This is likely because the lowest decile households are already spending a small total amount of money on energy, even though a large share of income.

[14] It should be noted that the AIDS model is for the aggregate UK, and then the predictions are for the aggregate UK and are scalable by the typical household, or typical household with a particular income level, and the middle points of the income decile groups for NI were used. However, the scale of the model is per household for the whole UK, so the correct division is to divide by the number of households in the UK, even though we predicted the values ‘given’ the NI norms.

Some intuition for this may be that lower income households benefit less from the price change as they have less to spend to begin with. Higher income households may benefit more from a price drop if they are already consuming more of the good. However energy is estimated to be an inferior good, so higher income households substitute out of the energy good. On the other hand, the income effect tends to increase expenditure on all goods, broadly in proportion to their expenditure shares. Finally, there is an income boost to the policy of £400. The data and examples above suggest that these two effects may have been cancelling.

The net result is that in money terms, the models predict money-equivalent utility increases that are similar for all income groups. In other words, more well-off households did not get significantly 'more' utility than poor households because they had a big house and heated it more. The richest households didn't change energy use much while the poorer ones did and so the net impact was similar across deciles. However, across the board all deciles saw a greater money-metric-utility-value than a £600 lump sum would have provided.

It should be noted here that these results are driven by the aggregate and quarterly data available to us for this modelling work, meaning they do account mostly for long-run effects. These results should therefore undergo further sensitivity analysis using more disaggregated data.

2.6 Fuel Poverty[15]

In this subsection, we study the impacts of the measures on fuel poverty or energy burden. We followed the ONS's technical definition of fuel poverty which is as follows "after housing costs, the total fuel costs needed to maintain a satisfactory heating regime are more than 10% of the households adjusted net income."[16] Using cross-tabulations of the NI-EPC dataset and income bracket, and our predictions from the AIDS model, London Economics and income bracket and our predictions from the AIDS model we can estimate which categories of household were in fuel poverty on average under the different policy scenarios. NEED type data was not available for NI, but only EPC rating. Thus, we assumed that the usage profiles by EPC rating from GB applied to the actual EPC ratings in NI. Further, for NI and GB, to carry out these calculations the team assumed that households heat to a satisfactory level. As such the resulting figures may be an underestimation.

It should be noted that the only detailed family spending data from ONS is by region for typical household, whereas detailed expenditure data is available from the ONS family spending workbooks by disposable household income decile. It is noteworthy that the expenditure share on fuel from the ONS regional family spending data for NI is higher than the share for the UK or typical other GB regions. It also should be noted that the regional data from ONS is the

[15] The definitions and measurement of Fuel Poverty vary across countries, including within the United Kingdom. We have used the term fuel poverty as an indicative term and our results should only be interpreted in the terms of what we have assumed and estimated. There are explicit definitions of fuel poverty used in policies elsewhere that should not be confounded with our approach. For more information on the differences in Fuel Poverty definitions across the UK, refer to the House of Commons Library briefing paper.
[16] See: ONS (2023) How fuel poverty is measured in the UK

average of the last three financial years, so in fact is lagging the UK data. Below shows a comparison of the all UK decile-groups spending data compared to NI.

Table 6: UK household share of energy expenditure analysis, 2021-2023

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	All HHs
2021	9.4%	8.7%	7.1%	7.0%	6.4%	5.4%	5.4%	4.8%	4.5%	4.0%	5.6%
2022	8.6%	8.3%	7.2%	6.5%	6.3%	5.5%	5.4%	5.0%	4.7%	4.1%	5.6%
2023	12.2%	11.0%	8.6%	7.9%	8.3%	7.4%	7.1%	6.9%	6.2%	5.9%	7.5%

Source: ONS Detailed Household Expenditure, 2021-2023, Disposable household income

In the next table, the regional data for the UK and NI are compared[17]. First, the NI/UK ratio for share of energy expenditure and share of energy expenditure after housing expenditure were calculated.

Table 7: NI vs UK Household energy expenditure analysis, 2021-2023

	NI	UK	NI/UK Ratio
Total Expenditure	442.00	454.10	97.3%
Energy Expenditure	37.00	28.70	128.9%
Share of energy expenditure	8.4%	6.3%	132.4%
Share of energy expenditure after housing expenditure	9.40%	7.07%	148.7%

Source: ONS Detailed household expenditure by region (3-year average)(2021-2023), average UK and by Region

The NI/UK ratios calculated in Step 1 for share of energy expenditure and share of energy expenditure after housing expenditure were applied to the UK 2023 share of energy expenditure to calculate the share of energy expenditure and the share of energy expenditure after housing expenditure by income decile for NI. We scaled up each UK expenditure share decile from the ONS 2023 Detailed Expenditure Family Spending workbook by the ratios of the NI/UK expenditures in the ONS Regional Family Spending workbook (2021-2023). This resulted in the following table of expenditure shares for NI:

[17] It should be noted that the Regional Workbook data is average weekly for all of the region. The breakdowns by disposable income are to form the decile groups, but this is not relevant for the regional workbooks.

Table 8: NI Household energy expenditure ratios, 2023

	Income Decile										
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	All
Share of energy expenditure	16.2%	14.6%	11.4%	10.5%	11.1%	9.7%	9.5%	9.2%	8.3%	7.8%	10.0%
Share of energy expenditure after housing expenditure	18.8%	15.8%	12.6%	11.3%	12.0%	10.5%	10.1%	9.6%	8.7%	8.0%	10.7%

Source: ONS Detailed Household Expenditure, 2023

Once these estimates had been created for NI, the procedure was similar to that applied for GB. The predicted energy change from NI from the AIDS models was used given the income levels and % price changes specific to NI, but the model parameters were estimated for all of the UK.

To calculate these figures, we divided the expenditure shares obtained from the AIDS model by the share which corresponds to non-housing expenditure. The non-housing expenditure can be found in the ONS Family Spending Workbook. The ONS workbook has figures on average weekly spend by decile, which were converted to percentages of the total; it was assumed that housing costs are constant throughout the year. This provides the share of non-housing costs going towards fuel. The deciles are disaggregated to include EPC ratings using the fact that their expenditure share is proportional to usage (usage data by EPC and income are included in our NEED crosstabs), and the sum of usage in the disaggregation must be equal to the total we already have.

Highlighted in red are the categories which were in fuel poverty on average (within the category group). Comparing the £600 + EPG scenario (above) with the counterfactual of having no policy (below), we can see that the average household in the first and 2nd income decile for all EPC ratings were expected to be in fuel poverty by our measure and the various policies would not have changed this. This result was the same for NI and GB. Only the most efficient households in the middle to upper deciles are not in fuel poverty.

Table 9: Share of income towards fuel costs after housing costs by income decile - £600 + EPG scenario

EPC	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
A	17.6%	14.5%	11.7%	10.6%	11.1%	9.6%	8.8%	8.2%	7.5%	6.6%
B	16.8%	13.2%	10.3%	9.0%	9.2%	7.9%	7.6%	7.2%	6.6%	6.3%
C	18.5%	15.8%	12.7%	11.2%	11.7%	10.2%	10.2%	9.6%	8.9%	8.4%
D	21.7%	18.2%	14.5%	13.1%	13.8%	12.1%	12.1%	11.2%	10.2%	9.3%
E	23.8%	20.0%	16.0%	14.5%	15.4%	13.6%	13.7%	12.7%	11.7%	10.8%
F	23.3%	19.5%	15.8%	14.7%	15.7%	14.0%	14.3%	14.2%	13.5%	12.6%
G	22.3%	18.2%	14.5%	13.2%	14.2%	12.8%	12.8%	12.6%	12.0%	11.3%

Source: London Economics analysis

The next table below is the ‘no policy’ scenario. In this table, by the estimates given, almost all households are expected to be in fuel poverty without the policy, save the 6-9th decile groups for B rated household. It isn’t clear why A-rated household are slightly worse off, but perhaps because they have larger Housing units or are newer and relatively younger household with slightly lower incomes.

Comparing the first policy of £600 + EPG, indicates that for the household types indicated, the upper and more efficient households were indeed shifted out of predicted fuel poverty.

Table 10: Share of income towards fuel costs after housing costs by income decile – counterfactual no policy

EPC	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
A	20.3%	16.9%	13.8%	12.6%	13.4%	11.9%	11.2%	10.8%	10.6%	11.0%
B	19.4%	15.4%	12.2%	10.6%	11.1%	9.8%	9.7%	9.4%	9.3%	10.5%
C	21.4%	18.4%	14.9%	13.3%	14.1%	12.6%	12.9%	12.6%	12.5%	14.0%
D	25.0%	21.2%	17.1%	15.6%	16.7%	15.0%	15.4%	14.8%	14.4%	15.5%
E	27.5%	23.3%	18.8%	17.2%	18.5%	16.8%	17.5%	16.7%	16.4%	17.9%
F	26.9%	22.8%	18.6%	17.5%	18.9%	17.3%	18.2%	18.7%	19.0%	20.8%
G	25.7%	21.2%	17.0%	15.7%	17.1%	15.8%	16.4%	16.6%	17.0%	18.8%

Source: London Economics analysis

The next table shows the impact of the £600 policy with no EPG. Some households who did not have gas heat or an electricity supplier simply received a £600 payment and no EPG. As with GB, this shows the lack of EPG was significant as marginally more household types in the table are in fuel poverty with the £600 only measure.

Table 11: Share of income towards fuel costs after housing costs by income decile - £600

EPC	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
A	18.6%	15.3%	12.3%	11.1%	11.6%	10.1%	9.3%	8.6%	8.0%	7.1%
B	17.8%	13.9%	10.8%	9.4%	9.6%	8.3%	8.0%	7.5%	7.0%	6.8%
C	19.5%	16.6%	13.3%	11.7%	12.2%	10.7%	10.7%	10.1%	9.4%	9.0%
D	22.9%	19.1%	15.2%	13.7%	14.4%	12.7%	12.7%	11.8%	10.9%	10.0%
E	25.1%	21.0%	16.8%	15.2%	16.0%	14.2%	14.4%	13.3%	12.4%	11.6%
F	24.6%	20.5%	16.6%	15.4%	16.4%	14.6%	15.0%	14.9%	14.3%	13.5%
G	23.5%	19.1%	15.2%	13.8%	14.8%	13.4%	13.5%	13.2%	12.8%	12.2%

Source: London Economics analysis

2.6.1 Limitations

The categories in the tables and analysis should give a good approximation but do not give exact numbers in fuel poverty, because the distribution of energy use within each category of the table is not known. There would be some households with very small floor space, and or, very efficient use, etc, within each cell of the table. Given the exact distributions of energy usage by EPC rating and income decile it would be possible to estimate how many households were able to avoid falling into fuel poverty, however these distributions were not obtainable and so the analysis was conducted based on the average household in each category from crosstabs of the NEED dataset. Nonetheless, we would argue that the amount of error in the table is likely to be small, as for example, it is unlikely many households in the first 2-3 decile groups, particularly at the lower EPC ratings, would not have been in fuel poverty, and similarly very few households in the upper decile groups would have been in fuel poverty.

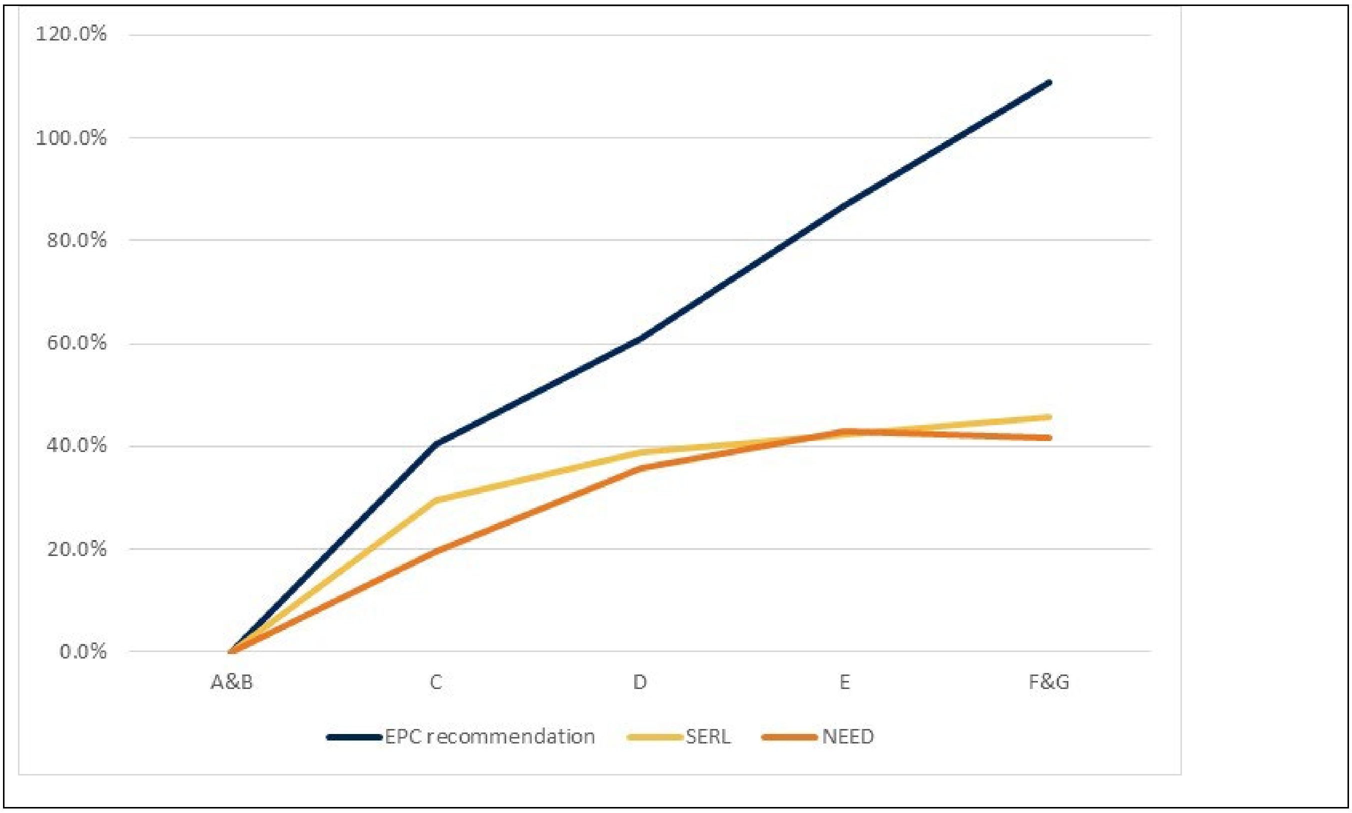
Another limitation of the analysis is that certain households in the poorest income decile groups may have/likely received other income support including fuel support and arguably this could have been excluded from the shares estimates (the impact to lower the % of the poorest households in fuel poverty).

On the other hand, it is also possible that some of the poorest households did not heat their housing units to an acceptable degree, but the estimates are of actual expenditures and consumption, etc. While an admitted limitation, this fact is unlikely to impact the results for the poorest households, as they are already well over the threshold of fuel poverty for all efficiency categories. Similarly, the worst/least efficient households for the least efficient categories, are already in fuel poverty by the estimates, and the actual consumption figures and shares should reflect the fact that they likely underheat certain parts of the housing unit. The likelihood of changing this measure would impact on the marginal household unit groups with near fuel poverty level shares of fuel expenditure, such as the C-rated and 5th group.

2.7 Underheating

While we don’t have ‘true’ measures of underheating, the EPC rating gives a standardized predicted usage value per meter squared per annum. This value takes account of a standardized set of weather, all the housing unit characteristics, efficiency, insulation, etc, and behavioural assumptions (such as heating to a certain temperature each room, etc). It is well known that for inefficient housing units, these estimates vastly over-predict the actual consumption. Estimates of household energy usage per metre squared were estimated by EPC rating and income decile using the scraped NI-EPC dataset. The AIDS model results could then be applied to predict the change in consumption under the different scenarios. These figures were then compared to the recommended usage by EPC, and UCL SERL data of actual usage, to give an estimate of the levels of underheating.

Figure 1: Extra energy usage per square metre over house with A/B rating



Source: London Economics, SERL

The figure above is from published SERL and London Economics' analysis of NEED data. No actual consumption data by EPC rating for NI was available, but data on EPC rating for household units was obtained; so the percentage changes in actual consumption by EPC rating category for GB were applied to NI.

The percentage gap between the lines in the chart above gives us the underheating estimates below. The percentage can be interpreted as the percent of consumption less than what would have heated the full floor space of the households to the EPC model behavioural assumption.

The percentage gap between the lines in the chart above provide the underheating estimates in the following table. The AIDS model is applied to the corresponding income deciles for each EPC rating and then the average is taken to give the estimates in the final two rows below. Also note that these percentages are simply indicative and likely just proportional to the true levels of underheating, which depends on the specific definition of underheating used.

Table 12: Estimates of underheating by EPC classification

Energy performance certificate rating					
	A&B	**C**	**D**	**E**	**F&G**
EPC recommendation	0.0%	0.0%	0.0%	0.0%	0.0%
SERL estimates	0.0%	7.9%	13.9%	23.8%	30.9%
NEED – £600+ EPG	0.0%	14.9%	15.7%	23.4%	32.8%
NEED – counterfactual no policy	0.0%	15.2%	16.1%	23.5%	32.7%
NEED – counterfactual £600	0.0%	14.9%	15.8%	23.5%	32.8%

Source: London Economics analysis, SERL

The positive effect of the policy can be seen here; however, the impact appears to be small. This analysis suggests that the £600 + EPG policy reduced the average degree to which households underheat.

We attempted to expand these tables out by income decile as well, however it became apparent there were other factors at play. As can be seen in the table below, higher income households with an A-D rating were using less energy per square metre of their home. This may be reflective of these households having larger homes and there is a per unit ‘scale economies’ factor in larger units. Alternatively, larger energy efficiency gains could have been more affordable to higher income households. Accounting for these in an expanded analysis would require more data and modelling, and improve the granularity /resolution of our results. Accounting for these in an expanded analysis would require more data and modelling, and only add the granularity of this discussion.

2.8 Conclusions

The AIDS model results indicated the model was well specified, in that the coefficients and elasticities were significant and of expected signs and of magnitudes consistent with decades of econometric research and evidence; elasticities derived from the model indicate that it fit in well to the expectation for these values according to economic theory. The QUAIDS model was also estimated on this data as a sensitivity test and it gave similar results, this gave further confidence to the AIDS model. Other sensitivities were also estimated such as generalized AIDS, which allows for minimum or ‘subsistence’ quantities, and with integer independent variable scaling to account for technology effects. These sensitivities indicated the results were very insensitive to the overall conclusions of own price elasticities c. 25% and income elasticities <0.

The AIDS model shows that the £600+EPG policy had a substantial effect on allowing/encouraging people to heat their homes better than they would have under no policy over the winter period of 2022/23. Indeed, the price support was well targeted on electricity, gas and other fuel and didn't cause major changes in spending to other areas. The model predicted that policy induced a 26% increase in energy usage for the lowest decile. This effect decreased for higher deciles until there was practically no effect for the highest income decile. The middle decile groups (4 to 6) households likely saw an uptick in energy usage of 13-18%. The importance of using a model such as AIDS is highlighted by these results as it indicates that the impact in terms of energy expenditure change was predicted to be higher for lower income deciles.

The £600 support would have been less well targeted and roughly cause a proportional (to current spending shares) increase in spending to all shares. It can also be seen that expenditure on food, drink, water and health (1, 4.4, 6) was not predicted to have a significant change under the policy or the counterfactual scenarios.

The £600 + EPG policy gave a higher equivalent variation and compensating variation (about £775 on average) compared to the £600 policy, which of course has an EV/CV of £600. So, the £600 + EPG policy had a higher utility to households. Middle incomes saw the highest benefit under the £600 + EPG measure, with their EV and CV just below £800. The high and low income saw a lesser benefit, in particular, the lowest income decile saw an EV and CV of about £710. The total monetary value of the policy was broadly similar at over £800 for all deciles, which gives a greater proportional impact for lower income deciles.

The results on fuel poverty indicate that the £600 + EPG policy helped the average household in the first income decile with higher EPC ratings to avoid fuel poverty over the implementation period. Again, the £600 policy had a positive effect in this metric but was outdone by the £600 + EPG scenario.

Finally, levels of underheating were considered. The effects here follow a similar trend as above with the £600+EPG having a stronger positive outcome than the £600 policy. The absolute effects here are small, however they indicate the policy performed better on lower income households. This greater impact is due to their smaller energy usage, and the policy being worth a greater proportion of their income.

Overall, not surprisingly, the £600 + EPG policy gave a greater benefit compared to the counterfactual £600 scheme or the do-nothing scenario, with the £600 policy coming in second of course.

Sub-Annex 1: AIDS and QUAIDS models

The choice of expressing prices on a logarithmic scale is motivated by the desire to simplify the modelling process. The logarithmic transformation allows for a more intuitive understanding of percentage changes in price and ensures all values are unitless. Assuming a constant elasticity in this framework, to estimate a demand equation can only ever give us a linear approximation.

$$\frac{\partial \ln(q)}{\partial \ln(p)} = \varepsilon \rightarrow \ln(q) = \varepsilon \ln(p) + \beta$$

It is important to note, however, that this constant elasticity approach can yield inaccurate approximations, particularly when dealing with substantial price fluctuations. But this can be avoided by using a more complex model, like the Almost Ideal Demand System (AIDS) model, introduced by Deaton and Muellbauer.[18] This model gives a first order approximation to any demand system, and aggregates perfectly over consumers. The AIDS model is based on the specification of its cost function, $c(u, p)$:

$$\ln\big(c(u,p)\big) = \alpha_0 + \sum_k \alpha_k \ln(p_k) + \frac{1}{2}\sum_k \sum_j \gamma_{ij}^* \ln(p_k) \ln(p_j) + u\beta_0 \prod_k p_k^{\beta_k}$$

Where, u is utility, p a vector of prices, and α_i, β_i and γ_{ij}^* are parameters. From this we can derive the budget shares, w_i:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln(p_j) + \beta_i u \beta_0 \prod_k p_k^{\beta_k}$$

Where $\gamma_{ij} = \frac{1}{2}(\gamma_{ij}^* + \gamma_{ji}^*)$. For a utility maximising household c(u,p) is equal to the total expenditure, x. We can hence rewrite the budget share equations as:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{x}{P}\right)$$

Where P is a price index.

This model can also easily be extended to the so-called Quadratic AIDS (QUAIDS) model, first specified by Banks, Blundell, and Lewbel.[19] The budget share equations for the QUAIDS model are of the form:

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[18] Deaton, A., and J. Muellbauer (1980): “An Almost Ideal Demand System,” American Economic Review, 70(3), 312–326.

[19] Banks, J., R. Blundell, and A. Lewbel (1997): “Quadratic Engel Curves and Consumer Demand,” The Review of Economics and Statistics, 79(4), 527–539.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{x}{P}\right) + \frac{\lambda_i}{\prod_i p_i^{\beta_i}} \left(\ln\left(\frac{x}{P}\right)\right)^2$$

This extends the capability of the model by accommodating non-linear Engel curves and gives a second order approximation to any demand system, while preserving the desirable properties of the AIDS model, in particular its perfect aggregation property, and homogeneity in prices. This ensures that the model remains theoretically sound while capturing more intricate aspects of consumer behaviour. Notably, both the AIDS model and the Translog model, of Christensen, Jorgenson, and Lau,[20] are special cases of the QUAIDS model. Each of these models will be more accurate, to varying degrees, under price shocks than the naïve linear approximation with constant elasticity.

[20] Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1975): “Transcendental Logarithmic Utility Functions,” The American Economic Review, 65(3), 367–383.

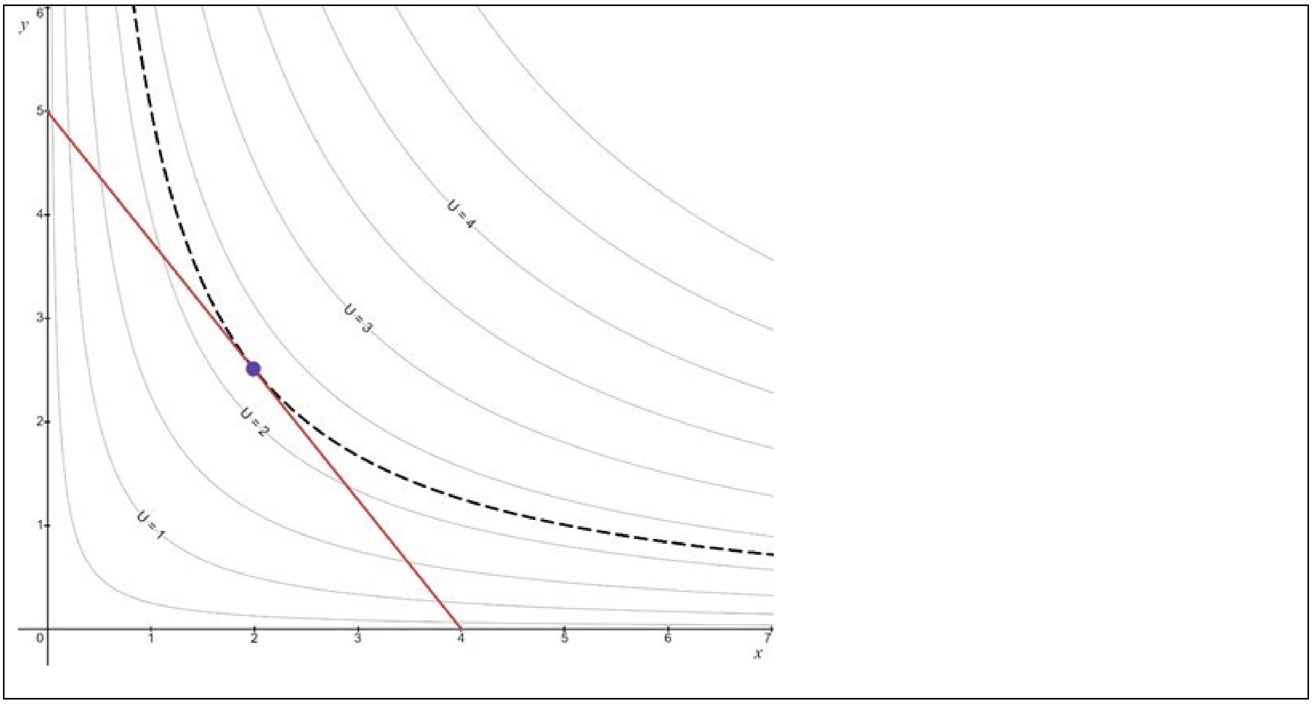
Sub-Annex 2: Equivalent Variation and Compensating Variation

The concepts of equivalent variation (EV) and compensating variation (CV) answer the question of how much the consumer should be compensated for this increase in price, so that their utility remains unchanged overall.

Suppose we have a consumer with a utility function $U(x, y)$, where x and y are the quantities of two goods. The consumer has a budget m and the goods have prices P_x and P_y respectively. The consumer's point of maximal utility lies on their budget line $xP_x + yP_y = m$, and is tangent to the contours of the utility function, $U(x, y)$. The contours of the utility function are known as indifference curves, these are the lines of equal utility.

In Figure 2, the budget line is the solid red line. The indifference curves are depicted in grey, except the one tangent to the consumers budget line which is in dashed black. The point of tangency is depicted in purple, this is the point of maximal utility for the consumer. We know this point is maximal thanks to the theory of Lagrange multipliers, which tells us that the extrema of utility will be at the point where the line is perpendicular to the gradient of utility (i.e. tangent to the contours).

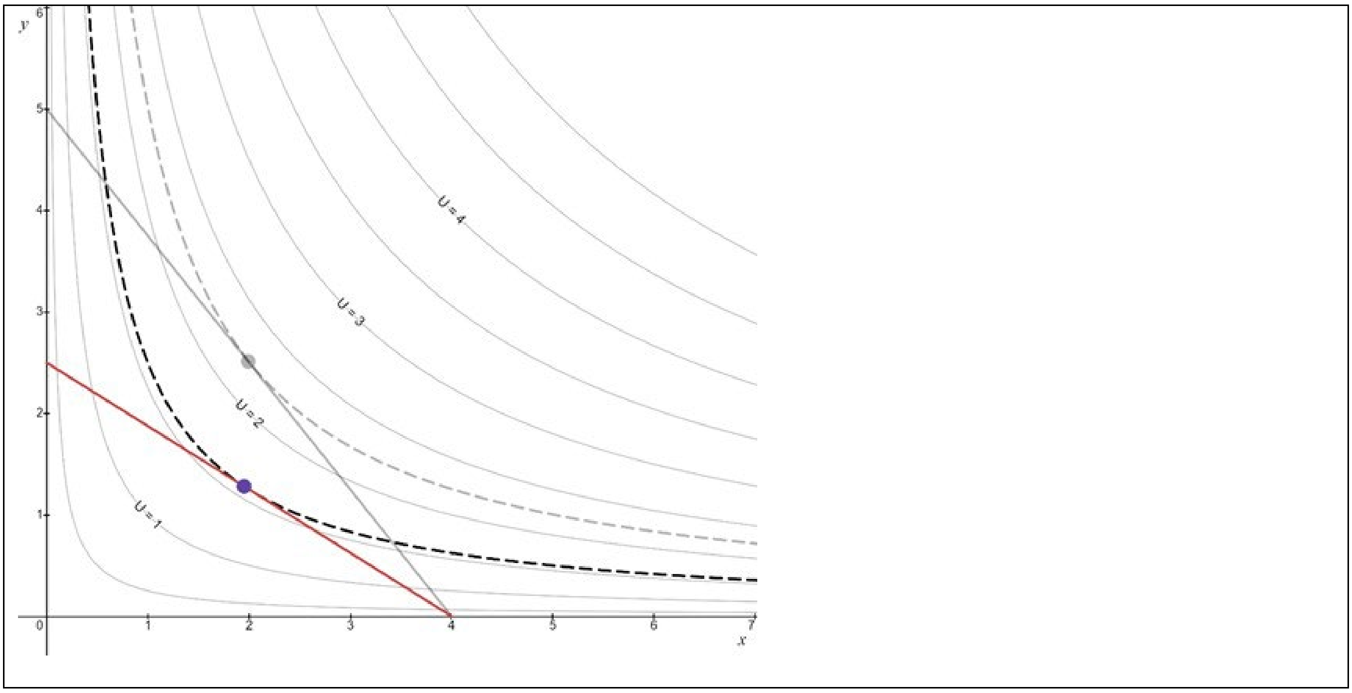
Figure 2: Budget line and indifference curves



Source: London Economics

Now suppose P_y increases to P_y'. In the graph below the new budget line is in red and the old lines have been greyed out. This new budget line is tangent to a lower indifference curve, meaning the consumer's utility has decreased.

Figure 3: Budget line after a price change

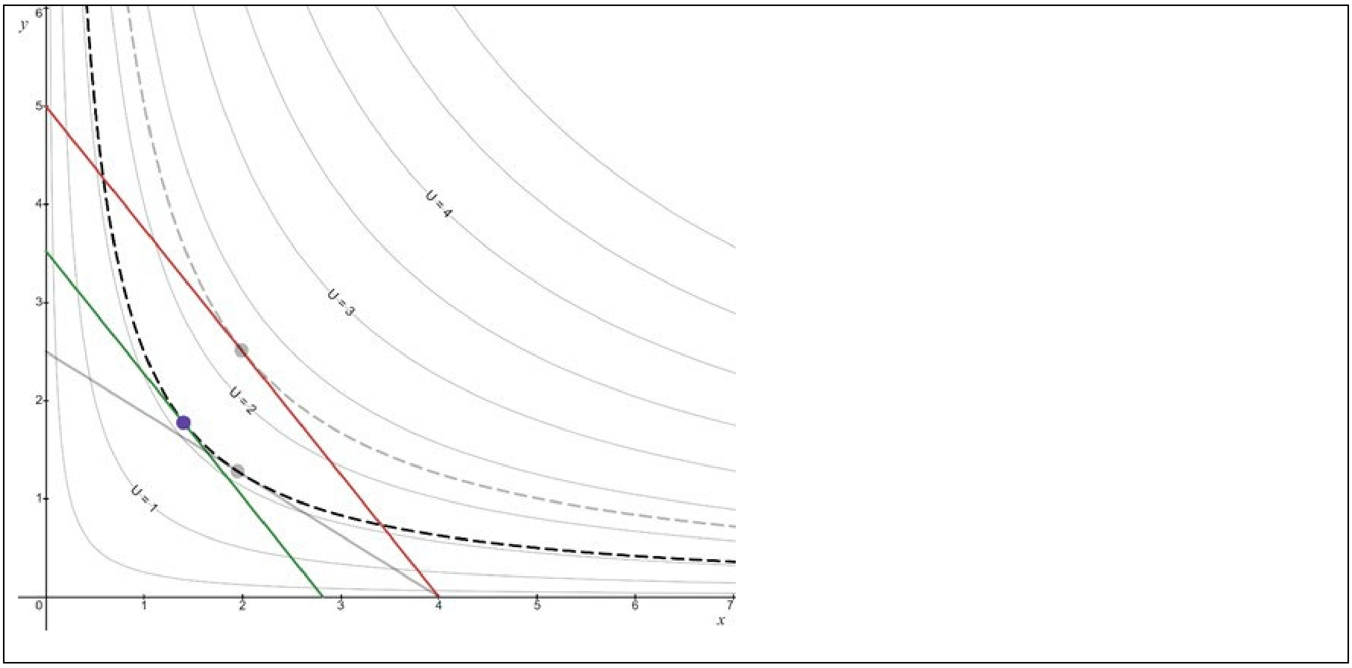


Source: London Economics

Equivalent Variation

The EV is the amount which the consumers budget m must have decreased, given the original prices, for the consumer's budget line to be tangent to the same indifference curve after the price change. To do this we find an m', such that the line $xP_x + yP_y = m'$ is tangent to our new indifference curve, this line is parallel to the original budget line, and depicted in green below.

Figure 5: Equivalent variation



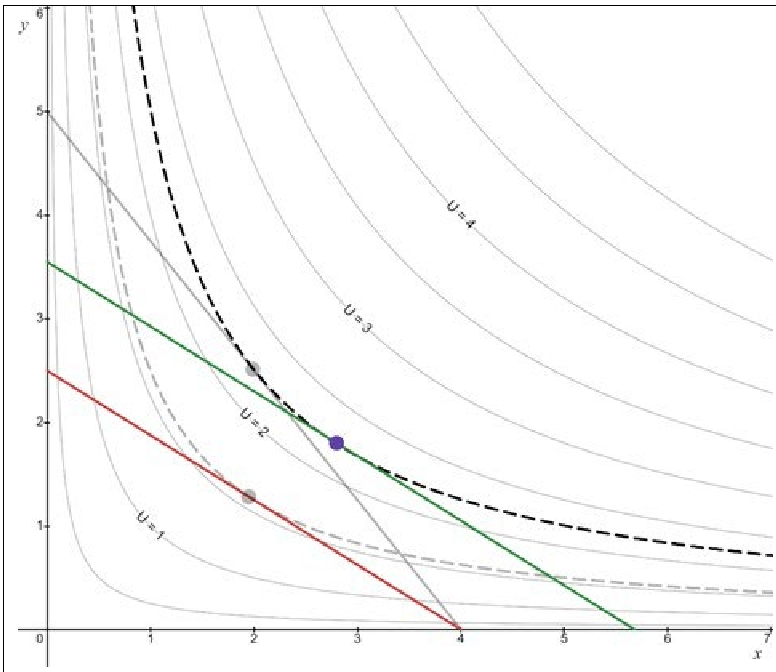
Source: London Economics

Then the EV is given by $EV = m - m'$.

Compensating Variation

The CV is the amount which the consumers budget m must be increase, given the new prices, for the consumer's budget line to be tangent to the original indifference curve. To do this we find an m', such that the line $xP_x + yP_y' = m'$ is tangent to the original indifference curve, this line is parallel to the budget line after the price increase and is depicted in green below.

Figure 5: Compensating Variation



Source: London Economics

Then the CV is given by $CV = m' - m$.

These methods can be generalised to any number of products, and an arbitrary utility function. Note that the consumer’s expenditure is always a linear combination of goods, but this does not mean the EV and CV figures are first-order approximations. Calculating the EV and CV follows directly from inferring the utility function from the model. The degree to which they are accurate is entirely dependent on the accuracy of the demand system model itself.

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