Evaluating the Impact of Energy Poverty in a Multidimensional Setting

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Motivation

At least 50 million people in EU are experience energy poverty (EC, January 2018). At least twice as much, by simply considering indicators such as the fact that households could not afford heating home properly, or were in arrears on their utility bills

- Health issues
- Social deprivation

Standard Indicators

- Expenditure on energy consumption (affordability)
- Arrears in utility bills (affordability)
- Inefficient and unhealthy dwellings (deprivation, *objective*)
- Inability to keep home adequately warm (deprivation, *subjective*)

Motivation

Energy Poverty (EP) is a multidimensional phenomenon:

- Each indicator provides a distinct snapshot of the issue
- Affordability measures mostly capture income/price effect
- Objective indicators on inefficient and unhealthy dwellings target a larger share of individual compared to affordability metrics
- Subjective indicators are informative, though sharing pros and cos of the more general category to which they belong

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To detect the actual occurrence of EP in the economy, all these distinct sources of information may (need to) be used by researchers and policy makers (e.g. Waddams Waddams Price et al, EP2012).

This paper

Presents an analysis of individuals' well-being where:

- the combined information from objective and subjective measures of EP is considered within a multidimensional approach;
- the information arising from the multidimensional approach is exploited to assess the relationship between EP and individual welfare by adopting a subjective well-being approach;
- the analysis is implemented by means of econometric methods suitable for the nature of data at hand.

Two main steps:

- Adapting a multidimensional poverty index to propose a Multidimensional Energy Poverty Index (MEPI) that combines both subjective and objective indicators to give an unique picture of EP
- Assessing the impact of different degrees of EP on the stated level of life satisfaction by exploiting the individual EP intensity measured by the MEPI.

Outline

Related literature

Studies with subjective measures of EP:

- Waddams Price et al. (2012): (UK) seminal work claiming for the use of different indicators, namely self-reported measures
- Papada and Kaliampakos (EP2016): to evaluate EP in Greece
- Lawson et al. (EP2015): comparing "10 per cent" fuel/income indicators and self-assessed affordability measures in New Zealand
- Rehdanz et al. (JEBO2015): in assessing the change in preference over nuclear power after Fukushima accident

Studies that evaluate the welfare effect of EP by referring to Subjective Well-Being (SWB) measures/approaches:

- Welsch and Biermann (EnJ2017) investigate the effects on life satisfaction of electricity, oil, and gas prices (standard objective measures) in different European countries
- Biermann (2016) studies the relationship between SWB and fuel poverty measures related to households' expenditure on energy (they are always associated with a significant negative effect on SWB that adds to that of income poverty)

Related literature

Studies where an explicit multidimensional approach is adopted:

- Nussbaumer et al. (RSER2012) adapt the methodology introduced in the poverty literature by Alkire and Foster (2011) to build and use a multidimensional energy poverty index (MEPI) in developing countries
- Nussbaumer et al. (Sus2013) in a global analysis of EP in developing countries
- Okushima (En2017) in evaluating EP in Japan before and after the Great East Japan Earthquake (and related Fukushima accident)
- Charlier and Legendre (EnJ2019) in capturing the degree of fuel vulnerability in France (*using an alternative methodology, based on geometric means and standardizations*)

Outline

A model for Subjective Well-Being and Energy Poverty

Considering energy poverty as one of the dimensions determining life satisfaction, we can subsume our empirical analysis by means of the following model:

$$SWB_i^* = S(\mathbf{x}_i, EP_i^*, \mu_{iSWB})$$
$$EP_i^* = P(\mathbf{x}_i, \mu_{iP})$$

where:

- $\mathbf{x}_i$ represents a vector of socio-economic characteristics that, in principle, may affect both SWB* and EP*
- μ_{iSWB} and μ_{iP} represent the unobservable individual heterogeneity that, in principle, may affect the perception of satisfaction as well as energy poverty (note: *key for endogeneity issues*)

Outline

The Data for our exercise: IT-SILC

We apply our multidimensional approach to the individual-level data from the Italian version of European survey of Statistics on Income Living Condition (EUSILC), released by ISTAT.

- 2014 Cross-sectional survey, referred to year 2013
- Household and individual information:
  - SWB indicator, age, education,income, marital status, children, employment status, health condition, material deprivation indicators
- Main advantage wrt EU-SILC is that it provides additional useful information on energy deprivations (that we use to construct multidimensional indices), namely:
  - the absence/presence of heating expenditure
  - whether the household lives in a damp home
  - or in a house with damages on the roof, ceilings and windows
- Life satisfaction (SWB) is measured according to a [0,10] scale

distribution of SWB

Energy Deprivations surveyed by IT-SILC (and sample incidence)

Variable	Question	Mean
ed1	Has the household been in arrears due to financial difficulties for utility bills for the main dwelling?	0.09
ed2	Has the dwelling any problems with the damp on walls, floors, ceilings or foundations?	0.18
ed3	Has the dwelling any problem with damaged roof, ceilings, doors, windows or floors?	0.11
ed4	Absence of any heating expenditure.	0.05
ed5	Is your dwelling too dark, meaning is there not enough day-light coming through the windows?	0.06
ed6	Can your household afford to keep its home adequately warm?	0.16

ITSILC data referring to 2013. The variables can be found into the dataset as hs021, umid, tetti, hs160, hh050, except for the ed4, which is recovered from the energy-specific expenditure analysis. The 'Mean' column refers to the incidence of each deprivation in the sample. Sample size: 23,193.

A Multidimensional Energy Poverty Index

Adapting Alkire and Foster (JPuEc2011) methodology, we construct a Multidimensional Energy Poverty Index (MEPI).
The method:

- is based on a first threshold to identify deprived individuals and a second threshold for the number of experienced deprivations
- Allows for different thresholds and weighting schemes of deprivations
- Provides:
  1. an individual level of EP intensity
  2. the average intensity of EP in the sample

A Multidimensional Energy Poverty Index

The Identification Function, for a reference cut-off k and weights w which sum is equal to the number of deprivations d, considers the (weighted) number of deprivations suffered by a single individual, c_i and classifies individual i as following:

$$\vartheta_k(g_i; z) = \begin{cases} 1 & iff \quad c_i \geq k, \quad when \quad 0 < k < d \\ 0 & otherwise \end{cases} \tag{1}$$

Given (1), we can compute a multidimensional index for individual i, corresponding to the weighted share of the possible deprivations identified for individual i:

$$MEPI_i^w = \frac{1}{d} \sum_{j=1}^{d} (c_i \times \vartheta_k(g_i; z)) \tag{2}$$

The previous index provides information about the intensity of EP that can be usefully inserted in the regression analysis, but with the caveat that it can only take $d + 1$ ordered values.

Aggregate multidimensional measures

An aggregate index of EP, for a given weighting scheme w, is obtained by taking the average of individual deprivation shares over the whole population:

$$MEPI^w = \frac{1}{n} \sum_{i=1}^{n} MEPI_i^w, \tag{3}$$

This index can be seen even as an *adjusted headcount ratio*, given by the product of the average deprivation share across the energy poor (A) and the share of energy poor identified by $\vartheta(g, z)$, i.e. the multidimensional headcount ratio $MHR = \frac{p}{n}$.
Therefore, an alternative expression for $MEPI^w$ is:

$$MEPI^w = A \times MHR(g, z). \tag{4}$$

Energy Poverty in Italy

Variable	(%)	Variable	Mean	Std.Dev.
Dual AB	3.75	Overall MEPI	0.09	0.17
MHR	23.97	MEPI among en. poor	0.36	0.16
Overlapping of Dual AB across MEPI levels			(%)	
MEPI Levels	(%)	Dual AB=1		
Level 0	76.03	58.08		
Level 1	6.53	11.39		
Level 2	10.56	15.15		
Level 3	4.61	10.07		
Level 4	1.60	4.65		
Level 5	0.62	0.66		
Level 6	0.05	0.00		

Strong difference between affordability and multidimensional measures; very low overlap in detecting energy poors.

Dual AB is a dual threshold affordability measure (Faiella and Lavecchia,2015), which considers an individual as poor if at least one condition holds between electricity consumption $> 0.10\times$ income and fuel consumption $> 0.05\times$ income. MHR is the multidimensional headcount ratio; MEPI is the multidimensional index of energy poverty. ITSILC data referring to 2013; Sample size:23,193.

SWB and EP | EP and income

Outline

Endogeneity of EP indicators when accounting for subjective deprivations

Considering subjective indicators of EP makes MEPI indices with subjective deprivations endogenous in their relationship with SWB.
This is mainly due to *unobservable latent factors*:

- e.g., *optimism*: affects individuals' statement on life satisfaction as well as the perception of being energy deprived or not.

Solution: triangular system estimation with exclusion restrictions

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Identifying assumption:

- A few objective and technical factors that describe dwellings directly influence the probability of being energy poor but do not directly affect the statement of SWB.
- operationally: the *dwellings' construction age* directly predicts the MEPI index (*testable hypothesis*) Excl but does not directly affect the subjective statement on SWB (*theoretical hypothesis*).

The empirical model

We estimate the following triangular system by means of a fully information simultaneous bivariate ordered probit (Sajaia,2008): LogL

$$\begin{aligned} SWB_i &= MEPI_i\beta_1 + \mathbf{x}_{1i}^{'}\delta_1 + e_i \\ MEPI_i &= \mathbf{x}_{1i}^{'}\theta_1 + \mathbf{x}_{2i}^{'}\theta_2 + u_i \end{aligned} \tag{5}$$

where:

- **SWB_i** and **$MEPI_i$**: ordered categorical variable, empirical counterpart of *latent utility* SWB_i^* and *latent energy poverty* EP_i^*.
- **$\mathbf{x_{1i}}$**: vector of observable characteristics common to SWB and EP ["large" vector (including *age, gender, marital status, education level, employment status, health status, income, material deprivation, house structure, degree of urbanization, macro-region*) aimed at purging the relationship between dwelling's age and SWB from self-selection due to personality and geographical traits];
- **$\mathbf{x_{2i}}$**: set of instruments (exclusion restrictions in the SWB equation).

Outline

Estimation Results

	MEPI Equation		SWB Equation		Dual AB Equation		SWB Equation	
Variables	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
MEPI			-0.704***	(0.103)				
Dual AB							-0.110	(0.084)
2000-2009	0.813***	(0.260)			-0.281	(0.300)		
1990-1999	0.570***	(0.062)			-0.061	(0.104)		
1980-1989	0.610***	(0.063)			0.005	(0.055)		
1970-1979	0.531***	(0.056)			0.014	(0.058)		
1960-1969	0.416***	(0.053)			0.043	(0.049)		
1950-1959	0.382***	(0.051)			-0.017	(0.066)		
1900-1949	0.218***	(0.058)			0.116***	(0.044)		
Before 1900	0.141***	(0.055)			0.123**	(0.058)		
Controls tab	Yes		Yes		Yes		Yes	
Regional residence	Yes		Yes		Yes		Yes	
AIC	122784.6				93542.1			
BIC	123791.0				94508.3			
Log-Likelihood	-61267.3				-46651.0			
Observations	23193				23193			

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Dual AB is a dual threshold affordability measure, which considers an individual as poor if at least one condition holds between electricity consumption $> 0.10\times$ income and fuel consumption $> 0.05\times$ income. MEPI is the multidimensional index of energy poverty. ITSILC data referring to 2013.

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Estimation Results: Robustness Checks

	AB equation		SWB Equation		MEPI Equation		SWB Equation	
Variables	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
AB			0.024	(0.045)				
MEPI							-0.666***	(0.113)
2000-2009	-0.158	(0.187)			0.802***	(0.261)		
1990-1999	-0.041	(0.083)			0.581***	(0.062)		
1980-1989	-0.003	(0.046)			0.624***	(0.062)		
1970-1979	0.010	(0.041)			0.547***	(0.055)		
1960-1969	0.032	(0.031)			0.432***	(0.052)		
1950-1959	-0.017	(0.058)			0.392***	(0.051)		
1900-1949	0.083**	(0.035)			0.235***	(0.058)		
Before 1900	0.068**	(0.031)						
Controls	Yes		Yes		Yes		Yes	
Regional residence	Yes		Yes		Yes			
AIC	97589.6				107284.0			
BIC	98555.8				108266.6			
Log-Likelihood	-48674.8				-53518.0			
Observations	23193				20424			

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. AB is the Bordman 10% rule, which considers an individual as poor if energy consumption $> 0.10\times$ income . MEPI is the intensity measure of energy poverty.

MEs of MEPI severity levels on life satisfaction levels

	Complete sample			Restricted sample		
	Min Level	3 Level	Max Level	Min Level	3 Level	Max Level
p1	-0.001	-0.003	-0.005	-0.001	-0.003	-0.004
p7	-0.039	-0.045	-0.047	-0.035	-0.042	-0.044
p10	-0.020	-0.012	-0.008	-0.021	-0.013	-0.009
	Richer than reference group					
p1	-0.0004	-0.001	-0.001	-0.0004	-0.001	-0.001
p7	-0.020	-0.024	-0.026	-0.018	-0.021	-0.023
p10	-0.016	-0.012	-0.010	-0.014	-0.011	-0.009
	Retired					
p1	-0.0005	-0.001	-0.002	-0.0004	-0.001	-0.002
p7	-0.028	-0.037	-0.040	-0.026	-0.035	-0.040
p10	-0.032	-0.022	-0.011	-0.035	-0.025	-0.019
	Unmarried					
p1	-0.001	-0.002	-0.003	-0.001	-0.001	-0.002
p7	-0.031	-0.037	-0.040	-0.030	-0.037	-0.040
p10	-0.022	-0.015	-0.011	-0.025	-0.017	-0.013
	Poor or Bad Health					
p1	-0.008	-0.012	-0.016	-0.007	-0.011	-0.015
p7	-0.037	-0.033	-0.030	-0.037	-0.034	-0.030
p10	-0.010	-0.006	-0.004	-0.011	-0.007	-0.005

Each reported ME yields the probability to change a given level of SWB when the MEPI is increasing by one level. Continuous variables are set at their own mean level. The restricted sample refers to the robustness specification where any observation referring to a dwelling built before 1900 is excluded. Sample size:23,193.

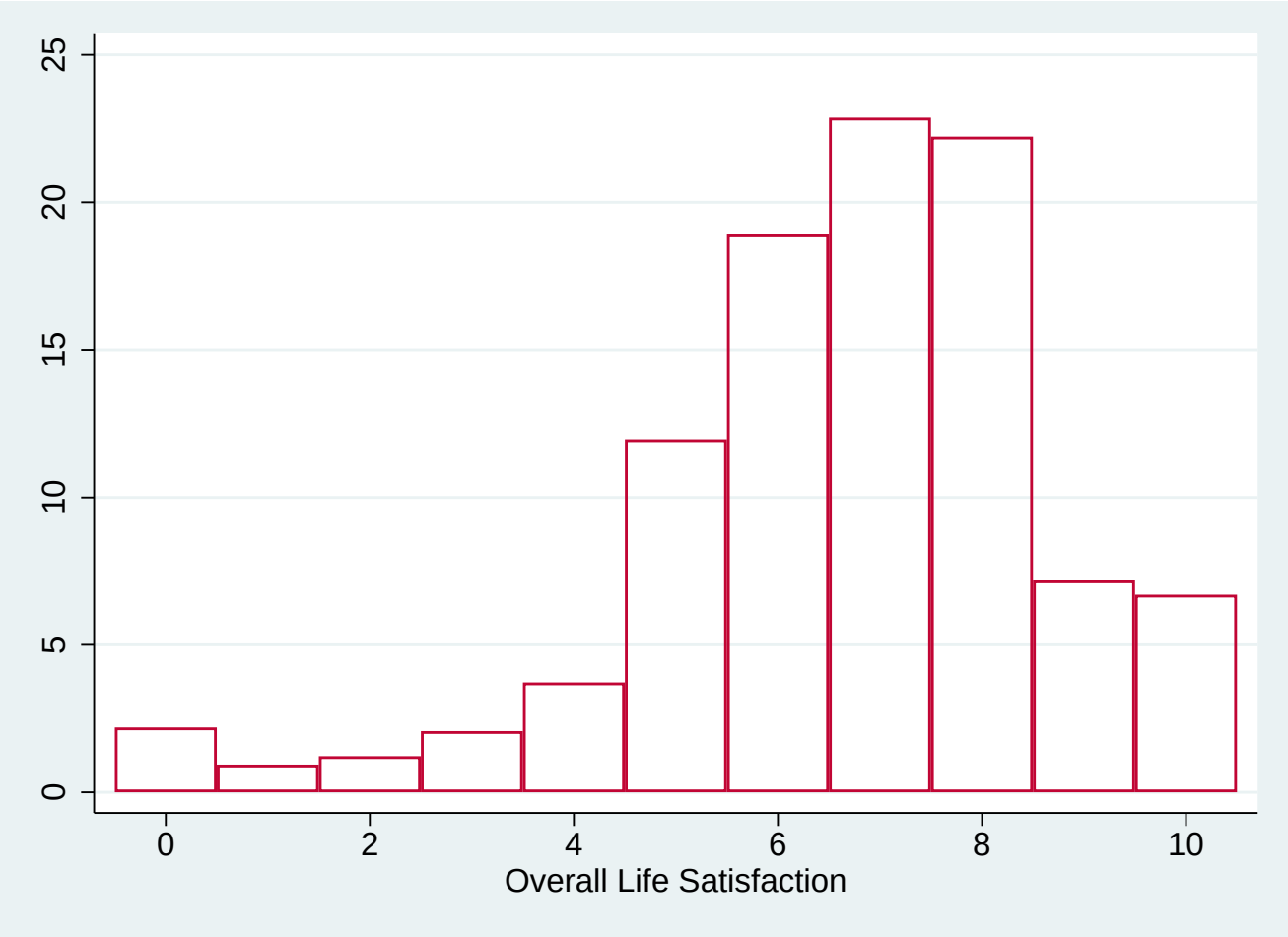
Conclusions

Analyses based on subjective perception particularly important for developed countries, in which basic needs are usually ensured

- Multidimensional measures of EP that combine objective and subjective indicators improve the targeting of energy poor.
- MEPIs can be used in econometric analyses:
  - the ordinal nature of SWB and MEPI measures can be modeled employing a bivariate ordered probit model, suitable for tackling endogeneity due to the subjective nature of WB and EP indicators.
- Using the individual-level information, the MEPI is able to detect a statistically negative relationship between EP and SWB not captured by standard affordability measures.
  - MEPIs key to identifying a large share energy poor individuals affected by EP, differently from those identified by affordability measures.
- The relationship between EP and SWB is pretty stable across different specifications and thresholds of the index.

Caveat: For the highest levels of life satisfaction, *very low sensitivity to EP* despite dwellings conditions, which represent an *objective* potentially harmful situation (impacting on health and economic productivity)

Figure – Percentage distribution of overall life satisfaction.



Graph shows the distribution of the overall satisfaction across the whole sample.
ITSILC data referring to 2013; Sample size: 23,193.

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Figure – Distribution of SWB over MEPI levels

Graph reports the distribution of the overall individual satisfaction for the different MEPI levels.
ITSILC data referring to 2013; Sample size: 23,193.

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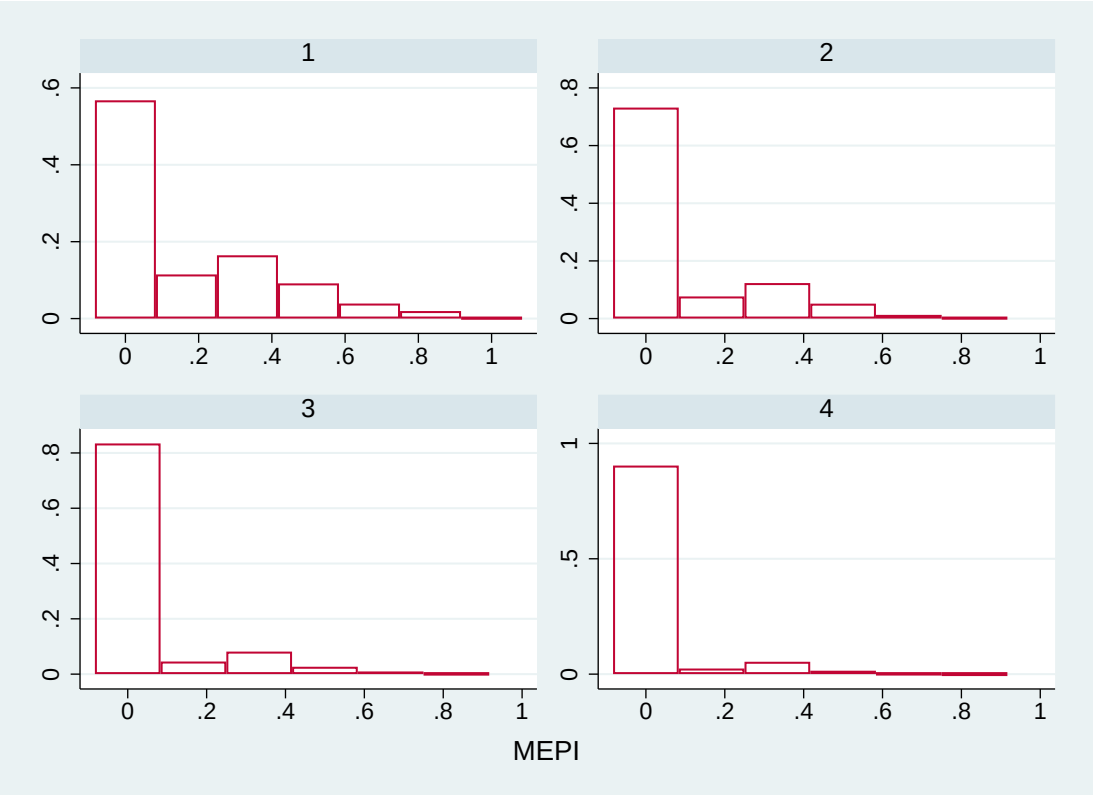
Figure – Percentage distribution of MEPI by equivalized income quartiles



MEPI is the multidimensional index of energy poverty.
ITSILC data referring to 2013; Sample size: 23,193.

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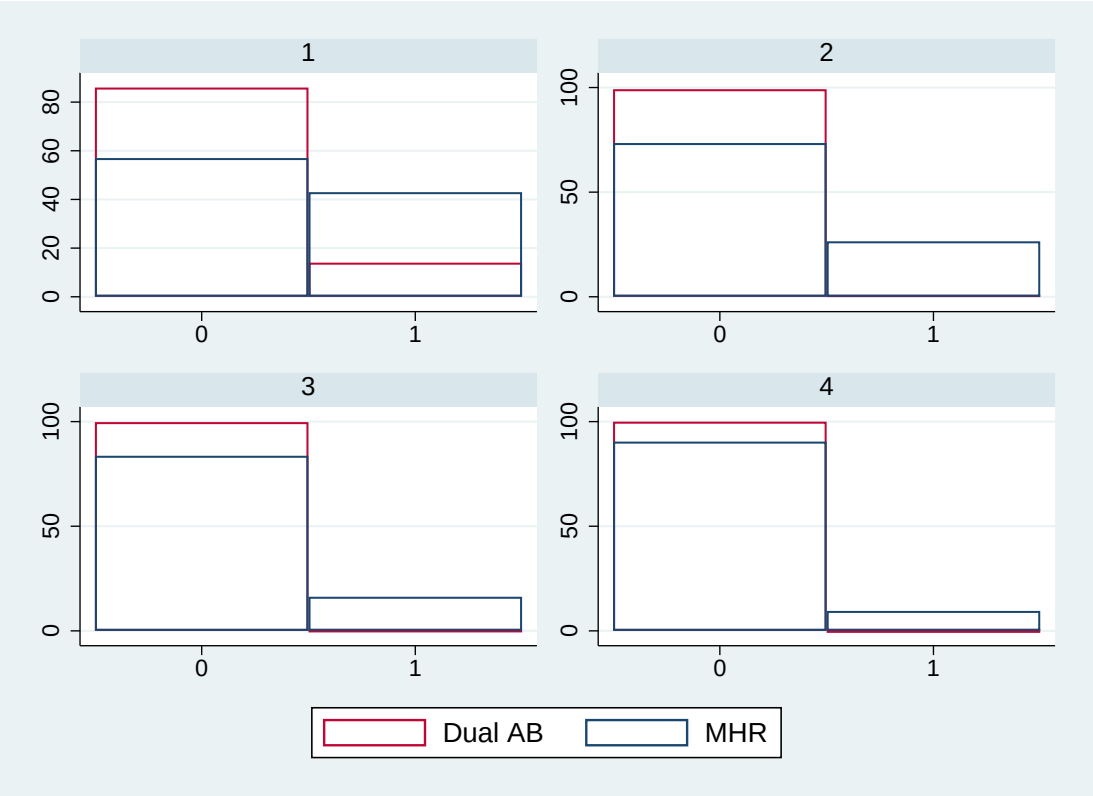
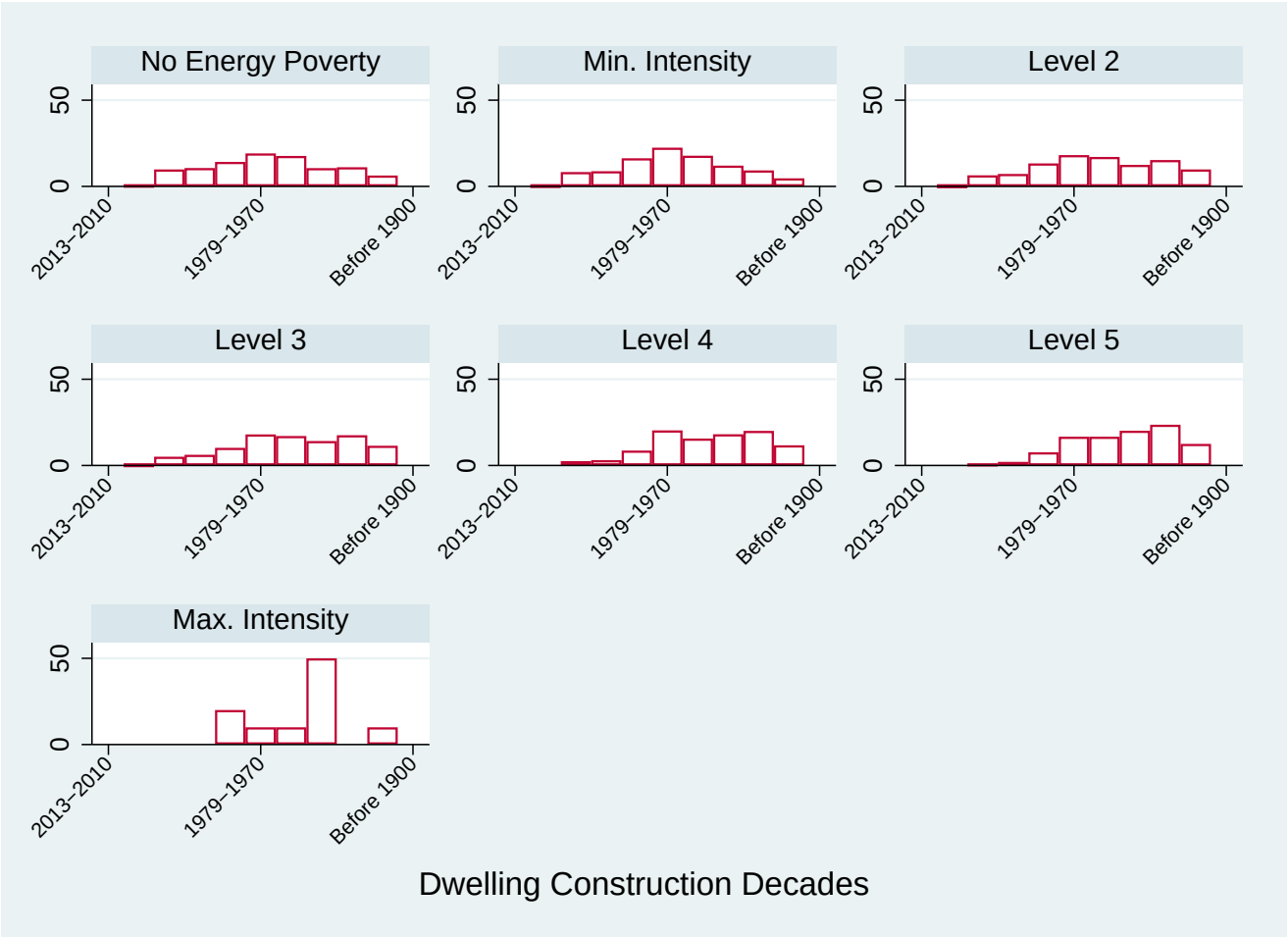
Figure – Percentage distribution of multidimensional headcount ratio (MHR) and a dual threshold affordability measure (Dual AB) by equivalized income quartiles



Dual AB is a dual threshold affordability measure, which considers an individual as poor if at least one condition holds between electricity consumption $> 0.10\times$ income and fuel consumption $> 0.05\times$ income. MHR is the multidimensional headcount ratio
ITSILC data referring to 2013; Sample size: 23,193.

Figure – Percentage distribution of dwelling construction decades among MEPI levels (2013–before 1900)



ITSILC data referring to 2013; Sample size: 23,193.

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The bivariate ordered probit model

The two equations are jointly determined by full information maximum likelihood (Sajaia, 2008).

Main applications:

- health insurance and SAH (Bunnings and Tautchmann, 2015);
- intra-family transmission of reading skills (Kalb and van Ours, 2014);
- women's personal finance behaviour (Farrell et al, 2016)

The log-likelihood function:

$$ln\mathcal{L} = \sum_{i=1}^{N}\sum_{j=1}^{J}\sum_{k=1}^{K}\mathcal{I}(SWB_i = j, MEPI_i = k|MEPI, X)$$

$$= lnPr(SWB_i = j, MEPI_i = k)$$

where:

- $\mathcal{I}[.]$ is an indicator function
- N is the # individuals
- J is the # level of SWB
- K is the # level of $MEPI$

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	MEPI Equation		SWB Equation		Dual AB Equation		SWB Equation	
Variables	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
MEPI			-0.704***	(0.103)				
Dual AB							-0.110	(0.084)
Richer than ref. group	-0.267***	(0.024)	0.116***	(0.021)	-1.369***	(0.082)	-0.661	(0.404)
MMDI	1.478***	(0.109)	-1.099***	(0.105)	0.524***	(0.199)	-0.712*	(0.396)
Male	-0.003	(0.017)	-0.045***	(0.013)	-0.160***	(0.034)	-0.129***	(0.042)
Age	0.007*	(0.004)	-0.028***	(0.003)	-0.004	(0.008)	-0.026***	(0.007)
Age2	-0.018***	(0.004)	0.027***	(0.003)	-0.001	(0.008)	0.023***	(0.008)
Unemployed	0.247***	(0.033)	-0.411***	(0.034)	0.494***	(0.056)	-0.080	(0.224)
Self-employed	-0.074**	(0.036)	-0.071***	(0.023)	0.377***	(0.059)	0.161	(0.121)
Retired	-0.051*	(0.029)	0.017	(0.022)	-0.081	(0.055)	-0.028	(0.044)
Pre-Primary	0.600***	(0.069)	-0.253***	(0.065)	0.704***	(0.132)	0.152	(0.268)
Primary	0.549***	(0.048)	-0.201***	(0.042)	0.578***	(0.091)	0.128	(0.212)
Low-Secondary	0.430***	(0.041)	-0.193***	(0.032)	0.437***	(0.075)	0.064	(0.168)
Upper-Secondary	0.182***	(0.039)	-0.112***	(0.022)	0.278***	(0.071)	0.057	(0.106)
Post-Secondary	0.170**	(0.067)	0.005	(0.041)	0.333***	(0.118)	0.186	(0.119)
Married	-0.061*	(0.033)	0.205***	(0.023)	-0.222***	(0.063)	0.044	(0.112)
Separeted	0.079	(0.052)	-0.162***	(0.041)	0.353***	(0.084)	0.064	(0.137)
Divorced	0.112*	(0.060)	-0.081*	(0.043)	0.275***	(0.098)	0.081	(0.110)
Widowed	0.045	(0.043)	-0.046	(0.033)	0.197**	(0.081)	0.071	(0.080)
Children	-0.014	(0.035)	0.143***	(0.022)	-0.058	(0.059)	0.082	(0.059)
Good Health	0.143***	(0.038)	-0.223***	(0.027)	0.023	(0.065)	-0.179***	(0.067)
Fair Health	0.450***	(0.042)	-0.520***	(0.039)	0.034	(0.075)	-0.438***	(0.127)
Poor	0.620***	(0.048)	-0.870***	(0.050)	0.038	(0.089)	-0.740***	(0.197)
Very Bad Health	0.879***	(0.067)	-1.193***	(0.079)	0.010	(0.136)	-1.049***	(0.266)
Dwelling Quality	-0.0003***	(0.00007)	0.0001***	(0.00003)	0.0002**	(0.0001)	0.0003***	(0.00007)
Homeowner	-0.316***	(0.028)	0.090***	(0.027)	-0.218***	(0.048)	-0.024	(0.090)
No urban area	0.033	(0.032)	0.077***	(0.019)	0.183***	(0.056)	0.161***	(0.048)
N. Rooms	-0.019	(0.012)	0.037***	(0.008)	-0.030	(0.022)	0.017	(0.022)
Semi-detached	-0.118***	(0.033)	0.039*	(0.023)	-0.064	(0.056)	0.005	(0.045)
Flat-less10	-0.145***	(0.035)	0.017	(0.026)	-0.211***	(0.064)	-0.094	(0.078)
Flat-more10	-0.173***	(0.039)	-0.011	(0.028)	-0.314***	(0.070)	-0.174*	(0.102)