EQUIVALENCE SCALES FOR THE DISTRIBUTION OF CONSUMPTION EXPENDITURES IN ITALY: PROPOSED METHODS TO UPDATE THE CARBONARO SCALE

Andrea Cutillo, Alessandro Romeo, Livia Celardo

Abstract. Comparing the well-being of different households requires knowledge not only of the resources available to them, but also of their needs. This seems to be possible, albeit with some effort and approximation, by defining an equivalence coefficient that indicates, using a reference household, how much a family with different characteristics needs to enjoy the same standard of living. Equivalence scales are typically used to make the expenditure of households of different size and composition comparable. In this paper, using data from the 2017-2019 Italian Household Budget Survey (IHBS), we propose an equivalence scale calculated using a simple method based on recent improvements in absolute poverty methodology. To validate our analysis, we compared the results with the original Carbonaro scale calculated in 1985, a version of the Carbonaro scale updated using the 2017-2019 HBS data, and scales calculated using complete household demand systems. Finally, we present a simple and intuitive method to assess which of these scales performs better in the Italian economic context. Preliminary results suggest that the Carbonaro scale, as originally constructed, is now outdated and needs to be revised. On the contrary, the proposed approach of using absolute poverty thresholds as a proxy for essential expenditure seems to provide encouraging results, especially in the light of the evolution of the Italian socio-economic context and the relationship that must exist between absolute and relative poverty.

1. Introduction

Comparing household welfare necessitates knowledge of their resources and needs. This is approximated by defining an equivalence coefficient indicating how much a family with different characteristics requires to enjoying the same living standard as a reference family. Equivalence scales offer parameters for comparing expenditure or income levels, accounting for economies of scale deriving from sharing expenditures. They are a key tool in welfare analysis, addressing income and consumption distributions, inequality and poverty (Buhmann et al., 1988; Deaton and Zaidi, 2002).

Deaton and Zaidi (2002) identify three main approaches for calculating equivalence scales: the subjective approach, which relies on household surveys; the normative approach, where institutions set scales based on objective assumptions; and the behavioural or utility-based approach, which analyses household consumption expenditure patterns. The subjective approach is generally seen as unsuitable for welfare analysis due to difficulties in designing effective surveys. The normative approach, such as the OECD modified scale, facilitates international comparisons but may not fully adapt to different socio-economic contexts. The behavioural approach appears more appropriate, expecially in country-specific studies, though it relies on assumptions that can be hard to verify and presents econometric challenges (Blundell and Lewbel 1991; Dudel et al., 2021). Importantly, inequality measures are highly sensitive to the equivalence scale used (Ferreira and Ravallion, 2011).

In Italy, the National Institute of Statistics (Istat) uses two equivalence scales: the modified OECD scale for calculating equivalent incomes and the At Risk of Poverty indicator, and the Carbonaro scale (Carbonaro, 1985), used for equivalent consumption expenditure and the Relative Poverty indicator. The Carbonaro scale, based on Engel's behavioural approach, adjusts expenditures according to household size. After the 2022 revision of Italy’s absolute poverty methodology, Istat is considering updating its relative poverty methodology, as the Carbonaro scale may no longer reflect the current socio-economic environment.

Preliminary findings suggest that the Carbonaro scale’s validity is declining. Even when updated with current data, the method - using food expenses as a proxy for essential needs - seems increasingly unsuitable in modern Italy. Methods based on complete demand systems have also shown unsatisfactory results, raising questions about whether well-being should be measured using only essential expenses or all types of expenditures. These methods also fail to clarify the best point in the expenditure distribution for calculating scale coefficients. In contrast, a modified Engelian approach, which builds on but diverges from the Carbonaro model, shows promising results. This approach uses absolute poverty thresholds as proxies for essential expenses, as they represent exactly the minimum expenditure required to avoid severe social exclusion in Italy today.

The paper proceeds as follows: Section 2 defines equivalence scales and their plausibility criteria. Section 3 outlines the methods compared. Section 4 presents results and discusses scale plausibility. Section 5 introduces a simple empirical method for selecting the most suitable scale. Section 6 concludes.

2. General definition of equivalence scale and plausibility of the scales

Let $\mathbf{z} = (z_1, \ldots, z_k)$ denote k household characteristics. All households can choose between m goods with prices captured in $\mathbf{p} = (p_1, \ldots, p_m)$. Household demand is then given by the demand function $D(p, y, z) = \mathbf{q} = (q_1, \ldots, q_m)$, where q_i is the demand for good i and y is household income. Household utility is given by $U(\mathbf{q}, z)$. The expenditure function can be defined by $E(u, \boldsymbol{p}, \boldsymbol{z}) = \min_q [\mathbf{p'q} | U(\mathbf{q}, z) = u]$. Then, household equivalence scales are defined as:

$$S(u, \boldsymbol{p}, \boldsymbol{z}_h, \boldsymbol{z}_r) = \frac{E(u,\boldsymbol{p},\boldsymbol{z}_h)}{E(u,\boldsymbol{p},\boldsymbol{z}_r)} \tag{1}$$

where $\boldsymbol{z}_h$ and $\boldsymbol{z}_r$ are the household characteristics of two different households h and r. Therefore, an equivalence scale is a function that calculates the ratio of expenditures between two households, with different compositions but the same level of utility and facing identical prices. According to the literature, several criteria have been proposed for assessing approaches for equivalence scale estimation by the resulting scale values, mainly based on empirical regularities.

We assume that the equivalence scales only depend on household size n, such that they can be written as $S(u, \boldsymbol{p}, n)$. Following Dudel et al. (2021) the criteria are:

$$S(u, \boldsymbol{p}, n+1) > S(u, \boldsymbol{p}, n), \tag{2}$$

$$S(u, \boldsymbol{p}, n+1) \leq S(u, \boldsymbol{p}, n) + 1, \tag{3}$$

$$S(u, \boldsymbol{p}, n+i+1) - S(u, \boldsymbol{p}, n+i) \leq S(u, \boldsymbol{p}, n+i) - S(u, \boldsymbol{p}, n+i-1). \tag{4}$$

Criterion (2) states that equivalence scales must be strictly increasing functions of household size, based on the assumption that each additional household member incurs costs. Criterion (3) posits that the effect of the household size must be no greater than one, due to economies of scale. Criterion (4) states that the increase in scale should diminish or at least remain constant with household size.

3. The scales under different approaches

- MODEL 1 - Engel's approach: the Carbonaro scale

The Carbonaro scale is a behavioural approach that reflects consumer behavior in Italy, following Engel's (1895) method of using household expenditure to assess welfare. Engel's approach suggests that the share of household expenditure on essential goods varies by household type and decreases as income rises. According to this theory, two households have comparable well-being if they spend the same proportion of their total expenditure on basic goods. As household size increases, expenditure on essentials grows, requiring a higher total expenditure to maintain the same ratio. Equivalence scales are derived by comparing the expenditures of different household types that allocate the same share of their budget to essential goods. Starting from the beginning, essential goods were associated with food expenditures, so much so that Engel's approach was often referred to as the Engel food ratio method. So did Carbonaro, who employed a double logarithmic function to model the Engel curve for food expenditure:

$$logA = a + blogY + clogN + u\ , \tag{5}$$

where *A* is the food expenditure of the generic household *i*, *Y* is the total consumption and *N* is the household size, while b and c are, respectively, the regression coefficients of total expenditure and household size in logarithmic form. Deriving with respect to the number of members, and equating the elasticity with respect to the number of members of total expenditure to the one of food expenditure (in order to keep the food ratio constant), the elasticity is found:

$$e = \frac{\delta(logY)}{\delta(logn)} = \frac{c}{1-b}. \tag{6}$$

Using data for the period 1981-1983, the Carbonaro scale was calculated on the basis of the elasticity obtained (e = 0.67). Moving from the constant elasticity to the equivalence coefficients, setting the scale coefficient for a household with a size equal to one as the reference (k_1=1), the scale for households with a larger size is:

$$K_{N+1} = K_N(1 + \frac{e}{N}). \tag{7}$$

- *MODEL 2 - Engel's approach: the absolute poverty threshold as a proxy of essential expenditures*

The basic idea of Engel's method is that essential goods are necessities, where consumer choice is very limited. While food expenses were initially identified as essential expenditures, today's socio-economic context. Carbonaro himself addressed this issue in 1985. However, even if other essential expenses like clothing and housing are considered alongside food, another challenge remains. The cost of these essentials can vary based on household preferences and available resources; for instance, fulfilling the need for clothing may involve purchasing more items and/or opting for higher-cost clothing, involving discretionary spending.

The methodology of absolute poverty thresholds (Istat, 2009; Cutillo et al., 2022), calculates poverty thresholds as the monetary value of a basket of goods and services deemed essential. This basket includes not only food but also housing costs, and a residual category covering clothing, education, health, mobility, information, and communication needs. Absolute poverty thresholds are determined based on the minimum costs required to meet essential needs, both in terms of necessities and the lowest market prices available. Therefore, these thresholds accurately represent the expenditure necessary for households to meet their basic needs. In other words, they are exactly what was previously measured by the proxy variable food expenditure.

This approach aligns with Engel's theory, where households allocate their income first to meet minimum essential needs, and after this threshold consider discretionary spending. For example, once the threshold is met, households might choose higher-quality food, greater heating in the home, purchasing branded clothing, and so forth.

Thus, we estimate the same equation as in (1), substituting food expenditure with the absolute poverty thresholds, which are specific to each type of household. Indeed, the thresholds vary by region, type of municipality, and the number and age of household members. Since the threshold is exogenous to survey data, its share relative to household expenditures can exceed 1 for all households in absolute poverty. This contrasts with food expenditure, which inherently does not pose this issue. It would be appropriate to exclude absolute poor households, as they do not even meet a minimal standard of well-being. However, empirical results are largely consistent, and we include the entire sample in this initial analysis to ensure comparability under the same conditions. This is also why we employ the original formulation of Carbonaro as presented in equation (1), despite other functional forms (e.g., Carbonaro, 1991; Deaton and Muellbauer, 1986; De Santis, 1996):

$$logT_i = a + blogY_i + clogN_i + u_i \ , \tag{8}$$

where *T* represents the absolute poverty line for the generic household *i* and the other letters have the same meaning as in equation (5). It can be seen that, with the exception of the dependent variable, the model is the same as equation (5) and therefore equations (6) and (7) are still valid for calculating elasticity and scale.

- *MODEL 3 - Engel's approach: absolute poverty threshold as a proxy of essential expenditures with territorial controls and non-constant elasticity*

The model in equation (4) is modified in order to take into account two aspects related to the number of components. First, a number of territorial variables in dichotomous form are added in order to control for the different distribution of households by size between different regions and different types of municipality:

$$logT_i = a + blogY_i + clogN_i + \sum_j d_j K_{ji} + u_i \ , \tag{9}$$

where K_{ji} is equal to 1 if the generic household *i* resides in the generic territory *j* (given by the interaction between region and type of municipality) and 0 otherwise.

Secondly, we allow the elasticity not to be constant as the number of components changes, but to be differentiated as the number of components varies[1].

- *MODEL 4 - A complete demand system: the Stone-Gary approach*

The Linear Expenditure System (LES) proposed by Stone (1954) is the first expenditure system based not on a single equation, but on a system of equations,

[1] We run the same regression in pairs of numbers of components (e.g. one and two components; two and three components; and so on). Other forms could be used (e.g. De Santis, 1996, p. 46) but for the sake of comparison in this step of the analysis, we prefer to use equations as similar as possible to the one in Carbonaro (1985).

each of which covers expenditures for one of the *m* goods (in our case, the Coicop divisions of expenditures). Starting from the Stone-Geary utility function:

$$X_i = p_i a_i + b_i\left(X - \sum_{j=1}^{n} p_j\, a_j\right) \tag{10}$$

with *X* denoting total expenditures, X_i expenditure on good *i; $p_i a_i$* being interpreted as the minimum expenditure on good *i* (prices by quantities); and b_i being the marginal budget share of good *i* , with the restriction that $\sum b_i = 1$. The system of equations can be estimated for each household type (Deaton 1975), whereby we set prices equal to one as a common practices in the literature (e.g. Dudel et al., 2021). The unit values of the scale *S* can then be estimated as follows:

$$S = \frac{\sum_{i=1}^{m} a_i^h}{\sum_{i=1}^{m} a_i^r} \tag{11}$$

where a_i^r is the reference household's minimum expenditure on good *i* facing prices *p* (set to one in our case) for good *i*; a_i^h is thus the comparison household's minimum expenditure on good *i*. The core idea of the model is that household expenditure on the good *i* depends on a minimum expenditure component (the constant term a_i) plus a fixed proportion of the supernumerary expenditure (the term in brackets in equation (10)). In this context, the scale is determined by the ratio of the sum of minimum expenditures between the household type *h* and the reference household *r*. Last, we estimated the parameters of interest non-linearly and we further added to equation (10) a quadratic term of the supernumerary expenditure to count for non-linearity of the Engel curves (Howe et al., 1979; Dudel et al., 2021).

- *MODEL 5 - A complete demand system: the quadratic almost ideal demand system*

The Almost Ideal (AI) demand system was first developed by Deaton and Muellbauer (1980) and it became very popular in the economic literature to measure household consumption behavior relative to change in commodity prices. Starting from the price-independent generalized logarithmic (PigLog) class of preferences and formalizing as in Ray (1983) in order to estimate equivalence scale:

$$w_i = a_i + \sum_{j=1}^{m} \gamma_{ij}\, log p_j + b_i^* \log\left(\frac{X}{SP}\right) \tag{12}$$

where w_i is the expenditure share for good *i*; a_i is a constant term. γ_{ij} represents the effect of a change in the price of commodity *j* on the share of expenditures on commodity *i*; $b_i^* = b_i + \eta_i d_h$, where b_i is the marginal effect of log expenditure and d_h is a dummy variable indicating the respective household type relative to the reference household; P is a price deflator for expenditure[2]; S is the unit value of the equivalence scale for each household type relative to the reference household ($S = 1 + \rho d_h$, where ρ measures the needs of the comparison household relative to the needs of the reference household). The sum of η_i and b_i gives the expenditure elasticity of each household type relative the comparison household. The parameters of the model can be estimated non-linearly also adding a quadratic term (Banks et al., 1997), thus coming up with a Quadratic Almost Ideal (QAI) demand system.

4. The results

The findings presented in this section are derived from pooling data from three consecutive years: 2017, 2018, and 2019[3]. Initially, we compute an updated Carbonaro scale using the same methodology (MODEL 1). Compared to the original model, we observe a substantial increase in the elasticity of consumption relative to household size (from 0.67 to 0.87), resulting in equivalence scale values detailed in Table 1 (with a two-person household serving as the reference) which entail a decrease of the economies of scale over the years for larger households.

However, these outcomes starkly contrast with observed trends in Italian consumer spending over recent decades, as also noted by the Inter Institution Scientific Commission on Absolute Poverty. Specifically, there has been an increase in economies of scale for larger families, particularly in three areas. Food expenditure (facilitated by the widespread availability of large-scale distribution, which allows large families to buy large packages at lower unit prices). Rent and imputed rent costs (with a significant increase in the cost per square metre of smaller dwellings compared to larger ones). Energy expenditure (due to system charges on bills, which have shifted from variable consumption-based to fixed costs).

The obtained results suggest that the original Carbonaro scale is no longer suitable for the contemporary Italian context. First, under consistent methodology, the results differ significantly. Second, these divergent outcomes cannot be justified based on prior findings. It appears plausible that food expenditure, particularly in an advanced socio-economic context such as Italy nowadays, may no longer serve as the most appropriate proxy for defining household essential needs.

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[2] The deflator P is obtained by setting a constant term and adding-up price products of different commodities. A formalized analysis of the deflator can be found in Deaton and Muellbauer (1980).

[3] As in the previous methodology, we used a pooled sample of three years (2017, 2018 and 2019) to obtain more robust estimates. Expenditure in 2020 and 2021 is distorted by the health emergency, which caused all expenditure categories except food and housing to fall, and 2022 was a year of very high inflation due to the economic recovery and the Russia-Ukraine war.

Table 1 – *Equivalence scales by different methods*.

Household size	Method					
	Carbonaro	Carbonaro updated	Absolute threshold without territorial controls and with constant elasticity	Absolute threshold with territorial controls and without constant elasticity	Stone-Geary	Quaids
1	0.60	0.53	0.67	0.69	0.70	0.87
2	1.00	1.00	1.00	1.00	1.00	1.00
3	1.33	1.44	1.25	1.29	1.17	1.15
4	1.63	1.86	1.45	1.55	1.34	1.21
5	1.91	2.27	1.63	1.78		
6	2.16	2.67	1.79	2.00	1.45	1.27
7+	2.40	3.07	1.94	2.24		
Relative poverty (%)	11.5	13.1	10.7	11.9	14.1	12.1

Before showing the results obtained through the Engel's approach based on absolute poverty thresholds (MODEL 2), some checks are necessary. First, given the same family structure, the amount of essential expenditure must increase as total expenditure increases, for all family sizes. The regression coefficient b in the equation $logT = a + bY$ is positive and statistically significant for all the different family sizes[4]. Secondly, given the same family structure, the share of essential expenses should decrease as total expenditure increases, for all family sizes. Through the equation $s_t = a + blogY$, where s_t is the share of essential expenses out of total expenses, the coefficient b is always negative and significantly different from 0.

Through this approach, the elasticity is 0.49, implying greater economies of scale for larger families, in line with the evolution of Italian society as described above[5]. Compared to the original Carbonaro scale, and using a two-person household as the reference, the coefficients now range from 0.67 for single-person to 1.94 for households with 7+ members (in the Carbonaro scale, 0.60 and 2.40 respectively).

When territorial controls are included and different elasticity with respect to component growth is allowed (MODEL 3), the scale adjusts slightly, with coefficients for larger families increasing. These values indicate that to maintain the same level of well-being, expenditure need to increase by 44.2% when moving from

[4] As the thresholds are exogenous and equal for identical households, this effect is due to territorial differentiation. The cost of living, and thus both the thresholds and household expenditure are higher in wealthier areas. From a mathematical point of view, whatever the motivation, it is important that this empirical rule is respected.

[5] Moreover, the R^2 is equal to 0.79 in respect of 0.42 when using the food expenditures.

one to two members, by 28% from two to three, by 20.4% from three to four, by 15% from four to five, by 12.4% from five to six, and by 12.2% from six to seven.

Regarding complete demand systems, estimated separately by household size, households with five or more members are grouped together. While MODEL 4 (the Stone-Gary approach) meets all the plausibility criteria outlined in Section 2, MODEL 5 (the quadratic almost ideal demand system) does not, particularly failing criterion (4) in section 2. Both scales exhibit a narrow range of values, indicating significant economies of scale, meaning that expenditure needs to increase minimally with household size to maintain the same level of well-being. Despite their theoretical validity, we argue that complete demand systems face three critical issues. First, it remains unclear whether to consider all expense types or focus solely on essential expenses when assessing a specific well-being level. Second, these systems are highly sensitive to the categorization of goods, which can vary significantly across different aggregations. Third, they fail to address a fundamental question about where to standardize welfare levels across households.

5. An empirical way to evaluate the scales

All the scales presented in the previous section, except for the Quaids (Table 1), meet the plausibility requirements outlined in Section 2. The results, however, vary significantly between scales. This variability is well-documented in the literature, as well as the fact that complete demand systems yield lower scale values than Engelian models. In evaluating the different approaches, in the previous section we considered their credibility within the socio-economic context. This section introduces a simple and empirical method to confirm or refute our choices, based on the relationship between absolute and relative poverty (based on equivalent consumption). In fact, relative poverty is a measure of inequality (Darvas, 2017), and it relies on the same rationale as the At Risk of Poverty Rate indicator on incomes. That is, also relative poverty indicates risk of poverty. It is thus expected that a significant percentage of absolute poor households are also relative poor[6]. In the 2017-2019 period, the incidence of relative poverty through the original Carbonaro scale is 11.5%, with 88.5% of absolute poor households also identified as relative poor. Using the updated Carbonaro scale (MODEL 1), the overlap decreases to 82.9%, though relative poverty rises to 13.1%, further indicating that food-ratio method is no longer valid.

Using the Engelian method based on absolute poverty thresholds (without differential elasticity and territorial controls – MODEL 2), the incidence of relative poverty is slightly lower (10.7% vs. 11.5%), and the overlap between absolute and relative poverty rises to 92.3%. When we allow the elasticity to vary with the number

[6] The overlap cannot be perfect (i.e. 100% of the absolute poor households are also relative poor), because absolute poverty thresholds differ for the cost of living in the territory, while the relative poverty threshold is single.

of household members and add territorial controls (MODEL 3), the incidence of relative poverty (11.7%) is nearly the same as the reference, and the percentage of absolute poor households who are also relative poor increases to 94.3%.

MODEL 4 shows a relative poverty incidence of 14.1%. Given the high number of households at risk of poverty, the percentage of absolute poor who are also relative poor is 92.7%, slightly lower than MODEL 3 despite the last has fewer households at risk of poverty. MODEL 5 yields a relative poverty incidence of 12.1%, but the percentage of absolute poor households at risk of poverty is notably low at 88.4%.

These results further support our choice to use an Engelian model with absolute poverty thresholds as a proxy for essential expenditure.

6. Discussion and conclusions

After the 2022 revision of the methodology for calculating absolute poverty in Italy, Istat is considering refining relative poverty measures by updating the Carbonaro scale (1985), which dates back to the 1980s and may no longer be in line with the current Italian economic system. In this paper, we have presented preliminary results by comparing different scales. In our considerations, we use both theoretical issues and empirical evaluations, also supported by a simple and intuitive method. Equivalence scales are used to calculate the incidence of relative poverty, an inequality indicator that identifies households at risk of poverty. It is expected that households that are poor in an absolute sense are also poor in a relative sense.

Our results suggest that Carbonaro scale is less and less suitable for today's Italy for two main reasons. First, new estimation with recent data produces different results. Second, the new estimates indicate a decrease in economies of scale over time for larger households, contradicting the trends observed in Italians' consumption expenditure in recent decades, as noted by the Inter Institution Scientific Commission on Absolute Poverty. In particular, economies of scale have increased for large households, especially for food, energy and rent expenditure.

Following an Engelian approach, we calculated equivalence scales using the absolute poverty methodology and its recent improvements. Absolute poverty thresholds represent the minimum monetary value of essential goods and services needed to avoid severe social exclusion, which goes beyond food and includes housing, clothing, education, health, mobility and communication. Calculated at minimum cost, these thresholds accurately reflect the expenditure required by households to meet essential needs, i.e. what was previously measured by the proxy variable food expenditure. The use of poverty thresholds has a double advantage. Firstly, the goods and services considered do not only include food, and thus seem to be better suited to the basic needs in an advanced socio-economic context. Furthermore, being calculated at the lowest affordable cost eliminates potential bias resulting from household preferences even in the purchase of essential goods.

The results of the Engelian scale based on absolute poverty thresholds outperform those of the updated Carbonaro scale, showing greater economies of scale for large households. Our model adjustments address regional disparities and different household composition, improving accuracy. In particular, the differentiated elasticity by household size maximises the overlap between households in absolute poverty and those at risk of poverty.

Scales based on complete demand systems have performed poorly for several reasons. Theoretical concerns include uncertainties about the inclusion of all or only essential expenditure and the inability to standardise welfare levels across households. Empirically, these systems do not meet the plausibility criteria of the equivalence scale, are sensitive to the choice of expenditure categories considered and show a low overlap between absolute and relative poverty.

Future research will prioritise the Engelian model, which ensures a consistent welfare level assumption based on equal allocation of expenditure to essential goods across different households. Ongoing considerations include refining the age scale, determining the inclusion or exclusion of households that are too poor (that do not even reach a minimum level of welfare) or too rich (that cannot be considered representative of the majority of the distribution) and exploring quadratic forms of the Engel curve. The latter point is relevant since the quadratic form implies that the elasticity depends on the level of expenditure itself, an issue that violates the income-independence assumption of Engel's model, but which can be resolved with some assumptions and simplifications.

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Andrea CUTILLO, Istat, cutillo@istat.it
Alessandro ROMEO, Istat, alessandro.romeo@istat.it
Livia CELARDO, Istat, livia.celardo@istat.it