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# Construction of an adaptable European transnational ecological deprivation index: the French version

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## ABSTRACT

**Background** Studying social disparities in health implies the ability to measure them accurately, to compare them between different areas or countries and to follow trends over time. This study proposes a method for constructing a French European deprivation index, which will be replicable in several European countries and is related to an individual deprivation indicator constructed from a European survey specifically designed to study deprivation.

**Methods and Results** Using individual data from the European Union Statistics on Income and Living Conditions survey, goods/services indicated by individuals as being fundamental needs, the lack of which reflect deprivation, were selected. From this definition, which is specific to a cultural context, an individual deprivation indicator was constructed by selecting fundamental needs associated both with objective and subjective poverty. Next, the authors selected among variables available both in the European Union Statistics on Income and Living Conditions survey and French national census those best reflecting individual experience of deprivation using multivariate logistic regression. An ecological measure of deprivation was provided for all the smallest French geographical units. Preliminary validation showed a higher association between the French European Deprivation Index (EDI) score and both income and education than the Townsend index, partly ensuring its ability to measure individual socioeconomic status.

**Conclusion** This index, which is specific to a particular cultural and social policy context, could be replicated in 25 other European countries, thereby allowing European comparisons. EDI could also be reproducible over time. EDI could prove to be a relevant tool in evidence-based policy-making for measuring and reducing social disparities in health issues and even outside the medical domain.

Studies on social disparities in health have gained interest in many European countries since the 1980s.<sup>1–3</sup> Evidence-based policy-making for reducing social disparities in health implies the ability to measure them accurately, to compare them between different areas or countries and to follow trends over time. A wide range of approaches exists for measuring socioeconomic status. Deprivation is a 'state of observable and demonstrable disadvantage relative to the local community or the wider society to which an individual, family or group belongs'.<sup>4</sup> As stated by Townsend,<sup>4</sup> 'the concept of deprivation covers the various conditions, independent of income, experienced by people who are poor'. Therefore, deprivation is a vast concept, closely linked with poverty.

Ecological deprivation indices have essentially been developed pragmatically from census data, which include a number of variables reflecting socioeconomic position with regard to the surrounding population.<sup>5</sup> The first and the most well-known census-based indices, the Carstairs and Townsend indices, were developed in the UK in the early 1970s and depend on the non-weighted sum of four socioeconomic variables, and other deprivation indices have been developed mainly in Europe and North America.<sup>4 6–16</sup> Whatever the method used for selecting and weighting components of these indices, ie, health expert opinion, principal component analysis, factor analysis, or more recently Bayesian factor analysis, these 'census-based' indices use variables of residential areas to obtain an ecological deprivation index, which is used as a 'proxy' of individual deprivation measure without referring to individual deprivation experience.

Our approach is rather different and relies mainly on the concept of perceived fundamental needs or necessities of life. This conceptual definition of deprivation, which is based on the population's own perception, is also the basis for the construction methodology of 'survey-based' British indices.<sup>17 18</sup> This methodology derives an individual deprivation indicator from the conceptual definition of deprivation, and selects ecological variables from censuses that are the most closely related to the individual deprivation indicator. This concept involves the use of surveys specifically designed to study deprivation at the individual level in order to investigate the multidimensionality of deprivation.

We propose a slightly modified methodology resulting in an 'adaptable transnational index' by using a European survey specifically designed to study deprivation. The basis of our approach is that the experience of being deprived in a community is widely shared in any culture or country. In contrast, this experience is related to various practical mechanisms in different cultures or countries. We propose a method of selecting a combination of variables that are available both at an individual level in a European survey and at a geographical level in a national census, and that best reflect individual experience of deprivation. As the same theoretical concept is explored, this ecological index should be well suited for different contexts while offering the possibility to compare different countries, even if the variables may vary from one country to another.

In summary, this paper describes a method for constructing a country-specific ecological deprivation index that best reflects individual experience of



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deprivation by using a European survey, and which allows European comparative studies to be performed. For practical purposes and for clarity, we constructed 'step by step' the French version of this European adaptable transnational index for use at the smallest geographical unit available.

## METHODS AND RESULTS

### Summary of the method

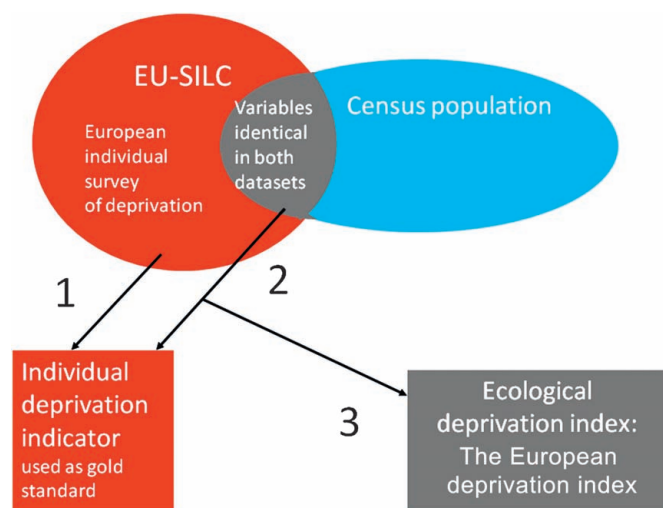
The construction of this European transnational ecological deprivation index involved three major steps (figure 1):

1. Construction of an individual deprivation indicator.
  - 1.1. Identification of people's fundamental needs by using a European survey specifically designed to study deprivation, because no gold standard of deprivation exists.
  - 1.2. Selection of fundamental needs that were associated with both objective and subjective poverty, because deprivation is not only determined by income.
  - 1.3. Definition of a binary individual deprivation indicator from these fundamental needs associated with both objective and subjective poverty.
2. Identification and dichotomisation of variables available both at an individual level (French European Union—Statistics on Income and Living Conditions; EU—SILC) and in census, these variables having to be phrased and coded in the same way in both the census population and the EU—SILC survey.
3. Construction of an ecological deprivation index, the European deprivation index (EDI).

3.1. Selection and weighting of those variables associated with the individual deprivation indicator using multivariate logistic regression.

3.2. Ecological step: the regression coefficients associated with these variables in the final model become the weights of these variables measured at the aggregated level in the ecological index.

A preliminary validation was conducted in order to assess the accuracy of EDI to measure individual deprivation, because an ecological deprivation index used as a 'proxy' of individual socioeconomic status is valid for a territory if this index correctly classifies persons into deprived areas. As addresses of respon-



**Figure 1** Steps involved in constructing the European deprivation index (EDI). In red: individual data from the EU—SILC survey. In blue: ecological data from the census population. In grey: variables available both at an individual and ecological level; EDI is composed of ecological variables related to an individual deprivation indicator. EU—SILC, European Union—Statistics on Income and Living Conditions.

dents of the EU—SILC survey were not available to geocode them and to attribute to them a score of EDI, data from a postal survey were used. We compared the degree of association between the score of EDI and two validation criteria measured at an individual level: income and education, and between the score of the Townsend index and these two individual validation criteria.

### Data sources

#### Data for construction process

In steps 1 and 3.1, data were drawn from the EU—SILC survey, in particular from its French version, the French EU—SILC survey conducted in 2006 (10 036 households, 24 940 individuals, 19 253 aged 16 years or over). The EU—SILC survey organised by Eurostat (the European Commission's statistical office) is based on a standardised questionnaire involving annual interviewing of a representative panel of households and individuals (60 500 households and approximately 130 000 individuals aged 16 years or more). It is designed to study deprivation and covers a wide range of domains such as income (including various social benefits), health, education, housing, demographics and employment characteristics (Eurostat website: [http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/eu\\_silc](http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/eu_silc)).

For each European country, the sum of weights for the sample design and the response rate to a national questionnaire tallies with the national population size. All analyses in steps 1 and 3 were weighted for non-response and adjusted on the sample design of the French EU—SILC survey, so that the representativeness of the results for the whole French territory was ensured.

In step 2, no statistical analyses were performed; only labels of questions phrased and coded in the same way in both the census population and the EU—SILC survey were used.

In step 3.2, ecological data at the IRIS (or regrouped statistical information blocks) level were drawn from the last exhaustive French census carried out in 1999 by the National Institute for Statistics and Economic Studies (INSEE). The geographical units used were IRIS as defined by INSEE, an IRIS representing the smallest geographical census unit available in France. The regional capital and other major towns are divided into several IRIS and small towns form one IRIS (INSEE website: <http://www.insee.fr>). Each French residential IRIS includes approximately 2000 individuals with relatively homogeneous social characteristics (N=49 989).

#### Data for preliminary validation

Individual-level data were drawn from an ongoing postal survey. This survey investigated the influence of social level at the individual scale on access to care in persons diagnosed with breast and colorectal cancer at age 50 years and over between 1 January 2005 and 31 December 2008 in a French department, Calvados. All 2635 patients meeting these inclusion criteria and registered in the Calvados cancer registries received a questionnaire covering several socioeconomic domains such as income, education and employment. Among the 1262 respondents (48%), 1248 persons were correctly attributed an IRIS thanks to the availability of an exact address, 77.2% being women because of the diagnosis of a cancerous site.

### Construction process

#### Construction of an individual deprivation indicator

##### *Identification of people's fundamental needs by using a European survey specifically designed to study deprivation*

As no gold standard of deprivation exists, we investigated how individuals in a given society define deprivation based on what

they considered necessary in a specific cultural context. In the EU–SILC survey, individuals were asked to indicate whether their household possessed certain goods or utilised certain services. For goods/services they did not possess/utilise they indicated whether this was because they could not afford them or for other reasons. Goods/services that a minority, ie, fewer than 50% of households did not possess/utilise because they could not afford them, in other words by renunciation and not by choice, were considered as fundamental needs and were consequently retained.<sup>17 18</sup>

For example, 95% of French households could not afford a swimming pool. ‘Having a swimming-pool’ was consequently not considered as a fundamental need, its non-possession not reflecting deprivation. In contrast, 7% of French households could not afford to eat meat or fish or a vegetarian equivalent once every 2 days. ‘Eating meat or fish or a vegetarian equivalent once every 2 days’ was therefore considered as a fundamental need, its non-realisation reflecting deprivation.

In the French EU–SILC survey, 19 goods/services were indicated by a minority (fewer than 50%) of households as not within their means, so they were considered as fundamental needs (table 1).

#### *Selection of fundamental needs that were associated both with objective and subjective poverty*

As the concept of deprivation is not only determined by income, we selected fundamental needs associated with both objective and subjective poverty.<sup>4</sup> Three independent poverty variables are

**Table 1** Fundamental needs for people: goods/services indicated by a minority of households (<50%) that they were not within their means, French EU–SILC survey 2006 (N=10 036)\*

Fundamental needs for people	Proportion of households who indicated that certain goods/services were not within their means, %*
Using your own means to cover a necessary yet unplanned expense of €800	34.1
Replacing worn-out furniture	32.7
Taking a week’s annual holiday away from home	32.4
Buying new clothes	11.8
Having friends/family for a drink or a meal at least once a month	10.0
Offering presents to family or to friends at least once a year	9.4
Having a computer	8.2
Having two pairs of shoes (for each adult in the household)	7.4
Eating a meal containing some meat or some fish or the vegetarian equivalent once every 2 days	6.7
Keeping your house sufficiently warm	6.7
Having a car	4.6
Spending a day with at least one complete meal over the past 2 weeks	2.9
Having a video recorder or DVD reader	2.8
Having a freezer	2.4
Having a washing machine	1.4
Having a microwave oven	1.3
Having a phone (including a mobile phone)	0.9
Having a colour TV	0.4
Having a refrigerator	0.1

\*Data weighted on non-response and adjusted on sample design of the French EU–SILC survey 2006.  
EU–SILC, European Union–Statistics on Income and Living Conditions.

available in the EU–SILC, one representing objective poverty and two representing subjective poverty.

To select fundamental needs associated with objective and subjective poverty using logistic regression models, we applied the following rules to dichotomise objective poverty and the two subjective poverties.

Objective poverty is represented by low income. An individual is considered poor when her/his household has a standard of living below 60% of the median standard of living among the whole national population, as defined by Eurostat (Eurostat website: [http://epp.eurostat.ec.europa.eu/statistics\\_explained/index.php/Income\\_distribution\\_statistics](http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Income_distribution_statistics)). Standard of living is equal to the net income of the household divided by the number of units of consumption. Standard of living is therefore the same for all individuals living in the same household. According to this definition, 14.2% of French households were ‘poor’ in the French EU–SILC (N=1367).

Subjective poverty was assessed by ‘perceived poverty’ and ‘income judged insufficient’.

‘Perceived poverty’ was constructed from the following ordered variable included in EU–SILC: ‘At present, would you rather say that financially:

- ▶ Answer 1 “You feel totally at ease”=2.1%.
- ▶ Answer 2 “You feel somewhat at ease”=11.5%.
- ▶ Answer 3 “You are just right”=31.2%.
- ▶ Answer 4 “Your situation is a bit tight, you need to pay attention”=39.2%.
- ▶ Answer 5 “You cope but with difficulty”=13.2%.
- ▶ Answer 6 “You cannot cope without getting into debt”=2.8%.’

To determine the threshold at which a person felt ‘poor’, we determined the best fit of the relationship between objective and perceived poverty by using univariate logistic regressions. Clustering of answers 1 to 5 formed five different dichotomous independent variables. The five univariate logistic regression models with ‘objectively poor’ as the binary dependent variable were the following:

- ▶ Model 1: ‘objectively poor’=answer 1 versus answers 2–6 ( $\chi^2$  value of model=8.9).
- ▶ Model 2: ‘objectively poor’=answers 1–2 versus answers 3–6 ( $\chi^2=97.0$ ).
- ▶ Model 3: ‘objectively poor’=answers 1–3 versus answers 4–6 ( $\chi^2=222.6$ ).
- ▶ Model 4: ‘objectively poor’=answers 1–4 versus answers 5–6 ( $\chi^2=310.2$ ).
- ▶ Model 5: ‘objectively poor’=answers 1–5 versus answer 6 ( $\chi^2=247.5$ ).

The best fit, which tallies with the highest  $\chi^2$  value of the model, was obtained using model 4. According to this definition, 16.0% of French households perceived themselves as ‘poor’ (N=1572).

The second variable of subjective poverty is ‘income judged insufficient to balance household budget’, which is directly available in EU–SILC and coded: No≈‘not poor’; Yes≈‘poor’. Among all French households, 18.6% (N=1882) judged their income insufficient to balance their budget.

In all, these three definitions of poverty—objective poverty, perceived poverty and income judged insufficient—identified 14.2%, 16.0% and 18.6% of ‘poor’ households, respectively. These discordances highlight the inadequacy of objective and subjective poverty in characterising deprivation. Objective poverty of French households according to their subjective poverty (on the one hand, their perceived poverty, and on the other hand, their income judged insufficient) (table 2), and

**Table 2** Objective poverty of French households according to their subjective poverty (perceived poverty and income judged insufficient), French EU–SILC survey 2006 (N=10 036)\*

N (%)	Objective poverty		
	'Not poor' (%)	'Poor' (%)	Total (%)
Perceived poverty			
'Not poor'	7595 (74.9)	866 (9.1)	8461 (84.0)
'Poor'	1071 (10.9)	501 (5.1)	1572 (16.0)
Total	8666 (85.8)	1367 (14.2)	10033† (100)
Income judged insufficient			
'Not poor'	7328 (72.8)	813 (8.6)	8141 (81.4)
'Poor'	1332 (13.0)	550 (5.5)	1882 (18.6)
Total	8660 (85.8)	1363 (14.2)	10023‡ (100.0)

\*Data weighted on non-response and adjusted on sample design of the French EU–SILC survey 2006.

†Missing data: n=3.

‡Missing data: n=13.

EU–SILC, European Union–Statistics on Income and Living Conditions.

income judged insufficient by French households according to their perceived poverty (table 3), also revealed discordances. For example, 5.4% of French households felt 'poor' but judged their income sufficient to balance their budget. Conversely, 8.0% of French households judged their income insufficient to balance their budget but did not feel 'poor' (table 3).

Fundamental needs associated with both objective and subjective poverty were selected by multivariate logistic regressions. To avoid affording greater weight to subjective poverty than to objective poverty, selected fundamental needs were those significantly ( $\alpha$  risk=5%) associated with objective poverty and with at least one of the two variables of subjective poverty (table 4).

Finally, fundamental needs that were associated with both objective and subjective poverty were:

- ▶ 'Using your own means to cover a necessary yet unplanned expense of €800'.
- ▶ 'Replacing worn-out furniture'.
- ▶ 'Taking a week's annual holiday away from home'.
- ▶ 'Offering presents to family or to friends at least once a year'.
- ▶ 'Having a car'.
- ▶ 'Having a microwave oven'.

#### Definition of a binary individual deprivation indicator from these fundamental needs associated with both objective and subjective poverty

We calculated for each subject his number of fundamental needs lacking through financial incapacity among the six variables identified in the previous step. Our binary individual deprivation indicator was obtained through dichotomisation of this ordered number of lacking needs.

**Table 3** Income judged insufficient by French households according to their perceived poverty, French EU–SILC survey 2006 (N=10 036)\*

N (%)	Income judged insufficient		
	'Not poor'	'Poor'	Total
Perceived poverty			
'Not poor'	7634 (76.1%)	819 (8.0%)	8453 (84.0%)
'Poor'	506 (5.4%)	1063 (10.6%)	1569 (16.0%)
Total	8140 (81.4%)	1882 (18.6%)	10022† (100.0%)

\*Data weighted on non-response and adjusted on sample design of the French EU–SILC survey 2006.

†Missing data: n=14.

EU–SILC, European Union–Statistics on Income and Living Conditions.

As for perceived poverty, the threshold of the number of lacking needs was determined statistically by selecting the model with the highest  $\chi^2$  value among six univariate logistic regressions models explaining poverty, dichotomised with each possible threshold. However, as neither objective nor subjective poverty is sufficient to characterise deprivation exhaustively, univariate logistic regressions were performed for three dependent variables already used in step 1.2: objective poverty and two variables of subjective poverty (perceived poverty and income judged insufficient).

Figure 2 suggests that for all types of poverty, the best fit was obtained using model '3+', ie, individuals were defined as deprived if they could not afford at least three fundamental needs among the six selected fundamental needs. They were defined as not deprived in all other cases.

#### Selection of variables available both at individual level (French EU–SILC) and in the French census

Eleven variables were phrased and coded in the same way in both the census population at IRIS level and the EU–SILC survey:

Five dichotomous variables:

- ▶ Education: 'Low level of education', ie, less than first stage of secondary-level education, versus 'all other levels of education'.
  - ▶ Overcrowded housing: 'More than 1 person per room' versus '1 or less person per room'.
  - ▶ Heating: 'No access to a system of central or electric heating' versus 'access to a system of central or electric heating'.
  - ▶ Car: 'No access to a car' versus 'access to a car'.
  - ▶ Nationality: 'Foreign nationality' versus 'French nationality'.
- And six unordered variables with two or more categories:
- ▶ Occupational classes in 10 categories (1='farmers'/2='craftsmen–storekeepers'/3='business leaders–company managers'/4='intermediate professions–technicians'/5='employees'/6='skilled workers'/7='unskilled workers–farm workers'/8='former managers'/9='other retired people'/10='other non-working individuals (unemployed persons and others)').
  - ▶ Household types (single pensioner/single-parent household/couple without children/couple with child(ren)/without family).
  - ▶ Number of persons in household ( $\geq 2$  persons/ $\geq 3$  persons/ $\geq 4$  persons/ $\geq 5$  persons/ $\geq 6$  persons).
  - ▶ Employment status (employment/unemployment/retired/other non-working individuals).
  - ▶ Tenure (owners/renters at market prices/renters in low-rent community housing/accommodated free of charge).
  - ▶ Basic amenities (no exclusive use of indoor toilet/no exclusive use of bath or shower).

To dichotomise these unordered variables with two or more categories, we sought the best fit between the individual deprivation indicator and one of the categories of the corresponding variable among others. For example, for the variable 'occupational classes', nine logistic regression models were performed, leading to the selection of the binary variable 'unskilled worker–farm workers' versus 'all others'.

Finally, the 11 variables retained were: 'unskilled-farm workers', 'single-parent household', 'household with six or more persons', 'unemployment', 'non-owner', 'no exclusive use of bath or shower', 'low level of education (less than first stage of secondary-level education)', 'overcrowding (more than one person per room)', 'no access to a system of central or electric heating', 'no access to a car', 'foreign nationality'.

**Table 4** Selection of fundamental needs associated with both objective poverty and subjective poverty by multivariate logistic regressions, French EU–SILC survey 2006 (N=10 036)\*

	Objective poverty OR (95% CI)	Subjective poverty	
		Perceived poverty OR (95% CI)	Income judged insufficient OR (95% CI)
<b>Using your own means to cover a necessary yet unplanned expense of €800</b>	1.29 (1.17 to 1.43)	2.12 (1.91 to 2.36)	1.68 (1.54 to 1.83)
<b>Replacing worn-out furniture</b>	1.27 (1.14 to 1.41)	1.60 (1.43 to 1.79)	1.47 (1.34 to 1.61)
<b>Taking a week's annual holiday away from home</b>	1.47 (1.33 to 1.63)	1.68 (1.51 to 1.86)	1.47 (1.34 to 1.60)
Buying new clothes	1.05 (0.93 to 1.18)	1.16 (1.04 to 1.30)	1.17 (1.05 to 1.30)
Having friends/family for a drink or a meal at least once a month	0.99 (0.88 to 1.10)	1.16 (1.04 to 1.30)	1.03 (0.93 to 1.15)
<b>Offering presents to family or to friends at least once a year</b>	1.12 (1.00 to 1.26)	1.14 (1.01 to 1.28)	1.01 (0.90 to 1.13)
Having a computer	0.94 (0.83 to 1.05)	1.47 (1.31 to 1.65)	1.23 (1.11 to 1.37)
Having two pairs of shoes (for each adult in the household)	1.13 (0.99 to 1.28)	1.31 (1.15 to 1.49)	1.13 (1.00 to 1.28)
Eating a meal containing some meat or some fish or the vegetarian equivalent once every 2 days	1.00 (0.87 to 1.15)	1.25 (1.10 to 1.44)	1.21 (1.07 to 1.37)
Keeping your house sufficiently warm	1.11 (0.99 to 1.25)	1.07 (0.94 to 1.24)	1.11 (0.98 to 1.25)
<b>Having a car</b>	1.42 (1.24 to 1.64)	1.00 (0.84 to 1.20)	1.19 (1.02 to 1.39)
Spending a day with at least one complete meal over the past 2 weeks	1.04 (0.86 to 1.24)	1.55 (1.27 to 1.89)	1.55 (1.31 to 1.84)
Having a video recorder or DVD reader	1.28 (1.08 to 1.53)	1.14 (0.92 to 1.42)	0.95 (0.79 to 1.15)
Having a freezer	1.08 (0.88 to 1.32)	1.19 (0.94 to 1.50)	1.17 (0.95 to 1.44)
Having a washing machine	1.53 (1.18 to 1.98)	0.99 (0.76 to 1.30)	0.84 (0.63 to 1.11)
<b>Having a microwave oven</b>	1.50 (1.16 to 1.95)	0.92 (0.68 to 1.24)	1.30 (1.00 to 1.70)
Having a phone (including mobile phone)	0.98 (0.74 to 1.29)	1.19 (0.87 to 1.63)	0.92 (0.68 to 1.23)
Having a colour TV	0.64 (0.38 to 1.08)	0.86 (0.54 to 1.38)	1.28 (0.81 to 2.00)
Having a refrigerator	2.13 (0.99 to 4.57)	0.82 (0.38 to 1.75)	1.03 (0.53 to 1.97)

\*Data weighted on non-response and adjusted on sample design of the French EU–SILC survey 2006.

In bold, selected fundamental needs because they were associated with objective poverty and with at least one of the two variables of subjective poverty. EU–SILC, European Union–Statistics on Income and Living Conditions.

### Construction of an EDI, the European EDI

#### *Selection and weighting of those variables associated with the individual deprivation indicator using multivariate logistic regression models*

Multivariate logistic regression was then run to select among these 11 individual variables those that were associated with the individual deprivation indicator in the French EU–SILC, in which individuals are sampled all over the country. As these selected variables were also available in the census data, but at the IRIS level, we were able to build an ecological index by using these variables.

One variable was removed ('no exclusive use of bath or shower'; OR=1.13; 95% CI 0.88 to 1.44;  $p=0.3376$ ). This left 10 variables for the EDI (table 5): 'overcrowding', 'no access to a system of central or electric heating', 'non-owner', 'unemployment', 'foreign nationality', 'no access to a car', 'unskilled worker-farm worker', 'household with six or more persons', 'low level of education (less than first stage of secondary-level education)', 'single-parent household'. Table 5 shows the significance of each variable and its adjusted coefficient  $\beta$  with 95% CI.

#### *Ecological step*

The regression coefficients associated with these variables in the final model (table 5) became the weights of these variables measured at the aggregated level in the ecological index. These variables available in the national census at IRIS level constituted an ecological measure.

Independently of weights, components of the ecological index represented rates for a geographical unit, and were: rate of overcrowded housing, rate of housing without access either to a system of central or electric heating, rate of household non-owners, rate of unemployment, rate of persons of foreign nationality, rate of households without access to a car, rate of unskilled workers or farm workers, rate of households with six

or more persons, rate of persons with less than the first stage of secondary education level and rate of single-parent households.

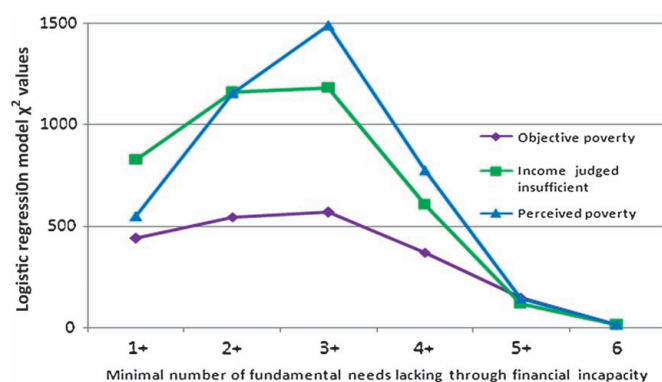
The score of the French EDI for a geographical unit is calculated using the following formula:

$$\begin{aligned} \text{Score} = & 0.11 \times \text{"Overcrowding"} \\ & + 0.34 \times \text{"No access to a system of central or electric heating"} \\ & + 0.55 \times \text{"Non-owner"} \\ & + 0.47 \times \text{"Unemployment"} \\ & + 0.23 \times \text{"Foreign nationality"} \\ & + 0.52 \times \text{"No access to a car"} \\ & + 0.37 \times \text{"Unskilled worker-farm worker"} \\ & + 0.45 \times \text{"Household with 6 + persons"} \\ & + 0.19 \times \text{"Low level of education"} \\ & + 0.41 \times \text{"Single-parent household"} \end{aligned}$$

Application of the French EDI is illustrated for the entire French mainland by calculating its score for all IRIS. All variables were normalised on the French national mean of all IRIS. For all French IRIS ( $n=49\,989$ ), the EDI score had the following distribution: min=-5.332, max=20.522, mean=0, STD=1.847. Each IRIS was classified into quintiles according to its degree of deprivation (for entire mainland France: quintile 1: -5.332; -1.323; quintile 2: -1.323; -0.650; quintile 3: -0.650; -0.007; quintile 4: -0.007; 0.948; quintile 5: 0.948; 20.522).

#### **Preliminary validation**

In order to assess the accuracy of the EDI to measure individual deprivation, we compared the degree of association between the EDI score and two validation criteria measured at the individual level: income and education, and between the Townsend score and these two individual validation criteria.<sup>19</sup> In the postal survey, personal income was classified into eight groups and was dichotomised as follows: '<€800' and '≥€800'. Educational level was dichotomised as follows: 'without diploma' and 'with diploma'. Like the EDI, the Townsend score was calculated for all French IRIS. Each IRIS was then classified into national



**Figure 2** Definition of an individual deprivation indicator by seeking the optimal degree of fit between deprivation and the minimal number of fundamental needs lacking through financial incapacity, according to which an individual is defined as 'deprived', French EU–SILC survey 2006 (N=9930). \* \*Data weighted on non-response and adjusted on the sample design of the French EU–SILC survey 2006. Horizontal axis caption: (six different logistic models for three dependent variables. In all, 18 different models): 1+: objectively or subjectively 'poor'='financial incapacity to possess/realise at least one fundamental need among the six selected fundamental needs' versus 'no financial incapacity'; 2+: objectively or subjectively 'poor'='financial incapacity to possess/realise at least two fundamental needs among the six selected fundamental needs' versus 'no financial incapacity or financial incapacity to possess/realise one fundamental need'; 3+: objectively or subjectively 'poor'='financial incapacity to possess/realise at least three fundamental needs among the six selected fundamental needs' versus 'no financial incapacity or financial incapacity to possess/realise a maximum of two fundamental needs'; 4+: objectively or subjectively 'poor'='financial incapacity to possess/realise at least four fundamental needs among the six selected fundamental needs' versus 'no financial incapacity or financial incapacity to possess/realise a maximum of three fundamental needs'; 5+: objectively or subjectively 'poor'='financial incapacity to possess/realise at least five fundamental needs among the six selected fundamental needs' versus 'no financial incapacity or financial incapacity to possess/realise a maximum of four fundamental needs'; 6: objectively or subjectively 'poor'='financial incapacity to possess/realise all six fundamental needs' versus 'no financial incapacity or financial incapacity to possess/realise a maximum of five fundamental needs'. EU–SILC, European Union–Statistics on Income and Living Conditions.

quintiles according to its degree of deprivation. Associations were analysed using the Cochran–Armitage test for trend of ordered variables.

The French EDI presented the highest association with two socioeconomic variables measured at an individual level, income ( $p$  trend=0.0059) and educational level ( $p$  trend=0.0070)

compared with the Townsend index (respectively,  $p$  trend=0.0409;  $p$  trend=0.2818) (table 6).

## DISCUSSION

This paper proposes the construction of an ecological deprivation index, the European Deprivation Index EDI, which provides a score available for all the smallest units of the entire French mainland. This index, which has been constructed from a European survey specifically designed to study deprivation and is composed of ecological variables identified best to reflect individual experience of deprivation, would make it possible to conduct European comparative studies that are replicable over time.

The French EDI presents certain advantages. First, because it is derived from a theoretical concept of deprivation based on the population's own perception, it is both specific to a given cultural context and well suited for different cultural contexts. This concept of individual experience of deprivation is widely accepted as an efficient measure of relative deprivation.<sup>17</sup> Moreover, our results show that subjective poverty is not closely linked to objective poverty, confirming the idea that deprivation is not only determined by income. Consequently, when deprivation is assessed, it is important to consider both objective and subjective poverty.

Second, apart from its multidimensional nature, one particularity of the EU–SILC is that it allows cross-country comparisons thanks to identical survey design and implementation procedures in each country, as well as centralised support provided by Eurostat. Consequently, the method used to build the French EDI is reproducible in all 26 European countries covered by the EU–SILC survey, unlike the British national survey-based indices. The approach is adaptable depending on the European country concerned, ie, measured deprivation tallied with variables that may differ from one country to another. Moreover, as weighting on a regional level is also available in the EU–SILC survey, regional adaptation is possible for all French regions. This will allow the construction of 22 regional deprivation indices. Thanks to the dynamic cohort of the EU–SILC system, the index can be replicated over time.

Finally, and unlike other survey-based indices, we chose to select fundamental needs that are associated with objective and subjective poverty and not with health indicators.<sup>17 18</sup> Our aim was to avoid overrepresenting the health domain when the EDI is used in the context of socioeconomic inequalities in health, as is recommended for use of the Index of Multiple Deprivation.<sup>20 21</sup>

The EDI also has some limitations. ecological deprivation indices used as a 'proxy' of individual socioeconomic status, the

**Table 5** Final model of multivariate logistic regression selecting components of EDI, which were associated with the individual deprivation indicator, French EU–SILC 2006\* (N=19 253)†

	$\beta$	95% CI	p Value
Overcrowding	0.11	0.02 to 0.20	0.0171
No access to a system of central or electric heating	0.34	0.25 to 0.43	<0.0001
Non-owner	0.55	0.50 to 0.60	<0.0001
Unemployment	0.47	0.38 to 0.55	<0.0001
Foreign nationality	0.23	0.13 to 0.32	<0.0001
No access to a car	0.52	0.46 to 0.58	<0.0001
Unskilled worker—farm worker	0.37	0.27 to 0.46	<0.0001
Household with more than six persons	0.45	0.34 to 0.56	<0.0001
Low level of education	0.19	0.13 to 0.25	<0.0001
Single-parent household	0.41	0.33 to 0.48	<0.0001

\*Data weighted on non-response and adjusted on sample design of the French EU–SILC survey 2006.

†Missing data: n=989.

EDI, European deprivation index; EU–SILC, European Union–Statistics on Income and Living Conditions.

**Table 6** Relationships between ecological deprivation indices scores, French EDI and Townsend scores, and individual deprivation criteria, personal income and educational level (N=1248)

N (row %)	Personal income			Diploma		
	<€800 (%)	≥€800 (%)	Total	Without (%)	With (%)	Total
Quintile 1*						
EDI	52 (23.7)	167 (76.3%)	219	35 (13.5%)	224 (86.5%)	259
Townsend	43 (25.4)	126 (74.6%)	169	26 (13.8%)	163 (86.2%)	189
Quintile 2						
EDI	62 (31.8)	133 (68.2%)	195	38 (16.4%)	194 (83.6%)	232
Townsend	35 (27.8)	91 (72.2%)	126	32 (20.5%)	124 (79.5%)	156
Quintile 3						
EDI	66 (37.3)	111 (62.7%)	177	32 (14.9%)	183 (85.1%)	215
Townsend	56 (37.3)	94 (62.7%)	160	32 (17.6%)	150 (82.4%)	182
Quintile 4						
EDI	76 (33.8)	149 (66.2%)	225	49 (17.0%)	240 (83.0%)	289
Townsend	79 (35.6)	143 (64.4%)	222	41 (14.2%)	248 (85.8%)	289
Quintile 5†						
EDI	64 (35.4)	117 (64.6%)	181	51 (22.9%)	172 (77.1%)	223
Townsend	107 (32.4)	223 (67.6%)	330	74 (18.4%)	328 (81.6%)	402
Total	320 (32.1)	677 (68.9%)	997‡	205 (16.8%)	1013 (83.2%)	1218§
EDI				p-trend¶		
Townsend				0.0059		0.0070
				0.0409		0.2818

\*The least deprived.

†The most deprived.

‡For personal income, 251 data were not actionable (207 refusals to answer, 24 unknown, 20 missing data).

§For educational level, 30 missing data.

¶Cochran–Armitage test for trend of ordered variables.

EDI, European Deprivation Index.

French EDI could spuriously classify individuals into deprived areas. Nevertheless, scores are available for the IRIS, ie, the smallest geographical units. This decreases the ecological bias, because the accuracy of socioeconomic measures decreases with the size of the geographical unit used.<sup>22 23</sup> Furthermore, construction of the French EDI is based on selecting the best subset of ecological variables related to deprivation at the individual level. Compared with techniques used to construct indices based on census, principal component analysis or factor analysis in which correlations between ecological variables are analysed without reference to the individual socioeconomic status, the methodology described here should minimise ecological bias.

The ability of the EDI to measure individual deprivation was assessed here in a preliminary validation. Even though scores were strongly associated with two individual socioeconomic variables, ie, income and education, more extensive validation is required.

Like other survey-based indices, this methodology requires access to variables available both at an individual (EU–SILC survey) and ecological level (census data). This limits the initial number of variables to be analysed when selecting those associated with the individual deprivation indicator.

As deprivation appears different in rural or urban areas, the French EDI may also present a well-known limitation shared by all deprivation indices, ie, the failure to take rural/urban contexts into account.<sup>24 25</sup> A single index cannot discriminate well rural/urban deprivation differences between rural and urban areas. As the EU–SILC survey does not allow weighting on urban/rural areas, it is not possible to take this issue into account.

Although the EDI aims to measure deprivation at a geographical level, the question of dependence among the ecological variables does not arise because its construction is based on individual-level variables. Nevertheless, when the EDI is used in studies to provide a deprivation measure at

a geographical level, the issue of spatial autocorrelation should be taken into account in analyses, because of potential autocorrelations between close geographical units.<sup>16</sup> If the geographical position of respondents in the EU–SILC survey was available, ecological data would be directly used in a geographically weighted regression, a recent geographical technique making it possible to take dependence among ecological variables into account.<sup>26</sup> However, for reasons of confidentiality, addresses were not available.

### What is already known on this subject

As stated by Townsend,<sup>4</sup> ‘the concept of deprivation covers the various conditions, independent of income, experienced by people who are poor’. Ecological deprivation indices have essentially been pragmatically developed from census data. These ‘census-based’ indices concern variables of residential areas, and are used as a ‘proxy’ of individual deprivation measure without referring to individual deprivation experience.

### What this study adds

This study presents a new ecological deprivation indices reflecting individual deprivation experience. The French EDI is novel because it is based on a European survey specifically designed to measure deprivation. EDI, which is specific to a given cultural and sociopolicy context, is not only replicable over 25 other European countries but also over time.



## Policy implications

- ▶ All EDI could be appropriate ecological measures of social inequalities in health to two types of users all over Europe: epidemiological researchers in order to harmonize analyses, and health authorities to implement country-specific interventions and policies.
- ▶ EDI could prove to be relevant tools in evidence-based policy-making with a view to reducing social disparities in health-related issues and even outside the medical domain.

In conclusion, this study presents a new ecological survey-based deprivation index reflecting individual deprivation experience. The French EDI is novel because it is based on a European survey specifically designed to measure deprivation. The index, which is specific to a given cultural and sociopolitical context, is not only replicable over 25 other European countries but also over time. It could prove to be a relevant tool in evidence-based policy-making with a view to reducing social disparities in health-related issues and even outside the medical domain.

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