# Spatiotemporal association between deprivation and mortality: trends in France during the nineties

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## ABSTRACT

### Background

Monitoring the time course of socioeconomic inequalities in mortality is a key public health issue. The aim of this study was to analyse this trend at an ecological level, in mainland France, over the nineties, using a deprivation index enabling time comparisons.

### Methods

Deprivation indexes (FDep) were built using the 1990 and 1999 data and the same methodology. The indices were defined as the first component of a principal component analysis including four specific socioeconomic variables. The time course of the association between mortality and deprivation was evaluated on the *'commune'* geographic scale (36,000 units in mainland France), without considering spatial autocorrelation, and on the larger '*canton*' scale (3700 units), considering spatial autocorrelation. The analysis was carried out by gender, age, and degree of urbanicity and applied to general mortality and a specific subcategory: 'avoidable' deaths.

### Results

Area-level socioeconomic inequalities in mortality tended to increase during the nineties. For the period 1997-2001, the standard mortality ratio (SMR) was 24% higher for the *communes* in the most deprived quintile than for those in the least deprived quintile, while this differential was of 20% for the period 1988-1992. This increase in the differentials concerned especially males and people aged less than 65 years. For both men and women, it was stronger for the “avoidable” mortality sub-category.

### Conclusion

As observed at the individual level in previous studies, area-level socioeconomic inequalities in health increased during the nineties, while general health improved.

## KEYWORDS

Deprivation; Index measurement; Inequalities; Mortality; Trends

## INTRODUCTION

Socioeconomic inequalities in health and, specifically, mortality, have been identified and widely studied in many countries. The time course of those inequalities constitutes a major public health issue. (1-17) Assessment of the trends is pertinent to monitoring public health policies in that it enables elucidation of the effects of socioeconomic changes on health. Assessment also enables estimation of the lag-time between socioeconomic change at population level and health-related events.

Two levels of association between mortality and socioeconomic characteristics are commonly considered (independently or jointly): the individual level and the area-based ecological level. The individual level enables ecological biases to be avoided and causal pathways to be identified. However, the individual level requires data that are usually not available. The ecological level provides a greater opportunity for introducing routinely-produced data and is interesting in that it enables elucidation of spatial health inequalities. Specifically, it helps to disentangle socioeconomic disparities from rural-urban gradient in the explanation of spatial health inequalities.(18) However, the scope for individual inferences is limited.

The evaluation of trends in socioeconomic inequalities in health requires a comparable measurement of socioeconomic level over time. At an individual level, socioeconomic characteristics are often measured in terms of educational level or occupational class. (3, 5-7, 19) These variables do not necessarily retain the same distribution and consequently the same meaning over different periods. In consequence, comparability issues may be encountered. (3) Similar issues are also encountered at ecological level. (1, 4, 10, 11, 13) In order to minimize them, the methodology used to build a measure of socioeconomic level has to be identical over time and relevant at each period.(13, 20, 21)

At the ecological level, the concept of deprivation is often used to measure the socioeconomic level of an area. It was introduced by Townsend as a “state of observable and demonstrable disadvantage relative to the local community or the wider society to which an individual,

family or group belongs".(22) Several deprivation indices have been developed.(22-25) For France, specific indices have recently been proposed.(18, 26-30) The FDep99 index was built with the aims of being representative for the whole of France and taking urban-rural comparability issues into account. (18) On the basis of this index, a strong association between mortality and deprivation over the period 1997-2001 was observed on the *commune* scale.(18)

In various countries, socioeconomic inequalities in mortality have increased over time. For France, this trend has been demonstrated at individual level by various studies (2, 5-7) but no recent measure of socioeconomic mortality differentials in the general population has been reported. Moreover, the impact of the urbanization process on the time course of socioeconomic inequalities in health has not been assessed.

The purpose of this study was to analyse the time course of socioeconomic inequalities at ecological level in France during the nineties. To the authors' best knowledge, no study of that type has ever been undertaken in France.

## METHODS

### Deprivation index

The 1990 deprivation index (FDep90) was computed on the basis of similar data to those used for calculation of the 1999 index (FDep99).(18) Both indices were constructed on the *commune* scale. The *commune* is the smallest administrative unit in France (36,000 units). The socioeconomic data were derived from the 1990 and 1999 population censuses (source: INSEE, National Institute for Statistics and Economic Studies), and from the tax authority's 1990 and 2001 household income data (INSEE).

In order to define the degree of urbanicity, 1990 Urban Unit Categories (UUC) were used in the same manner as the 1999 UUC were used to construct the FDep99. The UUC are defined using built area contiguity (<200m) criteria. There are five UUC characterising the *commune* level: rural (less than 2,000 people), quasi-rural (2,000 to 9,999), quasi-urban (10,000 to 99,999), urban (10,000 to 1,999,999) and Paris-and-suburbs (Paris Urban Unit).

The methodology was that used to build the FDep99 index. The index required to have the following properties: one-dimensional; maximization of the heterogeneity of the components; and consistent association with the components. The selection procedure led to a similar set of four variables: average household income; percentage high school graduates in the population aged 15 years and older; percentage blue-collar workers in the active population; and unemployment rate (Table 2 as Supplementary material). The only difference concerned household income. In 1999, median household income was used, but, in 1990, only average household income was available. Moreover it was only available for *communes* of more than 50 households (30,500 units) while in 1990 it was available for *communes* of more than 11 fiscal households (34,000 units). The four variables were correlated within and between the UUC. The 1990 deprivation index (FDep90) was the first component of a principal component analysis of the four variables. This first component accounted for 64% of the total

variation (68% in 1999). The deprivation index was also constructed on the *canton* scale. The *canton* is the second smallest administrative unit in France (3,700 units). For each *canton*, the deprivation index was calculated as the population weighted average score for all the *communes* in the *canton*.

**Measurement of the association between mortality and deprivation**

The mortality data were derived from the Inserm-CépiDc database for mainland France. Two five-years periods centred on census-years (1988-1992 and 1997-2001) were retained. All-cause and 'avoidable' causes mortality were both considered. The 'avoidable' causes were defined as the causes of death before age 65 years and linked to risk behaviours targeted by primary prevention.(31) The causes consisted of those related to smoking (lung, trachea and bronchus cancers (ICD9: 161-162; ICD10: C32–C34)), alcohol consumption (aerodigestive tract cancers (ICD9: 140-149; ICD10: C00–C14), oesophagus cancer (ICD9: 150; ICD10: C15), alcohol abuse (ICD9:291,303; ICD10: F10), and chronic liver disease (ICD9: 5710-5719; ICD10: K70,K73–K74)), transport accidents (ICD9: 800-848; ICD10:V01–V99), suicides (ICD9: 950-958; ICD10: X60–X84), and HIV infection (ICD9: 042-044; ICD10: B20–B24).

The Standard Mortality Ratio (SMR) was used to measure the association between mortality and deprivation. The SMR was defined, for each spatial unit, as the ratio between the observed mortality and the corresponding expected mortality, computed from the national mortality rates for the period applied to the spatial unit population by age and gender.

The time trends of the association between mortality and deprivation were assessed using two types of measurement:

- The log-linear trend, defined as the linear association between the logarithm of the SMR and the deprivation index. This measure was used in order to summarize the association over the

whole deprivation range. As the SMR were close to one, the log-linear trend was considered a linear trend. In order to maximize socioeconomic heterogeneity, the association between mortality and deprivation was measured on the *commune* scale for each period. All the *communes* whose FDep90 in 1990 and FDep99 in 1999 were available were incorporated in the analysis. On the *commune* scale, taking into account the spatial autocorrelation was not feasible (due to the large number of units). The linear trend was therefore measured on the *commune* scale, without considering spatial autocorrelation, and on the *canton* scale, considering spatial autocorrelation. Such a study allowed to measure the sensitivity of results to the spatial scale and to the introduction of spatial autocorrelation structure into the model. A log-linear BYM model (32) was used to estimate the association, taking overdispersion, temporal autocorrelation and spatial autocorrelation (*canton* scale) into account. In order to measure comparable relative spatial variations between the two periods, the deprivation indices for both periods were standardized. The log-linear trend of the association for each period was measured by $\beta_j$ using the following model:

$$\begin{cases} O_{ij} \propto P(\lambda_{ij}) \\ \log(\lambda_{ij}) = \log(E_{ij}) + \alpha + \beta_j \cdot FDep_{ij} + u_i + v_i + e_{ij} \end{cases}$$

in which $i$ is a spatial unit, $j$ the period, $O_{ij}$ the number of deaths, $E_{ij}$ the expected number of deaths, $u_i$ the spatial autocorrelation, $v_i$ the temporal autocorrelation and $e_{ij}$ the overdispersion.

- The ratio between the average SMR of the units in the fifth population deprivation quintile and the average SMR of the units in the first population deprivation quintile: $\frac{SMR_{Q5}}{SMR_{Q1}}$. In contrast with the log-linear trend, the ratio measures the mortality differentials between extreme values of the deprivation distribution.

For similar reasons, this ratio and its confidence interval were estimated on the *commune* scale without considering the spatial autocorrelation and on the *canton* scale considering the spatial autocorrelation.

**Statistical software**

SAS 9.1 was used for the main analysis, data management and mapping. The BYM models were computed using the packages: spdep and R-Inla in R, and WinBUGS.

## RESULTS

### Spatial distribution of deprivation

Deprivation in 1990 was greater in northern France than in the south (Figure 1). Moreover, the FDep90 index decreased with the level of urbanicity. It was lower in urban agglomerations and especially in the Paris area. The heterogeneity of deprivation increased with the level of urbanicity. The gap between the average values of the upper and lower quintiles was greater for the most urban UUC.

The spatial discrepancies in deprivation were very similar in 1990 and 1999.(18) The correlation coefficient between the FDep calculated on the *commune* scale for each period was 0.953.

The distribution of deprivation measured by the FDep remained stable. For 97.4% of the population and 89.0% of the *commune*s, deprivation did not change by more than one quintile between 1990 and 1999. The population that experienced a change in deprivation was mainly rural (80.2% of the population for which there was an increase in deprivation level and 68.6% of the population for which there was a decrease in deprivation level).

### Spatial distribution of mortality

On the *canton* scale, the geographic pattern of mortality in France for the period 1988-1992 was characterized by a South-North positive gradient (Figure 2). A vertical band of high mortality ran through the middle of France. A similar pattern, slightly more marked, was observed for the period 1997-2001.

### Trends in the association between mortality and deprivation

The association between mortality and deprivation for the two periods was almost linear for the whole of France and for each UUC (Figure 3).

The association between all-cause mortality and FDep was strong and significant for the two periods (on the *commune* scale, $\beta = 0.068$ for 1988-1992 and $\beta = 0.084$ for 1997-2001) (Table 1). On the *commune* scale, in 1988-1992, the all-cause mortality was 20% higher in the deprivation fifth quintile *communes* than in the first quintile *communes* (24% in 1997-2001). These increasing associations were significant both for the log-linear trend and for the fifth/first deprivation quintile SMR ratio.

Between the two periods, the increase in the association was markedly greater for the 'avoidable' mortality subcategory (on the *commune* scale, $\beta = 0.122$ in 1988-1992 and $\beta = 0.210$ in 1997-2001) (Table 1). In 1988-1992, the 'avoidable' mortality was 40% higher for the fifth deprivation quintile *communes* than for the first quintile *communes* (78% higher in 1997-2001). The increase in the association between the two periods was high for all the 'avoidable' cause of death considered separately.

On the *canton* scale, the association between mortality and deprivation was less strong (both for the SMR ratio and linear trend). But the time courses were of the same amplitude as those on the *commune* scale.

For the two periods, for both all-cause mortality and 'avoidable' mortality, the association was stronger for men than for women (Table 1).

The increase between the two periods in all-cause mortality difference between the first and fifth deprivation quintiles was marked for men (+23% in 1988-1992 and +32% in 1997-2001). For women, the increase was not statistically significant.

For 'avoidable' mortality, the time course was significant for both genders but the increase in mortality difference was greater for men (+41% in 1988-1992 and +83% in 1997-2001 for men; +33% in 1988-1992 and +58% in 1997-2001 for women). For each studied cause of death, the time course was significant for both genders.

On the *canton* scale, the association between mortality and deprivation was less strong than that on the *commune* scale, but the amplitude of the time course was similar.

Social inequalities in mortality increased markedly for people younger than 65 years (Table 1). For people younger than 25, in 1988-1992, the SMR was 19% higher for the fifth deprivation quintile than for the first quintile (41% in 1997-2001). For people aged between 25 and 65, the differential was 26% in 1988-1992 and 46% in 1997-2001. For people older than 65, the inequalities remained stable (+18% in 1988-1992 and +19% in 1997-2001). When the analysis was carried out within each UUC, the social inequalities in mortality changed to a lesser extent. The increase was only significant in the Paris-and-suburbs category for the fifth/first deprivation quintile SMR ratio, and, in the rural category, for the linear trend (Table 1).

On the *canton* scale, the change was statistically significant for all-cause mortality in the quasi-urban and Paris-and-suburbs categories.

## DISCUSSION

### Deprivation index

The construction of the FDep index resulted in comparable relative deprivation measurements for both periods, in the whole of France and in rural and urban areas.

In order to investigate the trend of the association between mortality and deprivation, the same FDep variables were used for two different periods. The link between the actual socioeconomic situation, in all its complexity, and its measurement by the variables used in the analysis may change depending on the period. This issue applied, in particular, to the percentage of high school graduates in the population and the percentage blue collar workers. In France, the overall educational level is rising and the share of tertiary sector in the economy is increasing. The 'high school graduate' and 'blue collar worker' categories in 1999 do not necessarily reflect the same social standing as the same categories ten years earlier.(33) The spatial distributions of the FDep index are very similar for the two periods considered. Therefore it was not possible to study, independently of the initial deprivation level, the impact of the change in deprivation in a *commune* on the mortality in that *commune*. Lastly, the index did not enable elucidation of the lag time between socioeconomic change and its impact on mortality.

### Scale and spatial autocorrelation

When analysing ecological data, the most relevant spatial scale should be chosen in order to maximize socioeconomic heterogeneity.(34, 35) However, analysing the data on the *commune* scale, the finest available scale, was not feasible when taking into account the autocorrelation of the observations, thus overestimating the power of the analyses. A larger scale was therefore considered in order to take spatial autocorrelation into account. The *canton* scale

results were more conservative. The confidence intervals were larger and the association between mortality and deprivation tended to be significant less often. However, the comparison of the two sets of results showed that there was no marked difference between the two methods. Generally, the association between mortality and deprivation and its time course were stronger on the *commune* scale than on the *canton* scale, but of the same amplitude. With the exception of Paris-and-suburbs, the association was weaker in rural UUC than in urban UUC. This result may be partly explained by the greater time variability of socio-economic variables in rural spatial units, due to their small population size. The greater variability may add noise to the association estimate. Potential alternative options enabling the limitation to be taken into account include using a scale whose fineness increases along the rural/urban gradient (36) and using smoothed socioeconomic variables.(37)

This study, carried out at an ecological level, may lead to fallacies when the inferences are generalized at the individual level.(38) However, the use of the finest spatial scale minimized that bias: the ecological level results were consistent with the individual level results obtained from previous studies.

**Trends of the association between mortality and deprivation**

The socioeconomic inequalities in mortality increased between the two periods, but the increase did not affect the entire population. The increase was significant for men but not for women. It affected people younger than 65 years but not people older than 65. For the 'avoidable' mortality category considered as a whole and each of its constitutive causes, the increase was greater for both men and women.

When the analysis was carried out for each UUC, there was no obvious increase in the inequalities. The increase in socioeconomic inequalities in mortality may thus be more related to between-UUC increases in socioeconomic inequalities than to within-UUC increases. The

possible explaining pathways may be that urbanicity level is a stronger discriminating factor of access to care, way of living and socioeconomic position in 1999 than in 1990.

For the period 1991-1999 and for men aged between 35 and 80, the SMR was 110% higher for blue collar workers than for executives, versus 80% for the period 1976-1984. For women of the same age, the SMR was 40% higher for blue collar than for executives for each periods.(7) Other studies in which educational level was used to measure the trend in socioeconomic inequalities have generated similar results.(5) Although the periods, socioeconomic dimensions and age groups considered were not directly comparable, it is noteworthy that the ecological level results were of smaller amplitude, but consistent with the individual level results.

The results reported herein are similar to those generated by other studies based on an area-based deprivation index conducted in the United Kingdom, the United States and New Zealand.(3, 4, 8-12, 14-17) The studies show a widening gap between more deprived and less deprived areas.

As has been previously reported, (3, 11, 20) mortality has fallen at all deprivation levels. Thus, the increase in inequalities in mortality was due to a slower decrease in mortality in the more deprived areas than in the less deprived areas.

The strongest risk factors for social inequalities in mortality and, particularly, 'avoidable' mortality, include alcohol and smoking. With regard to the particularly marked increase in socioeconomic differentials observed for 'avoidable' mortality, the increase in social inequalities may largely be explained by the lesser impact of primary prevention and higher prevalence of risk behaviours in the most deprived areas.(33)

The greater increase in inequalities for men has several explanations. The contribution of 'avoidable' mortality to all-cause mortality is greater for men than for women. The socioeconomic gradient of breast cancer, which accounts for considerable female mortality, is

generally low.(39) Lung cancer rates are mainly related to a history of smoking, which is more frequent among women in higher social classes than those in lower classes.(40) Other studies have shown that cardiovascular diseases, which particularly affect men, have markedly declined in higher socioeconomic groups.(3, 33)

## Conclusion

Increasing life expectancy affects the population in a differential manner, depending on the level of deprivation, and thus induces an increase in socioeconomic mortality differentials. The ecological approach, using a deprivation index, constitutes a tool for routinely monitoring the trends of socioeconomic inequalities in mortality.

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**CONFLICT OF INTERESTS**

None declared

**KEY POINTS**

- Monitoring socioeconomic inequalities is strongly constrained by data availability on a routine base. In several countries, those data are routinely available only at an ecological level.
- An increase in socioeconomic mortality spatial differentials in the nineties was found in France, especially for males and for people aged less than 65 years and “avoidable” mortality sub-category.

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**TABLES**

**Table 1 Time course of the association between mortality and deprivation by gender, age and degree of urbanicity**

| | β [95% CI] | | | $SMR_{Q5}/SMR_{Q1}$ [95% CI] | | |
|---|---|---|---|---|---|---|
| | **1988-1992** | **1997-2001** | **P-value** | **1988-1992** | **1997-2001** | **P-value** |
| **All-cause mortality** | | | | | | |
| **Both gender** | 0.068 | 0.084 | < 0.0001 | 1.20 | 1.24 | < 0.0001 |
| **Men** | 0.080 | 0.106 | < 0.0001 | 1.23 | 1.32 | < 0.0001 |
| **Women** | 0.057 | 0.062 | 0.1030 | 1.16 | 1.17 | 0.2270 |
| **< 25 years** | 0.071 | 0.123 | < 0.0001 | 1.19 | 1.41 | 0.0003 |
| **25 – 65 years** | 0.087 | 0.137 | < 0.0001 | 1.26 | 1.46 | <0.0001 |
| **≥ 65 years** | 0.063 | 0.070 | 0.0064 | 1.18 | 1.19 | 0.0459 |
| **UUC** | | | | | | |
| **Rural** | 0.048 | 0.055 | 0.036 | 1.10 | 1.11 | 0.1397 |
| **Quasi-rural** | 0.066 | 0.071 | 0.422 | 1.14 | 1.17 | 0.4518 |
| **Quasi-urban** | 0.093 | 0.100 | 0.434 | 1.18 | 1.20 | 0.1367 |
| **Urban** | 0.123 | 0.116 | 0.124 | 1.30 | 1.29 | 0.3039 |
| **Paris-and-suburbs** | 0.071 | 0.074 | 0.538 | 1.27 | 1.30 | 0.017 |
| **'Avoidable' mortality** | | | | | | |
| **Both gender** | 0.122 | 0.210 | < 0.0001 | 1.40 | 1.78 | <0.0001 |
| **Men** | 0.127 | 0.221 | <0.0001 | 1.41 | 1.83 | < 0.0001 |
| **Women** | 0.099 | 0.167 | <0.0001 | 1.33 | 1.58 | < 0.0001 |
| **Related to:** | | | | | | |
| **Alcohol** | 0.242 | 0.295 | <0.0001 | 1.88 | 2.19 | < 0.0001 |
| **Smoking** | 0.091 | 0.136 | < 0.0001 | 1.28 | 1.44 | < 0.0001 |
| **Transport accident** | 0.185 | 0.247 | < 0.0001 | 1.65 | 1.94 | < 0.0001 |
| **Unsafe sexual practice** | -0.426 | -0.235 | < 0.0001 | 0.20 | 0.49 | < 0.0001 |
| **Suicide** | 0.177 | 0.229 | < 0.0001 | 1.67 | 1.95 | < 0.0001 |

$SMR_{Q5}$ / $SMR_{Q1}$: ratio of the SMR of *communes* whose FDep90 index is higher than the fourth quintile and SMR of the *communes* whose FDep90 index is lower than the first quintile for the period 1988-1992 and ratio of the SMR of *communes* whose FDep99 index is higher than the fourth quintile and SMR of the *communes* whose FDep99 index is lower than the first quintile for the period 1997-2001
β: linear trend of the association between deprivation and mortality for the periods 1988-1992 and 1997-2001
All βs and $SMR_{Q5}$ / $SMR_{Q1}$ are statistically significantly different from 0 and from 1 respectively, at the 5% level
P-value: p-value of equality test of SMRQ5 / SMRQ1 for the two periods and p-value of equality test of β for the two periods
Alcohol: aerodigestive tract cancers, oesophagus cancer, alcohol abuse, and chronic liver disease
Smoking: lung, trachea and bronchus cancers
Unsafe sexual practice: HIV infection

## FIGURES

### Figure 1: Geographic distribution of the FDep90 index on the *canton* scale

FDep: first component of a PCA on the commune scale of the following variables in 1990: average household income, percentage high school graduates in the population aged 15 years and older, percentage blue-collar workers in the active population and unemployment rate

### Figure2: Geographic distribution of all-cause mortality on the *canton* scale

SMR: standardized mortality ratio for the periods 1988-1992 and 1997-2000

### Figure 3: SMR as a function of various deprivation index quintiles, on the *commune* scale, by degree of urbanicity (UUC)

SMR: standardized mortality ratio for the periods 1988-1992 and 1997-2001
FDep90: first component of a PCA on the commune scale of the following variables in 1990: average income, % high school graduates, % blue-collar workers and unemployment rate
FDep99: first component of a PCA on the commune scale of the following variables in 1999: median income, % high school graduates, % blue-collar workers and unemployment rate

**SUPPLEMENTARY MATERIAL**

**Table 2 Descriptive statistics of mortality and socioeconomic data at the commune and canton scales in 1990 and 1999**

| | | 1990 | | | 1999 | | |
|---|---|---|---|---|---|---|---|
| | | **Min** | **Max** | **Avg** | **Min** | **Max** | **Avg** |
| **Commune** | **Population** | 25 | 800309 | 1657 | 80 | 797491 | 1899 |
| **(N=30,500)** | **Number of deaths** | 0 | 43308 | 2383 | 0 | 38767 | 2224 |
| | **FDep** | -9.11 | 3.88 | 0 | -4.11 | 3.53 | 0 |
| | **%Blue collar workers** | 0 | 100 | 30.47 | 0 | 90.14 | 26.9 |
| | **%Unemployed** | 0 | 43.1 | 10.98 | 0 | 45.28 | 13.06 |
| | **%High school graduates** | 0 | 71.43 | 19.12 | 3.19 | 63.93 | 26.42 |
| | **Income (€)** | 2033 | 112099 | 12640 | 4549 | 35456 | 15035 |
| **Canton** | **Population** | 135 | 800309 | 15265 | 116 | 797491 | 13439 |
| **(N=3,700)** | **Number of deaths** | 2 | 43308 | 2732 | 6 | 38767 | 2875 |
| | **FDep** | -5.34 | 2.25 | 0 | -4.07 | 2.35 | 0 |
| | **%Blue collar workers** | 4.62 | 62.39 | 29.75 | 4.24 | 56.5 | 23.3 |
| | **%Unemployed** | 2.26 | 24.44 | 10.5 | 2.64 | 31.81 | 14.73 |
| | **%High school graduates** | 4.78 | 51.56 | 19.21 | 9.88 | 62.97 | 30.16 |
| | **Income (€)** | 5291 | 51969 | 12731 | 7894 | 35188 | 15359 |

Avg: population-weighted average
Income: average household income in 1990, median household income in 1999