Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
The role of economic structural factors in determining pandemic mortality rates: Evidence from the COVID-19 outbreak in France

Stéphane Goutte\textsuperscript{a,b,⁎}, Thomas Péran\textsuperscript{c,d}, Thomas Porcher\textsuperscript{e}

\textsuperscript{a} Université Paris-Saclay, UVSQ, CEMOTEV, 78280 Guyancourt, France
\textsuperscript{b} International School, Vietnam National University, Hanoi, Viet Nam
\textsuperscript{c} ROLACC Geneva, 211 route de Ferney, CH1218 Le Grand-Saconnex, Switzerland
\textsuperscript{d} Université de Paris, Paris, France
\textsuperscript{e} PSB, Paris School of Business, 59 rue Nationale, 75013 Paris, France

A R T I C L E   I N F O

JEL classification:
I14
I18
J14
H12
R11

Keywords:
Pandemic
COVID-19
Social distancing
Health system
Territorial vulnerabilities
Poverty
Housing

A B S T R A C T

Among the majority of research on individual factors leading to coronavirus mortality, age has been identified as a dominant factor. Health and other individual factors including gender, comorbidity, ethnicity and obesity have also been identified by other studies. In contrast, we examine the role of economic structural factors on COVID-19 mortality rates. Particularly, focusing on a densely populated region of France, we document evidence that higher economic “precariousness indicators” such as unemployment and poverty rates, lack of formal education and housing are important factors in determining COVID-19 mortality rates. Our study will help inform policy makers regarding the role of economic factors in managing pandemics.

1. Introduction

The Director General of the World Health Organization (WHO) declared the COVID-19 epidemic as a pandemic on the 11th of March 2020. By this period, more than 110 countries were already heavily affected worldwide, with approximately 120,000 confirmed cases of the coronavirus disease (WHO, 2020a). In what follows, researchers from around the World devoted their work to the study of this new virus, by mainly using three different approaches. First, a race against the clock was launched by epidemiologists to find a vaccine (Shoenfeld, 2020; Cohen, 2020; Le et al., 2020) and reach in the earliest possible delay a satisfactory level of collective immunity (Altmann et al., 2020). Second, the medical profession devoted itself to studying the effects of the virus on the health of individuals. Lastly, the majority of researchers has attempted to identify the most effective ways to staunch this global scourge. In particular, the last group of studies aim to explore the factors behind the transmission of the coronavirus (see, e.g., Li et al., 2020) and the worsening of the health situation (see, e.g., Di Lorenzo and Di Trolio, 2020). Corresponding to this group of studies, this current study, also explores the extent of the economic consequences that the health crisis has inevitably caused (McKee and Stuckler, 2020; Yue et al., 2020).

⁎ Corresponding author at: Université Paris-Saclay, UVSQ, CEMOTEV, 78280 Guyancourt, France.
E-mail address: stephane.goutte@uvsq.fr (S. Goutte).

https://doi.org/10.1016/j.ribaf.2020.101281
Received 19 May 2020; Received in revised form 10 June 2020; Accepted 12 June 2020
Available online 23 June 2020
0275-5319/ © 2020 Elsevier B.V. All rights reserved.
The first group of studies reveals fundamental elements in understanding the COVID-19 phenomenon. These studies have demonstrated that the pandemic first started in the Chinese city of Wuhan in Hubei Province and that in the category of elderly individuals, the highest mortality rate was recorded (NHS England, 2020). These findings were quickly refined to permit a precise identification of other comorbidity factors (Bacon et al., 2020). Thus, for example, it seems very likely that patients suffering from other pathologies such as diabetes (Klonoff and Umpierrez, 2020) or asthma (Abrams and Szefler, 2020; WHO, 2020b) are more affected than healthiest patients, but also that the rhesus of the blood group and the ethnic origin of the patients (Mihm, 2020; NHS England, 2020; Hooper et al., 2020) could constitute a medical field fostering the mortality of the virus. In other words, a standard “robot portrait” of the most endangered patients of the coronavirus disease was drafted.

Furthermore, geographical studies have shown that not a single continent is sheltered (Hopman et al., 2020; Gilbert et al., 2020), and that the West recorded the highest morbidity rate. The COVID-19 morbidity rate following top global ranking includes the United States of America (≥79,500 deaths), United Kingdom (≥31,900 deaths), Italy (≥30,500 deaths), Spain (≥26,600), France (≥26,300).² To improve the understanding of the vectors of the virus transmission as well as the morbidity factors, it seems interesting to conduct comparative studies at the three continental, regional and State levels.

However, the first observations establish that biases exist and that it therefore could be reasonable to limit comparative analyzes to territorial units with the same human and climatic characteristics (Desjardins et al., 2020; Liu et al., 2020). For example, it has

---

¹ It also seems that not a single country has been sheltered and that the few localities where no deaths have been recorded have chosen not to report the cases. Refer to figures from Johns Hopkins University which are widely accepted by the Global Scientific Community. Available at: https://coronavirus.jhu.edu/map.html (accessed 10 May 2020).

² Figures updated to May 11, 2020.
been observed that in Sub-Saharan Africa, the contamination and transmission rates are extremely lower relative to countries in the North and West of the Globe (Martinez-Alvarez et al., 2020; Nuwagira and Muzoora, 2020). The positive effects of various factors including the protective role of previous injections of Malaria vaccine on populations exposed to COVID-19 have been explored (Sargin and Yavasoglu, 2020). Moreover, the global death reports indicate that the number of national deaths appears to vary largely. Some countries report exclusively deaths in hospitals (like France at the early stage of the pandemic) while others merge deaths in hospital, domestic and nursing homes (like Germany). Accordingly, an international study seems to be unrealistic at the moment.

Unlike previous papers focusing on human factors, our study proposes an approach to explore the structural factors of contamination, contagion and mortality of COVID-19. Indeed, in addition to genetics and geography, we aim to explore new elements that may be put forward to explain the excess mortality in certain populations. To do this, we limit our study to Île-de-France. As shown in Fig. 1, the Île-de-France is a French region which includes eight departments, which has the unique characteristic of not constituting a cluster of contamination due to an identifiable and outstanding event.

### Table 1
Explication weights of each variable on the two main axis factor.

| Variable                                      | F1   | F2   |
|-----------------------------------------------|------|------|
| Unemployment rate                            | 0.381558 | 0.5903711 |
| People 65y and more                          | 0.700227 | 0.2170222 |
| People 75y and more                          | 0.684784 | 0.1869943 |
| Aging index                                   | 0.936031 | 0.002343 |
| Population density                            | 0.697611 | 0.2897714 |
| Average household size                        | 0.959639 | 0.0040854 |
| Median standard of living                     | 0.659438 | 0.3188606 |
| Share of taxed tax households                 | 0.49332 | 0.488439 |
| Share of unemployment benefits in the rev. avail. | 0.24914 | 0.7274552 |
| Part des prestations logement dans le rev. disp. 2016 | 0.343963 | 0.6314759 |
| Share of social minima in rev. avail.         | 0.315023 | 0.6619699 |
| Taux de pauvreté 2016                         | 0.107143 | 0.8820404 |
| Share of pops. with little or no diploma out of school 15 years or more | 0.721121 | 0.2702388 |
| Share of graduates of higher education in pop. out of school 15 years or more | 0.965011 | 0.0075429 |
| Share of apartments in total housing          | 0.556234 | 0.3294512 |
| Share of houses in total housing              | 0.559437 | 0.3305705 |
| Share of owners of their residences           | 0.351085 | 0.6040112 |
| Share of HLM tenants in main residences       | 0.116735 | 0.518652 |
| Share of workers in the number of jobs        | 0.741465 | 0.183661 |
| Activity rate by age group                   | 0.651726 | 0.2236003 |
| Public service workforce                     | 0.670789 | 0.1730079 |
| Average hourly net salary                    | 0.85455 | 0.0579598 |
| Share of admin positions, public, education, health and social action in institutions assets | 0.409242 | 1.106E−05 |
| General practitioner                          | 0.780782 | 0.0758108 |
| Nurses                                        | 0.564617 | 0.0727833 |
| Pharmacy                                      | 0.798154 | 0.1077442 |
| Elderly accommodation                         | 0.807258 | 0.0102245 |
| Nursery                                       | 0.911818 | 0.0793671 |
| Pôle emploi                                   | 0.094789 | 0.0435737 |
| Infant school                                 | 0.191453 | 0.0657052 |
| Elementary school                             | 0.058083 | 0.1342393 |
| Middle school                                 | 0.344103 | 0.2657882 |
| High school                                   | 0.662656 | 0.1517911 |
| Emergency service                             | 0.683236 | 0.0466165 |
| Number of main residences overcrowded part (%) | 0.017171 | 0.9595219 |
| Population living in apartments part (%)      | 0.570496 | 0.3373785 |
| People living in an apartment in a household of at least 4 people | 0.721121 | 0.2702388 |
| Share of private park accommodation potentially unworthy (PPPP) – Source Dhrill | 0.011567 | 0.828304 |
| Share of unemployed and more                  | 0.409242 | 1.106E−05 |
| Share of private park accommodation potentially unworthy (PPPP) – Source Dhrill | 0.045632 | 0.9143809 |

### Table 2
Projection of IDF departments on the two main PCA axis.

| Department                   | F1   | F2   |
|------------------------------|------|------|
| Paris                        | 9.605195 | 2.654331 |
| Seine-et-Marne               | −3.14978 | −2.797914 |
| Yvelines                     | 0.442294 | −4.153429 |
| Essonne                      | −1.7583 | −2.790276 |
| Hauts-de-Seine               | 3.911152 | −0.734134 |
| Seine-Saint-Denis            | −4.79127 | 7.2151162 |
| Val-de-Marne                 | −0.45865 | 0.7085487 |
| Val-d’Oise                   | −3.80063 | −0.102243 |

been observed that in Sub-Saharan Africa, the contamination and transmission rates are extremely lower relative to countries in the North and West of the Globe (Martinez-Alvarez et al., 2020; Nuwagira and Muzoora, 2020). The positive effects of various factors including the protective role of previous injections of Malaria vaccine on populations exposed to COVID-19 have been explored (Sargin and Yavasoglu, 2020). Moreover, the global death reports indicate that the number of national deaths appears to vary largely. Some countries report exclusively deaths in hospitals (like France at the early stage of the pandemic) while others merge deaths in hospital, domestic and nursing homes (like Germany). Accordingly, an international study seems to be unrealistic at the moment.

Unlike previous papers focusing on human factors, our study proposes an approach to explore the structural factors of contamination, contagion and mortality of COVID-19. Indeed, in addition to genetics and geography, we aim to explore new elements that may be put forward to explain the excess mortality in certain populations. To do this, we limit our study to Île-de-France. As shown in Fig. 1, the Île-de-France is a French region which includes eight departments, which has the unique characteristic of not constituting a cluster of contamination due to an identifiable and outstanding event.
Indeed, certain territorial units have formed clusters of contamination largely responsible for the degree of contamination at the National level. For example, in the French city of Mulhouse belonging to the Grand Est region, a major gathering of faithful

---

**Table 3**

Economic, social and financial variables.

|                        | Unemployment benefit in income | Poverty rate | Social minima in income | Little or no graduate in the workforce |
|------------------------|--------------------------------|--------------|-------------------------|---------------------------------------|
| Seine-Saint-Denis       | 39.13%                         | 84.07%       | 118.18%                 | 46.12%                                |
| Paris                  | −5.14%                         | 1.69%        | −27.27%                 | −30.97%                               |
| Seine-et-Marne         | −5.14%                         | −25.34%      | −7.44%                  | 5.85%                                 |
| Yvelines               | −14.62%                        | −37.57%      | −47.11%                 | −15.24%                               |
| Essonne                | −8.30%                         | −16.98%      | −14.05%                 | −0.29%                                |
| Hauts-de-Seine         | −11.46%                        | −21.48%      | −33.88%                 | −21.76%                               |
| Val-de-Marne           | −1.98%                         | 7.48%        | 5.79%                   | 4.70%                                 |
| Val-d'Oise             | 7.51%                          | 8.13%        | 5.79%                   | 11.60%                                |

---

Fig. 3. Link between age and excess mortality.

Fig. 4. Economic inequalities.

Indeed, certain territorial units have formed clusters of contamination largely responsible for the degree of contamination at the National level. For example, in the French city of Mulhouse belonging to the Grand Est region, a major gathering of faithful

---

3 In France, administrative levels in order of importance (ascending order) are municipalities/agglomerations (35,357 units), departments (101 units) and regions (18 units).
evangelists is considered to be responsible for a non-negligible part of the whole excess mortality linked to COVID-19 among the State. In addition, the Île-de-France region is highly populated with 12,174,880 million inhabitants (19% of the whole French population) and is socially heterogeneous in terms of ethnicity, professional qualification of workers, graduate of higher education and quality of the health system, etc. However, its boarders stand inside a small geographic area with no climatic ecosystems effects. Under these conditions, Île-de-France constitutes a relevant field of study for the various structural factors other than individual ones like age or comorbidities promoting the contamination, contagion and mortality rates of COVID-19.

2. Data and approach

The INSEE collects, analyses and disseminates information on the French economy and society. We start with a large panel of 66 variables, which are representative of the economic, financial or structural factors relating to housing in Île-de-France and its population. Then, using the principal component analysis (PCA), we select a closer panel of 30 variables which appear to be very

Table 4
Housing variables.

| Department          | Potentially unworthy housing | Household size | Overcrowded housing |
|---------------------|------------------------------|----------------|---------------------|
| Seine-Saint-Denis   | 104.78%                      | 9.47%          | 68.16%              |
| Paris               | 77.47%                       | −20.00%        | 29.80%              |
| Seine-et-Marne      | −37.20%                      | 5.26%          | −38.78%             |
| Yvelines            | −64.51%                      | 1.05%          | −40.41%             |
| Essonne             | −72.70%                      | 5.26%          | −28.98%             |
| Hauts-de-Seine      | −4.44%                       | −7.37%         | 6.12%               |
| Val-de-Marne        | −1.71%                       | −3.16%         | 11.84%              |
| Val-d’Oise          | −1.71%                       | 9.47%          | −7.76%              |

Table 5
Values of the delta percentage of our panel of data for each department – Part I.

| Departments          | Excess mortality | 0 → 19yrs  | 20 → 39yrs | 40 → 59yrs | 60 → 74yrs | ≥ 75yrs  |
|----------------------|------------------|------------|------------|------------|------------|----------|
| Paris                | 73.90%           | −37.41%    | 18.28%     | −4.97%     | 7.17%      | 14.38%   |
| Seine-et-Marne       | 71.70%           | 5.55%      | −8.82%     | 2.29%      | 3.93%      | −7.41%   |
| Yvelines             | 66.60%           | 2.34%      | −15.93%    | 3.63%      | 6.78%      | 14.38%   |
| Essonne              | 88.20%           | 4.76%      | −6.47%     | 0.98%      | −0.54%     | 2.45%    |
| Hauts-de-Seine       | 127.80%          | −6.54%     | 3.56%      | 1.31%      | −3.09%     | 8.48%    |
| Seine-Saint-Denis    | 128.10%          | 10.44%     | 4.51%      | −2.28%     | −15.50%    | −38.51%  |
| Val-de-Marne         | 96.50%           | −1.70%     | 1.44%      | −0.13%     | −0.93%     | 2.71%    |
| Val-d’Oise           | 88.60%           | 9.18%      | −4.52%     | −1.36%     | −1.22%     | −15.54%  |

Fig. 5. Inequalities linked to housing.
significant in terms of segmentation of the departments in Île-de-France, and particularly Seine-Saint-Denis.

2.1. Principal components analysis

Thus, in order to characterize the best set of discriminant variables, we proceed with a principal component analysis. This approach allows us to best capture the explanatory and segmenting power of the available variables. Fig. 2 shows the best representation (projection) in two dimensions of the 8 departments regarding the set of available variables. We see clearly that the department of Seine-Saint-Denis is far away from the others (in the upper left position), which argues in favor of a significant difference in terms of values of the variables from other departments in Île-de-France. Consequently, this proves that an examination of the specifics of these departments is useful and relevant in understanding and explaining the reasons and factors which brought to the excess COVID-19 mortality in Seine-Saint-Denis. More so, we can see that the most distant and therefore different departments with respect to Seine-Saint-Denis are Paris and Hauts-de-Seine.

To offer a deeper analysis of this segmentation, we take a look on the weight of each variable as represented by each of the two axis. These results are provided in Table 1. We can see that a positive value on the first axis (i.e. horizontal) characterizes the following:

- A high share of graduates of higher education in population out of school 15 years or more at a level of 96.50%;
- Average household size at a level of 95.96%;
- A high value of the aging index at a level of 93.60%;
- A high average hourly net salary at a level of 85.45%.

This suggests that a department with a high coordinate in Factor 1 exhibits all these points and that higher is its coordinate in these factors. The projection of IDF departments on these two main PCA axis are presented in Table 2.

The departments of Paris and Hauts-de-Seine which take a high value in this axis projection are so fundamentally and intrinsically characterized and determined by a population with a high level of education, with a higher salary than the other departments and also an older population. This last factor is, of course, the main reason why the mortality rates are important in both departments.

Conversely, the Seine-Saint-Denis department which takes the most negative value in this projection is largely characterized by a younger population with a lower level of education and a medium value of salary at the end. But, as we showed previously, its mortality rate due to COVID-19 is the highest. Furthermore, we consider the second axis (i.e. vertical) given that the Seine-Saint-Denis appears to be also isolated from other departments in the upper region (i.e. positive values).

Here, we can see that a positive value in this factor characterizes the following:

- A high number of main residences overcrowded at a level of 96.00%;
- A high share of private park accommodation potentially unworthy (PPPI) at a level of 91.44%;
- A high number of people living in an apartment as a household of at least 4 people at a level of 88.83%;
- A high poverty rate at a level of 88.20%;
- A high value of share of unemployment benefits in the revenue available at a level of 72.74%.

This implies that Seine-Saint-Denis is highlighted by very difficult economic and health conditions, overcrowded housing potentially unworthy, a low-income population, and mostly from income linked to unemployment benefits. Hence, these socio-economic conditions cause a higher mortality rate in the period of COVID-19 pandemic.

---

Table 6
Values of the delta percentage of our panel of data for each department – Part II.

| Department       | 2019-Q4 quarterly unemployment rate | Population density | Average household size | Median of standard of living | Share of taxable households | Share of unemployment benefits in disposable income |
|------------------|------------------------------------|--------------------|------------------------|-------------------------------|----------------------------|-----------------------------------------------|
| Paris            | −14.04%                            | 270.31%            | −20.00%                | 15.85%                        | 8.98%                      | −5.14%                                         |
| Seine-et-Marne   | −7.11%                             | −95.79%            | 5.26%                  | −2.43%                        | −1.78%                     | −1.94%                                         |
| Yvelines         | −14.04%                            | −88.83%            | 1.05%                  | 11.60%                        | 10.40%                     | −14.62%                                        |
| Essonne          | −9.88%                             | −87.29%            | 5.26%                  | −0.06%                        | 2.81%                      | −8.30%                                         |
| Hauts-de-Seine   | −12.65%                            | 62.69%             | −7.37%                 | 14.83%                        | 10.72%                     | −11.46%                                        |
| Seine-Saint-Denis| 44.19%                             | 21.21%             | 9.47%                  | −26.55%                       | −24.40%                    | 39.13%                                         |
| Val-de-Marne     | −0.17%                             | 0.22%              | −3.16%                 | −5.11%                        | −1.46%                     | −1.98%                                         |
| Val-d’Oise       | 13.69%                             | −82.52%            | 9.47%                  | −8.13%                        | −5.26%                     | 7.51%                                          |

4 Taken from the French statistical database of The National Institute of Statistics and Economic Studies (INSEE).
Table 7
Values of the delta percentage of our panel of data for each department – Part III.

| Department       | Share of social minima in disposable income | Poverty rate | Share of those with little or no education in the out-of-school population aged 15 and over | Share of higher education graduates in the out-of-school population of 15 years or more | Share of apartments in total housing | Share of houses in total housing |
|------------------|---------------------------------------------|--------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------|---------------------------------|
| Paris            | −27.27%                                     | 1.69%        | −30.97%                                                                         | 52.54%                                                                          | 44.56%                             | −97.14%                         |
| Seine-et-Marne   | −7.44%                                      | −25.34%      | 5.85%                                                                           | −25.87%                                                                         | −39.52%                            | 84.59%                          |
| Yvelines         | −47.11%                                     | −37.57%      | −15.24%                                                                         | 10.18%                                                                          | −16.22%                            | 35.35%                          |
| Essonne          | −14.05%                                     | −16.98%      | −0.29%                                                                          | −10.73%                                                                         | −22.49%                            | 49.01%                          |
| Hauts-de-Seine  | −33.88%                                     | −21.48%      | −21.76%                                                                         | 31.61%                                                                          | 29.62%                             | −63.15%                         |
| Seine-Saint-Denis| 118.18%                                     | 84.07%       | 46.12%                                                                          | −33.69%                                                                         | 10.51%                             | −22.48%                         |
| Val-de-Marne     | 5.79%                                       | 7.48%        | 4.70%                                                                           | −2.43%                                                                          | 13.50%                             | −29.47%                         |
| Val-d’Oise       | 5.79%                                       | 8.13%        | 11.60%                                                                          | −21.59%                                                                         | −19.96%                            | 43.29%                          |
The French Government is authorized to rule into legislative matters by decree when it concerns the minimum social benefits or level of education, and other variables specific to the structure of housing, we offer a chance to implement tailor-made structural policies. For instance, in regard to unemployment benefits, we observe that the number of jobs in Seine-Saint-Denis (+68.16%), Paris (+77.47%) and Yvelines (+9.47%) (see poverty rate in Fig. 4). Among the cluster, all the other departments have negative deltas (see unemployment benefit income) in Fig. 4).

With respect to the poverty rate using the same observation, four departments have positive deltas with a clear demarcation of the Seine-Saint-Denis (+84.07%), Val-d’Oise (+8.12%) and Seine-Marne (+7.48%) (see poverty rate in Fig. 4). We find similar result at the observation of social minima where three departments including Seine-Saint-Denis, Val-d’Oise and Val-de-Marne have positive deltas with a clear demarcation for Seine-Saint-Denis (+118.20%), Val-d’Oise and Val-de-Marne tied (+5.79%) (see Social minima in income in Fig. 4). Finally, in regard to the share of individuals without diploma into the workforce, Seine-Saint-Denis still occupies the first place with a delta of +46.12% compared to the average of the cohort. It is followed by Val-d’Oise (+116.64%), Seine-Marne (8.35%) and Val-de-Marne (+7.48%) (see poverty rate in Fig. 4).

Based on the analysis of economic and financial variables, the first conclusion that can be drawn is that there are several common points between Seine-Saint-Denis and Val-d’Oise. These are two departments with a smaller population of 75+ but with significant excess mortality, despite social distancing measures implemented by the French Government. Indeed, following the promulgation of the Law 2020-290 of March 23, 2020 code-named “Emergency to face the epidemic of COVID-19”, extended by the Law 2020-546 of May 11, 2020, the French Government is authorized to rule into legislative matters by decree when it concerns the fight against COVID-19 epidemic in France.

In addition, regarding inequalities relating to the structure of housing, with particular reference to unworthy housing, the two departments with positive deltas are Seine-Saint-Denis (+104.77%) and Paris (+77.47%) (see “Potentially unworthy housing” in Fig. 5). For the average size of households, five departments have a positive delta: Seine-Saint-Denis (+9.47%), Seine-Marne (+5.26%), Yvelines (+1.05%), Essonne (+5.26%) and Val-d’Oise (+9.47%) (see “Household size” in Fig. 5). Finally, regarding the variable “overcrowded main residences”, four departments have positive deltas including Seine-Saint-Denis (+68.16%), Paris (+29.79%), Hauts-de-Seine (+6.12%) and Val-de-Marne (+11.83%), with a delta far above that of Seine-Saint-Denis (see “Overcrowded housing” in Fig. 5).
|                     | Elderly accommodation | Emergency service | No. of overcrowded main residences | Population living in apartment | People living in apartments in a household of at least 4 people | Share of housing in the potentially unworthy private housing stock (PPPI) – Source Dhrill |
|---------------------|----------------------|------------------|-----------------------------------|-----------------|---------------------------------------------------------------|----------------------------------------------------------------------------------|
| Paris               | 52.58%               | 34.74%           | 29.80%                            | 53.73%          | 60.00%                                                        | 77.47%                                                                           |
| Seine-et-Marne      | 2.41%                | −7.37%           | −38.78%                           | −44.59%         | −25.33%                                                       | −37.20%                                                                          |
| Yvelines            | −6.53%               | 1.05%            | −40.41%                           | −20.36%         | −49.71%                                                       | −64.51%                                                                          |
| Essonne             | 4.47%                | 1.05%            | −28.98%                           | −25.11%         | −29.90%                                                       | −72.79%                                                                          |
| Hauts-de-Seine      | 10.65%               | 9.47%            | 6.12%                             | 32.52%          | 0.57%                                                         | −4.44%                                                                           |
| Seine-Saint-Denis   | −27.15%              | 1.05%            | 68.16%                            | 11.78%          | 53.90%                                                        | 104.78%                                                                          |
| Val-de-Marne        | −14.78%              | −15.79%          | 11.84%                            | 14.47%          | 8.19%                                                         | −1.71%                                                                           |
| Val-d'Oise          | −21.65%              | −24.21%          | −7.76%                            | −22.42%         | −17.71%                                                       | −1.71%                                                                           |
4. Conclusion and opening to future work

Seine-Saint-Denis differs from other departments in Île-de-France when grouped according to a number of important variables. On one hand, these variables relate to the main field of financial economic poverty while on the other, there are structural factors relating to housing. These variables shed light on the excess mortality during social distancing and lockdown policies implemented by the French Government. Six of these seven variables are also significant in Val-d'Oise, another department which, like Seine-Saint-Denis, has a significant excess mortality with a lower proportion of people over the age of 75. Thus, our study provides political leaders with a number of inputs which allows them to better implement effective measures in the event of a second wave of COVID-19 or new pandemics due to viruses within the COVID-19 family.

Territorial units with higher precariousness indicators (unemployment benefit income, poverty rate, social minima in income, little or no graduate in the workforce) and less suitable housing (unworthy housing, household size, overcrowded housing) are more at risk, including when their population is younger. Therefore, it is a requirement to set up new health policies facilitating an accurate monitoring of the inhabitants and their environment in these departments or agglomerations, with the main objective of breaking human-to-human transmission chains more quickly and efficiently. Regarding future studies, it would be interesting to corroborate the results obtained from this study with evidences from other countries and other continents regarding the analysis of structural factors and mortality rates during pandemics.

Conflict of interest

The authors declare that there is no conflict of interest.

Appendix

References

Abrams, E.M., Szelfer, S.J., 2020. Managing asthma during COVID-19: an example for other chronic conditions in children and adolescents. J. Pediatr. https://doi.org/10.1016/j.pediatrics.2020.04.049.

Altmann, D.M., Doonek, D.C., Boyton, R.J., 2020. What policy makers need to know about COVID-19 protective immunity. Lancet. https://doi.org/10.1016/S0140-6736(20)30865-5.

Bacon, S., Bates, C., et al., 2020. OpenSAFELY: Factors Associated with COVID-19-Related Hospital Death in the Linked Electronic Health Records of 17 Million Adult NHS Patients. Working Paper. University of Oxford https://doi.org/10.1101/2020.05.06.20092999.

Cohen, J., 2020. Vaccine designers take first shots at COVID-19. Science 368 (6486), 14-16. https://doi.org/10.1126/science.368.6486.14.

Desjardins, M.R., Hohl, A., Delmelle, E.M., 2020. Rapid surveillance of COVID-19 in the United States using a prospective space-time scan statistic: detecting and evaluating emerging clusters. Appl. Geogr. 118, 102202. https://doi.org/10.1016/j.apgeog.2020.102202.

Di Lorenzo, G., Di Trollo, R., 2020. Coronavirus disease (COVID-19) in Italy: analysis of risk factors and proposed remedial measures. Front. Med. 7, 140. https://doi.org/10.3389/fmed.2020.00140.

Gilbert, M., Puliano, G., et al., 2020. Preparedness and vulnerability of African countries against importations of COVID-19: a modelling study. Lancet 395 (10227), 871–877. https://doi.org/10.1016/S0140-6736(20)30411-6.

Hooper, M.W., Nápoles, A.M., Pérez-Stable, E.J., 2020. COVID-19 and racial/ethnic disparities. JAMA. https://doi.org/10.1001/jama.2020.8598.

Hopman, J., Allegranzi, B., Mehtar, S., 2020. Managing COVID-19 in low- and middle-income countries. JAMA 323 (16), 1549–1550. https://doi.org/10.1001/jama.2020.4169.

Klono, D.C., Umpierrez, G.E., 2020. COVID-19 in patients with diabetes: risk factors that increase morbidity. Metabolism. https://doi.org/10.1016/j.metabol.2020.154224.

Le, T.T., Andreadakis, Z., et al., 2020. The COVID-19 vaccine development landscape. Nat. Rev. Drug Discov. 19 (5), 305–306. https://doi.org/10.1038/s41573-020-00073-5.

Li, X., Xu, S., et al., 2020. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. J. Allergy Clin. Immunol. https://doi.org/10.1186/s41591-020-0863-y.

Liu, J., Zhou, J., et al., 2020. Impact of meteorological factors on the COVID-19 transmission: a multi-city study in China. Sci. Total Environ. 726, 138513.

Li, X., Xu, S., et al., 2020. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. J. Allergy Clin. Immunol. https://doi.org/10.1016/j.jaci.2020.04.006.

Liu, J., Zhou, J., et al., 2020. Impact of meteorological factors on the COVID-19 transmission: a multi-city study in China. Sci. Total Environ. 726, 138513.

Martinez-Alvarez, M., Martínez, L.Á., et al., 2020. COVID-19 pandemic in west Africa. Lancet Glob. Health 8 (5), 631–632.

Mceek, M., Stickler, D., 2020. If the world fails to protect the economy, COVID-19 will damage health not just now but also in the future. Nat. Med. 26, 640–642. https://doi.org/10.1038/s41591-020-0863-y.

Mihm, S., 2020. COVID-19: possible impact of the genetic background in IFNL genes on disease outcomes. J. Innate Immun. https://doi.org/10.1159/000508076.

NHS England, 2020. COVID-19 Daily Deaths. https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-daily-deaths.

Nuwagira, E., Muzoora, C., 2020. Is Sub-Saharan Africa prepared for COVID-19? Trop. Med. Health 48 (18). https://doi.org/10.1186/s41182-020-00206-x.

Rayet, S., Umpierrez, G.E., 2020. COVID-19 in patients with diabetes: risk factors that increase morbidity. Metabolism. https://doi.org/10.1016/j.metabol.2020.154224.

Sargi, G., Yasavoglu, S., 2020. Is Coronavirus Disease 2019 (COVID-19) seen less in countries more exposed to Malaria? Med. Hypotheses 140. https://doi.org/10.1016/j.mehy.2020.109756.

Shoenfeld, Y., 2020. Corona (COVID-19) time musings: our involvement in COVID-19 pathogenesis, diagnosis, treatment and vaccine planning. Autoimmun. Rev. 19, 102561. https://doi.org/10.1016/j.autrev.2020.102538.

WHO, 2020a. WHO Director-General’s Opening Remarks at the Media Briefing on COVID-19 – 11 March 2020. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19-11-march-2020.

WHO, 2020b. Clinical Management of Severe Acute Respiratory Infection When COVID-19 Is Suspected. https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected.

Yue, X.G., Shao, X.F., et al., 2020. Risk prediction and assessment: duration, infections, and death toll of the COVID-19 and its impact on China’s economy. J. Risk Financ. Manag. 13 (4), 66. https://doi.org/10.3390/jrfm13040066.