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► **To cite this version:**

Stéphane Goutte, Thomas Péran, Thomas Porcher. Social Inequalities and Vulnerability of population facing the COVID-19: the case of Seine-Saint-Denis in Ile-de-France. 2020. halshs-02613278

HAL Id: halshs-02613278

<https://shs.hal.science/halshs-02613278>

Preprint submitted on 20 May 2020

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Social Inequalities and Vulnerability of population facing the COVID-19: the case of *Seine-Saint-Denis* in *Ile-de-France*.

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May 19, 2020

Abstract

The vast majority of research focuses on the individual factors leading to coronavirus mortality. Numerous studies have shown that the age of the population is the dominant factor explaining mortality. Other more recent work has added gender, comorbidity, ethnicity and obesity. Based on the most populous and dense region of France — Île-de-France, grouping 8 heterogeneous departments in terms of wealth — our study seeks to identify whether economic and financial or structural factors related to housing can explain a faster circulation of the virus during social distancing like lockdown, and therefore lead to excess mortality. We show that agglomerations with higher precariousness indicators (unemployment benefit income, poverty rate, social minima in income, little or no graduate in the workforce) and less suitable housing (potentially unworthy housing, household size, overcrowded housing) are more at risk, including if their population is younger. Our study therefore provides political leaders with a number of indications allowing them to take effective measures in the event of a second wave of COVID-19 or forthcoming coronavirus pandemics.

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

*JEL classification:*I14; I18; J14; H12; R11

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1 Introduction

On the 11th of March 2020, the Director General of the World Health Organization (WHO) declared the COVID-19 epidemic as an ongoing pandemic, while more than 110 states were heavily affected worldwide, totalizing approximately 120,000 cases of coronavirus (WHO, 2020a). Very quickly, 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; Thanh, Andreadakis et al., 2020) and reach in the earliest possible delay a satisfactory level of collective immunity (Altmann, Douek and Boyton, 2020). Second, the medical profession devoted itself to studying the effects of the virus on the health of individuals. Finally, the major part of researchers has tried to identify the most effective ways to staunch this global scourge. Relative to this last axis in which this current study fully fits, we aim to understand what are the factors of transmission of the virus (Li, Xu et al., 2020) and worsening of the situation health (Di Lorenzo and Di Trolio, 2020), but also to assess the extent of the economic consequences that the health crisis inevitably causes (McKee and Stuckler, 2020; Yue, Shao et al., 2020).

Fundamental elements to understand the COVID-19 phenomenon are immediately revealed by the first studies. It is thus demonstrated that the source of the pandemic is to be located in the Chinese city of Wuhan inside Hubei Province and that in the category of elderly individuals (NHS England, 2020) the highest mortality rate is to be deplored. Extremely fast, these results are refined to allow a precise identification of other comorbidity factors (Bacon, Bates 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 Szefer, 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; Webb Hooper, Nápoles and Pérez-Stable, 2020) could constitute a medical field fostering the mortality of the virus. In other words, a standard “robot portrait” of the patient most at risk in front of COVID-19 is already drafted.

On the other hand, geographical studies show that if not a single continent is sheltered¹ (Hopman, Allegranzi and Mehtar, 2020; Gilbert, Pullano et al., 2020), we observe within the West the highest morbidity rate, according to the following top Global ranking: United States of America ($\dot{\iota}$ 79,500 deaths), United Kingdom ($\dot{\iota}$ 31,900 deaths), Italy ($\dot{\iota}$ 30,500 deaths), Spain ($\dot{\iota}$ 26 600), France ($\dot{\iota}$ 26,300)². Therefore, in order to better understand 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.

¹It 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).

²Figures updated to May 11, 2020.

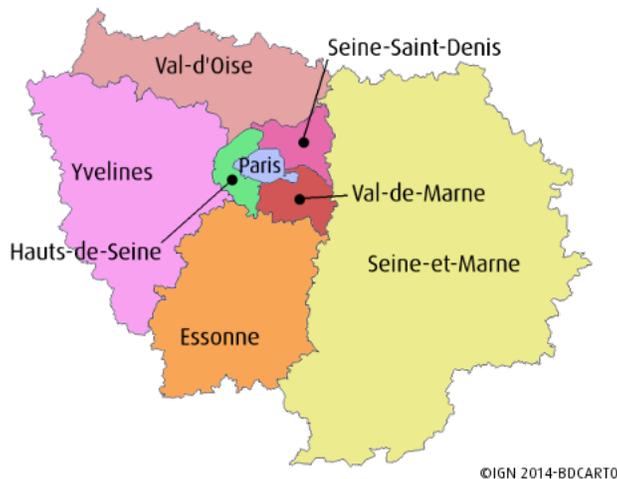


Figure 1: Map of Île-de-France

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, Hohl and Delmelle, 2020; Liu, Zhou et al., 2020). For example, the observation is made that in Sub-Saharan Africa, the contamination and transmission/propagation rates are extremely low compared to the countries in the North and West of the Globe (Martinez-Alvarez, Jarde et al., 2020; Nuwagira and Muzoora, 2020). The positive effects of various factors are discussed in this regard, such as the protective role of previous injections of Malaria vaccine on populations exposed to COVID-19 (Sargin and Yavasoglu, 2020). Moreover, the global death Report show that the counting of national deaths is not uniform. Some countries report exclusively deaths in hospital (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.

Compared to the other research papers mentioned above, our study proposes an approach to the structural factors of contamination/contagion/mortality, rather than a focus on human factors. In other words, it is a question of asking whether, in addition to genetics and geography, new elements can be put forward to explain the excess mortality in certain populations. For this, we have limited our research to Île-de-France (see Figure (2.1)), a French region built of eight departments³, which has the unique characteristic of not constituting a cluster of contamination due to an identifiable and outstanding event.

³In France, administrative levels in order of importance (ascending order) are municipalities/agglomerations (35 357 units), departments (101 units) and regions (18 units).

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 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 socially heterogeneous (ethnicity, professional qualification of workers, graduate of higher education, quality of the health system...) but its borders 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/mortality tryptic.

2 Data and Approach

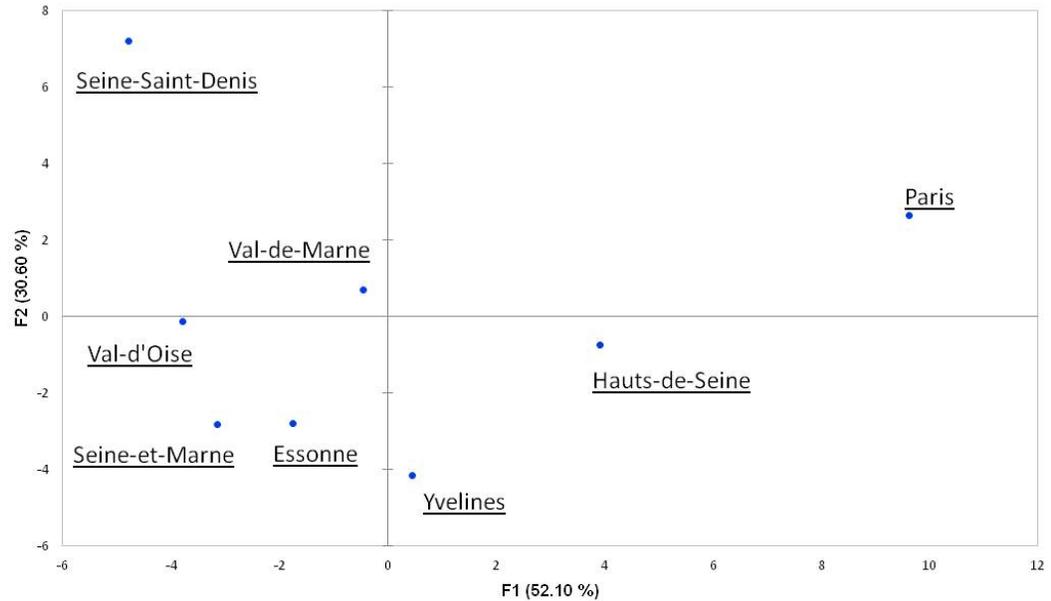
Starting with a large panel of 66 variables⁴ which were representative of the economic, financial or structural factors related to housing in Ile de France and its population. This data collects, analyses and disseminates information on the French economy and society. We finally select using a Principal Component Analysis (PCA) a closer panel of 30 variables which are all more significant in term of segmentation of our Departments (and in particular the 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 variables we have.

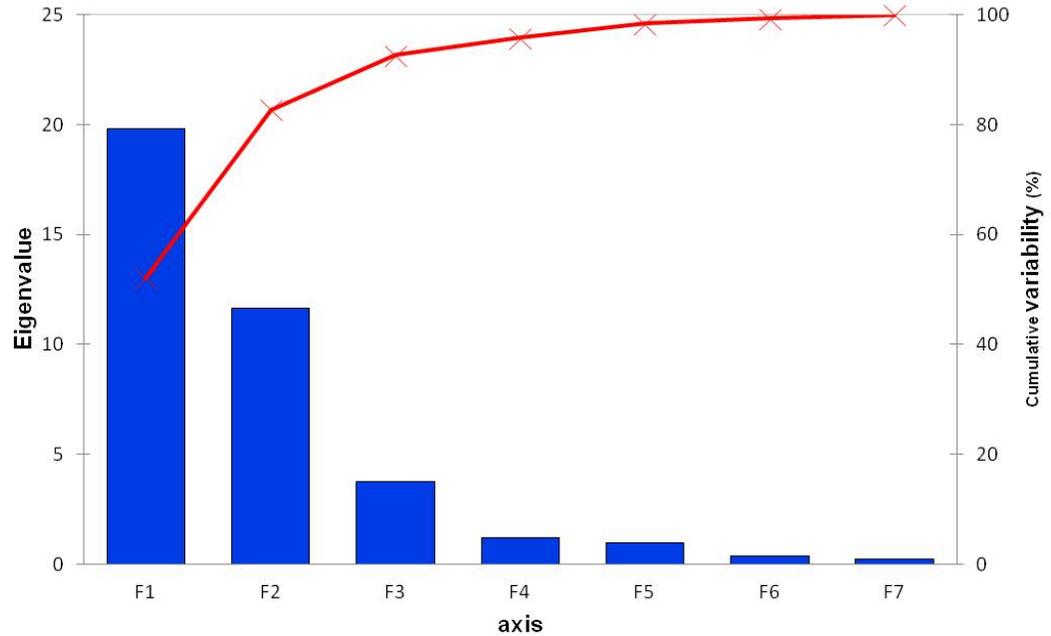
⁴taken from the statistical database of The National Institute of Statistics and Economic Studies (INSEE)

Figure 2: Projection of IDF Departments on the two main PCA axis



The Figure 2.1 shows the best representation (projection) in two dimensions of our 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 term of variable values from the others departments in Ile de France. Thus, this prove that a study of the specificities of this departments is useful and relevant to understand and explain the reasons and factors which brought to this excess of mortality in Seine-Saint-Denis. Moreover, we can see that the most distant and therefore different departments with respect to Seine-Saint-Denis are Paris and Haut de Seine. The can see in Figure 2.1, the cumulative variability obtained by taking a representation in this only two main factor axis equals 82.70%. This prove the statistical relevance of this projection.

Figure 3: Cumulative Variability obtained for each factor axis



If we want to go more deeply in the explanation of this segmentation, we can take a look on the weights of each variables given by each two axis. These results are provided in Table 1. We can see that a positive value on the first axis (i.e. horizontal) characterizes:

- a high share of graduates of higher education in pop. 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 means that a department with a high coordinate in this Factor 1 exhibits all this points; and higher is its coordinate higher is these factors. The projection of IDF Departments on the these two main PCA axis are stated in Table 2.

The Departments of Paris and Haut 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 an older population than the other one. This last factor is of course the main reason why the mortality are important in both departments.

Conversely, the Seine-Saint-Denis department which takes the most negative value in this projection is so characterized by a younger population with a less level of education and so an average value of salary at the end. But, as we show previously, its excess of surmortality dues to COVID-19 is the higher. We so have to look the interpretation of the second axis (i.e. vertical) since the Seine-Saint-Denis is again isolated than the other departments in the upper region (i.e. positive values).

We can see that a positive value in this factor characterizes:

- 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 in 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 rev. avail. at a level of 72.74%

This means that the Seine-Saint-Denis is highlighted by very difficult economic and health conditions: overcrowded housing, potentially unworthy; a low-income population, mostly from income linked to unemployment benefits. Hence, conditions socio-economics which bring surmortality in period of pandemic.

Table 1: Explication Weights of each variables on the two main axis factor

	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	0,0183661
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
which population living in apartments Part (%)	0,570496	0,3373785
People living in an apartment in a household of at least 4 people	0,141567	0,828304
Share of private park accommodation potentially unworthy (PPPI) - Source Dhrill	0,045632	0,9143809

Table 2: Projection of IDF Departments on the two main PCA axis

	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

3 Results

The list of these variables can be see in Tables 3 to 7 in Appendix. To compare the values of these set of variables we decided to evaluate the variation in percentage of each value for each department with respect to the average of the region. It means that a value of 10% represents that this department has a value 10 % higher than we average of all departments in Ile de France.

	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%

Our study provides interesting results. We note in Figure 3 that the link between the population over age of 75 and excess mortality is not absolute.

	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%

Figure 4: Link between Age and Excess mortality

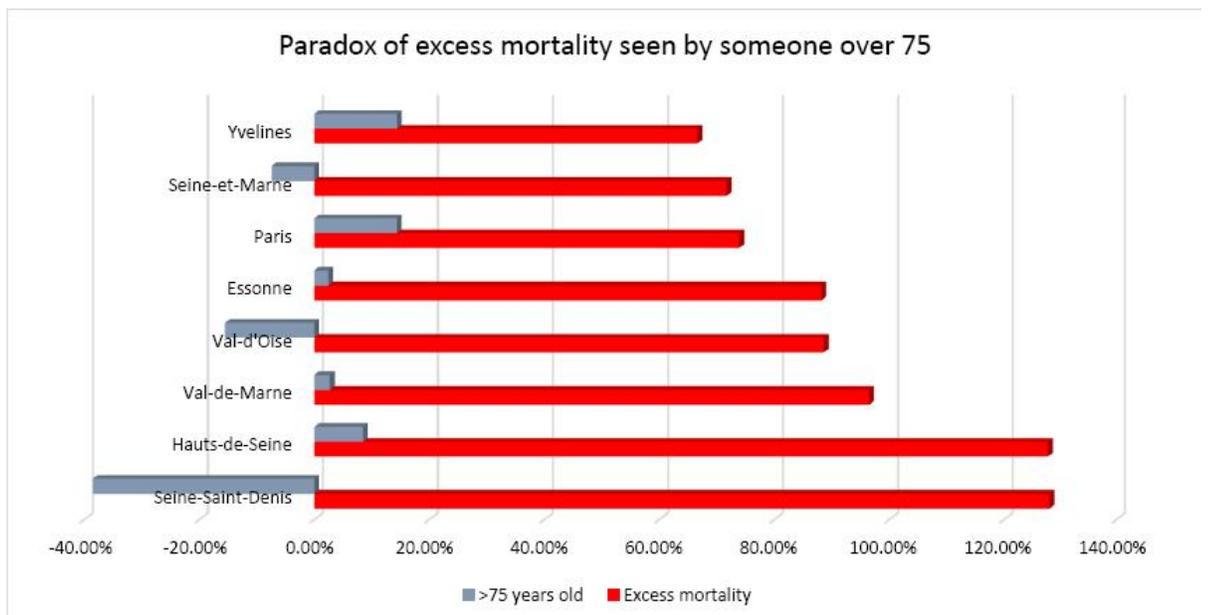
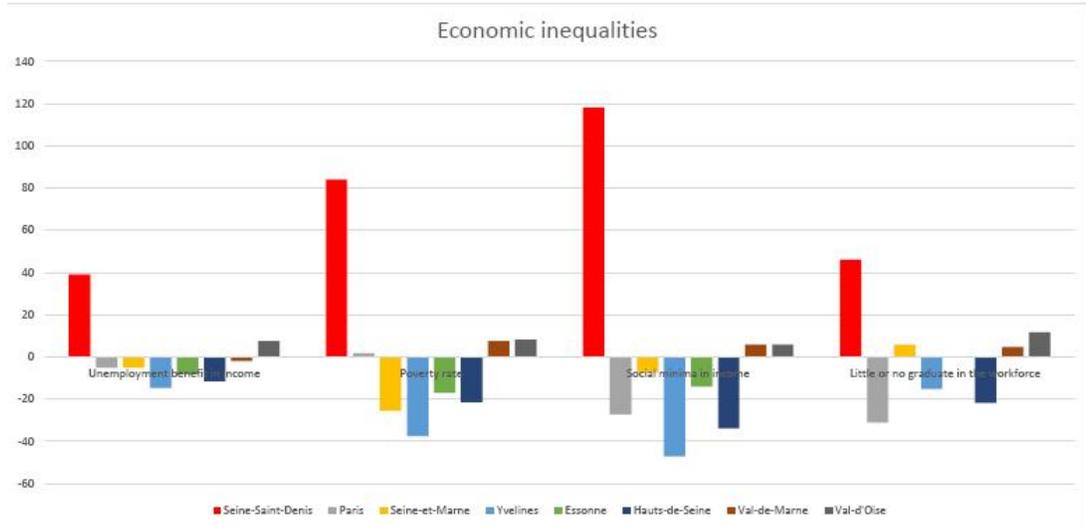
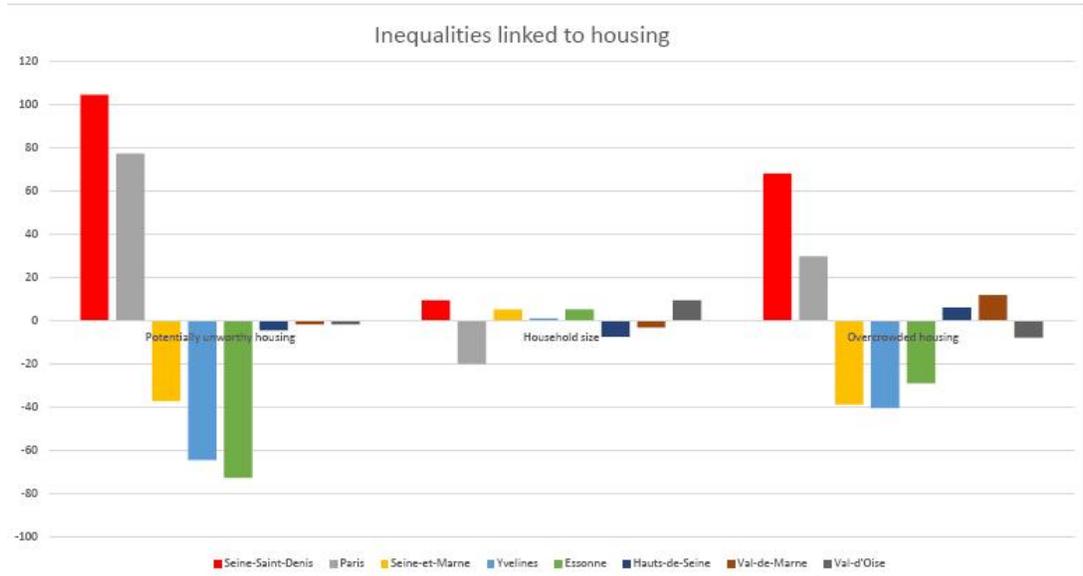


Figure 5: Economic Inequalities



Two departments with the highest population deltas over age of 75, Paris (+14.38%) and Yvelines (+14.38%), are among the departments with the lowest excess mortality (respectively +73.90% and +66.60%). Conversely, while Seine-Saint-Denis department displays the lowest delta on the population over 75 (-38.51%) it shows the highest excess mortality (+128.10%). Theoretically, the standard observation would have been the opposite side: The high mortality rate observed among people over 75s in France, representing 78.3% of deaths with an average age of 81.2 (Santé Publique France, 2020), should have led to a negative ranking on such departments. The Val-d'Oise is also a department with a negative delta regarding the population over 75 years old (-15.54%) but with the fourth excess mortality in Île-de-France (+88.6%). Seine-et-Marne department has also a smaller population of over 75 (-7.41%) associated to an excess mortality rate of +71.70%.

Figure 6: Inequalities linked to housing



Our study allows us to identify a broader number of factors, first, and to point out the specificity of each department with a significant excess mortality despite their more advantageous demography compared to others, second. By taking economic, social and financial variables that can reveal the insecurity of department populations, such as unemployment benefits, poverty rate, minimum social benefits or level of education, and by adding variables specific to the structure of housing, we offer a chance to implement tailor-made structural policies. For instance, in regard to unemployment benefit income, we observe that Seine-Saint-Denis and Val-d'Oise are the only departments to have a positive delta (respectively +39.13% and +7.51%), with a very clear demarcation for Seine-Saint-Denis (see Figure 3). Among the cluster, all the other departments have negative delta (see unemployment benefit income in Figure 3). We come to the same observation according to the poverty rate, where four departments have positive deltas with a clear demarcation of the Seine-Saint-Denis (+84.07%), then we rank Val-d'Oise (+8.12%) and Val-de-Marne (+7.48%) (see Poverty rate in Figure 3). We find similar result at the observation of social minima where three departments (Seine-Saint-Denis, Val-d'Oise and Val-de-Marne) have all 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 Figure 3). Finally, concerning the part 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, followed by Val-d’Oise (+11.60%), Seine-et-Marne (5.84%) and Val-de-Marne (+4.69%) (see graph little or no graduate in the work force in Figure 3). Based on the analysis of economic and financial variables, the first conclusion that can be drawn is that there are therefore several common points between Seine-Saint-Denis and Val-d’Oise, two departments having a smaller population of 75+ but suffering a significant excess mortality, despite social distancing measures implemented by the French Government. Indeed, since the promulgation of the Law 2020-290 of March 23, 2020 said ‘Emergency to face the epidemic of COVID-19’, prolonged by the Law 2020-546 of May 11, 2020⁵, the French Government is authorized to rule into legislative matters by decree when it comes to fight against the epidemic in France. In addition, regarding inequalities related to the structure of housing, specifically the unworthy housing, the two departments with positive deltas are Seine-Saint-Denis (+104.77%) and Paris (+77.47%) (see Potentially unworthy housing in Figure 3). For the average size of households, five departments have a positive delta: Seine-Saint-Denis (+9.47%), Seine-et-Marne (+5.26%), Yvelines (+1.05%), Essonne (+5.26%) and Val-d’Oise (+9.47%) (see Household size in Figure 3). Finally, four departments have positive deltas at the variable “overcrowded main residences”: Seine-Saint-Denis (+68.16%), Paris (+29.79%), Hauts-de-Seine (+6.12%) and Val-de-Marne (+ 11.83%), with a delta far above for Seine-Saint-Denis (see Overcrowded housing in Figure 3).

4 Conclusion and opening to future work

Seine-Saint-Denis differs from other departments according to a number of important variables. These variables, on the main field of financial economic poverty, on the one hand, and structural factors linked to housing, on the other hand, may explain the excess mortality during social distancing and lockdown put in place by 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. Our study therefore provides political leaders with a number of inputs allowing them to better implement effective measures in the event of a second wave of COVID-19 or new pandemics due to viruses inside the coronavirus family. Agglomerations 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. It is therefore 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. It would be interesting in an additional work to see if, in other countries and other continents, the results obtained at

⁵Refer to <https://www.legifrance.gouv.fr/>.

the occasion of the analysis of structural factors go in the same direction as in Seine-Saint-Denis in France.

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Table 3: Values of the delta percentage of our panel of data for each departments
- Part I

Departments	Excess mortality	0 to 19y	20 to 39y	40 to 59y	60 to 74y	75y and more
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%

6 Appendix

Table 4: Values of the delta percentage of our panel of data for each departments
- Part II

	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%	-5,14%
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%

Table 5: Values of the delta percentage of our panel of data for each departments
- Part III

	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%	-10,75%	-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%

Table 6: Values of the delta percentage of our panel of data for each departments
 - Part IV

	Share of workers in the number of jobs	average hourly net wages	Share of public administration, education, health and social work	General practitioner 2018	Nurse	Pharmacy
Paris	-37,74%	28,90%	-9,94%	116,64%	126,70%	114,95%
Seine-et-Marne	39,25%	-14,55%	6,47%	-15,67%	-1,90%	-23,91%
Yvelines	-4,27%	14,69%	-0,09%	-9,61%	-24,89%	-15,39%
Essonne	11,80%	-8,35%	8,30%	-26,61%	-12,76%	-27,05%
Hauts-de-Seine	-47,11%	24,93%	-38,38%	1,67%	-24,71%	4,98%
Seine-Saint-Denis	12,47%	-25,12%	4,65%	-16,09%	-17,10%	-14,28%
Val-de-Marne	1,76%	-6,78%	12,31%	-21,39%	-28,24%	-12,43%
Val-d'Oise	23,85%	-13,71%	16,68%	-28,96%	-17,10%	-26,87%

Table 7: Values of the delta percentage of our panel of data for each departments
- Part V

	Elderly accommodation	Emergency service	Nb. of overcrowded main residences	Which 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%	-72,70%
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%