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Centralization of Care in High Volume Hospitals and Inequalities in Access to Care

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ABSTRACT

In 2018, the French National Health Insurance proposed to increase the minimum volume threshold for breast cancer and to set a specific threshold for ovarian cancer in order to get an authorization to treat these patients. Using an exhaustive nationwide data set, the aim of this study is to evaluate the impact of the application of minimum volume thresholds for breast cancer and ovarian cancer in France on socioeconomic and spatial inequalities in patient access to care, taking into account patient preferences for their preferred provider. Our findings indicate that it would increase spatial inequalities and introduce socioeconomic inequalities in access to specialized care in terms of travel distance and will contribute to the medical desertification in rural areas that already have less access to non-specialized care. Our results underline that ignoring patient preferences when assessing the impact of such policies drastically underestimate the deterioration in patient access to care.

Keywords: Inequalities; Access to Care; Volume outcome relationship; France, Epithelial Ovarian Cancer; Breast Cancer; Organization of care; Minimum Volume Standard; Centralization of Care; Volume-Threshold

JEL Codes: C31; I11; I14; I18

1. Introduction

Inequalities in health and in access to healthcare are a major concern for global society. There is ample evidence of disparities in the health status of different social groups in all countries – whether low-, middle- or high-income (Beckfield and Olafsdottir, 2013). Strong inequalities in access to specialized care in favor of richer people have also been underlined in most OECD countries, which are substantially influenced by spatial variation in the supply of healthcare for different social groups (Doorslaer et al., 2006). These inequities have significant social and economic costs for both individuals and societies, and are the target of many policies.

Over the 21st century, increasing efforts have been made to improve the quality of care for complex and risky procedures. Worldwide, the centralization of complex care has moved to the center of the health policy debate as a unique opportunity to increase the quality of care through reorganization of the supply side of the market. In the US, incentives toward centralization have been put forward by the Leapfrog Group (a coalition of large healthcare purchasers representing collectively over 20 million people in the United States), which introduced minimum volume standards for eight procedures as part of their safety initiative. In Europe, a few countries made this jump and experimented with centralized practice, such as the centralization of surgeries for advanced ovarian cancer in Norway, the centralization of acute stroke care in London (UK), and the application of minimum volume standards for eight medical procedures in Germany (Aune et al., 2012; De Cruppé et al., 2015; Friebel et al., 2018). As part of the general interest in centralization, the French National Health Insurance published a report in 2018 with proposals to improve the efficiency of the French healthcare system. It has been put forward to increase the minimum volume threshold for breast cancer from 30 to 150 surgeries per year, and to set a specific volume threshold for ovarian cancer at 10 or 20 surgeries per year (French National Health Insurance, 2018). The proposed thresholds are in line with the guidelines of the European Commission Initiative on Breast Cancer, as well as the guidelines of the European Society of Gynecological Oncology (ESGO) (Perry et al., 2008; Querleu et

al., 2016b). The French healthcare system combines universal coverage, provided by the French National Health Insurance, with a public–private mix of hospital (Rodwin, 2003). Providers performing surgeries for cancer care are mandated to have specific authorization from the French Cancer Institute. Implementing the policy, hospitals which had a level of activity below the proposed thresholds would have their authorization revoked. To date, the French National Health Insurance has only made a proposed policy by publishing their annual report with proposals to improve the French healthcare system (French National Health Insurance, 2018). The French Minister of Health and Solidarity has also mandated the expertise of the French National Cancer Institute, which has recently published a report comparing two strategies to assess hospital volume activities for cancer care (French Cancer Institute, 2019). The application of minimum volume thresholds is intended to withdraw the lowest volume hospitals from the market based on the belief that increasing hospital volume activities would increase the quality of care. There have been hundreds of studies investigating the volume-outcome relationship in healthcare, and they indeed tend to confirm that higher volume hospitals tend to provide higher-quality care, especially for complex diseases such as cancer (Cowan et al., 2016; Gaynor et al., 2005; Hentschker and Mennicken, 2018; Huguet et al., 2018; Yen et al., 2017).

However, the centralization of care sparks a debate on the trade-off between quality of care and patient access to care. In most developed countries, patients are free to pick the provider that best matches their preferences. In France, patients need to be referred by their general practitioner (GP) in order to be fully reimbursed by the social security system for specialized care. Note that the French payment scheme is such that GPs have no financial incentives during the referral process, nor contract with providers. In this context, patient preferences are likely to be an important driver of the impact of centralized care on patient access to care, since patients do consider several factors they care about when choosing where to be treated, rather than basing their choice on only the relative distance of each provider (Beckert et al., 2012; Victoor et al., 2012). Moreover, although centralized care would obviously have a detrimental effect on patient access to care, its impact on

socioeconomic and spatial inequalities remains unclear. Its impact on spatial inequalities is particularly uncertain, since inequalities in access to care could be reduced if hospitals located in areas already suffering from medical desertification are, to some extent, already centralized, thanks to a potentially lower degree of competition in these areas. Conversely, it could widen inequalities in the opposite scenario. Similarly, socioeconomic inequalities in access to care are, to some extent, induced by the existence of spatial inequalities. They are therefore hard to predict *ex ante*, as they strongly depend on the existence and the strength of spatial inequalities.

Using a nationwide database, the aim of this study is to evaluate the impact of the application of minimum volume thresholds for breast cancer and ovarian cancer in France on socioeconomic and spatial inequalities in patient access to care, based on a simulation approach. We use hospital discharge data from the Medical Information Systems Program (PMSI), which records comprehensively hospital stays in French hospitals (Boudemaghe and Belhadj, 2017). To evaluate the impact of a minimum volume threshold on patient access, the first stage is to predict how patients would reallocate when a portion of all hospitals is withdrawn from the market. To that end, we elicit patient preferences based on observed choices before the centralization of care and predict patient probabilities of hospital choice. After a transformation on the probabilities, we predict the flows of patients from hospitals withdrawn from the market to high volume hospitals. Then, to explore spatial inequalities, we investigate whether there are spatial variations in expected patient-hospital distances, expected square distances, expected additional distances, and rate of patients affected by the policy. We evaluate socioeconomic inequalities through jointly investigating two mechanisms. Firstly, the likelihood of being affected by the policy, which may correlate with patients' socioeconomic characteristics. Secondly, variations in the degree of deterioration in patient access among the subgroup of patients affected by the policy according to socioeconomic characteristics. As a benchmark, we also use the evaluation strategy often used in the literature, which consists of assuming that patients will choose to be reallocated to their closest available hospital (Hentschker et al., 2018; Hentschker and Mennicken, 2015; Kobayashi et al., 2015). By making this assumption,

patients are no longer given the choice of their preferred provider and we thus predict a reallocation of patients to high volume hospitals that minimizes patient-hospital distances. In the analysis, breast and ovarian cancer are studied separately because they differ on several aspects. Breast cancer is the most frequent cancer among women, affecting 2.1 million women each year, while ovarian cancer is rather a rare disease with 300 000 new cases each year. Statistics from the Surveillance, Epidemiology, and End Results Program (SEER) indicate a five-year conditional relative survival of 93.2% for breast cancer against 69.9% for ovarian cancer for a 65+ year old woman (Source: https://seer.cancer.gov).

Our contribution to the literature stems from several aspects. The key feature of this study is that we took into account patient preferences for their preferred provider in order to evaluate the impact of centralizing care. Conversely, studies in the existing literature instead assumed that patients would choose their closest hospital after centralization, and therefore estimated the lowest boundary of the deterioration in patient access (i.e., patient-hospital allocations that minimize distances). This study also contributes to the literature by investigating socioeconomic and spatial inequalities in access that are caused by a centralization of care.

2. Data

In this study, we used three data sets in order to obtain detailed information on patient characteristics, hospital characteristics, and patient residential location characteristics for our two populations of interest. Firstly, we identified patients treated for breast cancer or ovarian cancer in France by using hospital discharge data from the Medical Information Systems Program (PMSI), managed by the government agency *Agence Technique de l'Information sur l'Hospitalisation* (ATIH). The PMSI is an exhaustive nationwide database that records information about each hospital stay in France (Boudemaghe and Belhadj, 2017). The inclusion criteria were being diagnosed for breast or

ovarian cancer, surgically treated in a hospital in mainland France in 2017, and living in mainland France. More details about the inclusion criteria are provided in appendix A. For each patient, the information recorded included the FINESS number (a unique identifier for hospitals in France), the exact location of hospitals, the residential location of patients (at municipality level), patients' length of stay at hospital, and the age of the patients. We also computed straight-line distance in kilometers between patients' residential municipalities and the exact location of all hospitals in mainland France. Using the patient-hospital distances, we computed patient choice set size as the number of available hospitals (i.e., having an authorization to treat patient's cancer) within a radius of 50 km.

Secondly, we included hospital characteristics from the French Hospital Survey (Statistique annuelle des établissements - SAE), managed by the *Directorate for Research Studies Evaluation and Statistics* (DREES). We included information about the type of hospital (public, private for profit, private not for profit), whether there is a department of oncology, the number of hospital stays in oncology, the number of surgical rooms, the bed occupation rate, and the number of employees for the prevention of nosocomial infection.

Lastly, we included aggregate information about patients' residential location from open access data sets, which are managed by the *National Institute of Statistics and Economic Studies* (INSEE). We obtained detailed information about the municipalities, such as the population size, median standard of living (in euro), number of drug stores, number of ambulances, and number of households having a car within each municipality in mainland France. We also obtained broader information on department characteristics, such as the number of emergency units and the number of short-stay hospitals within each department.

3. Methods

The aim of this study is to evaluate the impact of the application of minimum volume thresholds for breast cancer and ovarian cancer on socioeconomic and spatial inequalities in patient access to care in France. Our empirical strategy is composed of three steps.

(i) First, we will predict the expected hospital volume activities of the high volume hospitals (HV), when a threshold *k* is applied. In this context, all hospitals below the threshold *k* (i.e. fewer than *k* patients treated per year in that hospital) will lose their authorization to treat the cancer considered (i.e. breast cancer, ovarian cancer or both). We will refer to patients who were treated in hospitals below the threshold as patients needing to be reallocated, in the sense that they will have to choose another hospital among the HV hospitals in order to be treated. The volume activities of the remaining hospitals will increase on average, as the group of patients needing to be reallocated will have to choose a provider among the remaining ones. Thus, the expected hospital volume activity of a HV hospital when a threshold of *k* is applied corresponds to its observed volume activity (i.e. number of patients treated in that hospital initially) plus the flow of patients who were treated in a LV hospital initially and chose to be treated in that HV hospital.

As a benchmark, we follow the method used in the existing literature to assess patient flows (Hentschker et al., 2018; Hentschker and Mennicken, 2015; Kobayashi et al., 2015). Following this method, patients needing to be reallocated are assumed to have chosen to be treated in their nearest HV hospital when threshold k is applied. This assumption is very conservative when assessing patient access to care, since it does not take into account patient preferences for hospital choice. Therefore, we also employed an alternative method that takes into account patient preferences in the prediction of patient flows from LV to HV hospitals. In this alternative method, patient flows are modeled in terms of probabilities. Thus, we define the expected hospital volume activity of a HV hospital *j* when a threshold *k* is applied as:

$$E\left(Volume_j^k\right) = Volume_j + \sum_{i \in N^{LVH}} P_{ij}^* \qquad (1)$$

Where $Volume_j$ is the observed volume activity of hospital *j* initially and P_{ij}^* is the probability that patient *i* chooses to be treated in hospital *j*. Note that $\sum_{j \in HVH} P_{ij}^* = 1$, which ensures that the sum of the expected volume activities over all HV hospitals, will correspond to the initial population size.

The first challenge is to estimate the probabilities P_{ij}^*. Indeed, we cannot directly estimate these probabilities because we did not observe a choice among the HV hospitals for patients needing to be reallocated, since they were treated in an LV hospital initially. To overcome this issue, we estimated a Conditional Logit model in order to estimate the probabilities of hospital choice (i.e. probability that a patient *i* chooses to be treated in hospital *j*) over all hospitals, regardless of their volume activities (McFadden, 1974). Since the Conditional Logit is estimated on the full choice set: $\sum_{l=1}^{J} P_{il} = 1$.

$$P_{ij} = \frac{e^{\beta' H_{ij}}}{\sum_{l=1}^{J} e^{\beta' H_{il}}} \qquad (2)$$

Where H_{ij} is a matrix of hospital-specific characteristics used as predictors of patient choice. We included the distance between patient's home and hospital location as our main predictor of patient's hospital choice. The distance was included as a continuous variable (i.e. in kilometers), as a dummy variable indicating whether the hospital is the closest, and in interactions with the age of patients and their length of stay at hospital to allow for heterogeneous preferences for distance. Patient distance aversion might indeed vary according to age and the degree of illness (Victoor et al., 2012). The full set of hospital-specific characteristics included the type of provider (i.e. public, private for profit, private not for profit), the specialization profile (e.g. an indicator indicating whether there is a unit specialized in oncology and the number of hospital stays in oncology), the number of surgical rooms, the bed occupation rates, and the number of employees for prevention of nosocomial infections. An important assumption of the Conditional Logit model is the Independence from Irrelevant Alternatives (IIA). This assumption implies that for any two hospitals *j* and *k*, the ratio of the Logit probabilities is:

$$\frac{P_{ij}}{P_{ik}} = \frac{e^{\beta' H_{ij}} \,/\, \sum_{l=1}^{J} e^{\beta' H_{il}}}{e^{\beta' H_{ik}} \,/\, \sum_{l=1}^{J} e^{\beta' H_{il}}} = \frac{e^{\beta' H_{ij}}}{e^{\beta' H_{ik}}} \qquad (3)$$

It can be seen in equation *(3)* that this ratio does not depend on any hospitals other than *j* and *k*. Thus, adding or eliminating a hospital in the choice set will have no impact on the ratio of probabilities for the remaining hospitals. Based on the IIA property, after deleting all LV hospitals from the choice set and by adding the constraint that the probabilities sum to 1 over the remaining hospitals, we can compute our probabilities of interest P_{ij}^{*}, needed to compute the expected hospital volume activities as described in equation *(1)*.

(ii) The second step of our evaluation strategy is to determine the additional distance that patients treated in hospitals under the minimum thresholds will have to travel with the application of minimum volume thresholds. This additional distance is the difference between the patient-hospital distances post-centralization of care and the patient-hospital distance observed initially. Following the benchmark method, it is possible to directly compute this additional distance, since the post-centralization of care hospital is assumed to be the closest to patient residential location and is thus observed in the data. However, it is not as straightforward with the alternative method that takes into account patient preferences, since we do not know in which hospital a patient who needs to be reallocated will choose to be treated. Nevertheless, we know the probabilities P_{ij}^{*} associated with each of the remaining HV hospitals. Thus, it is possible to compute the expected additional distance patient *i* will have to travel as a sum of the additional distance from patient *i* to each hospital *j* weighted by the probabilities that this patient chooses to be treated in each of the HV hospitals after centralization of care.

$$E(add_distance)_i = \sum_{j \in HVH} \left(Distance_{ij}^{Post} - Distance_{i}^{Init}\right) * \; P_{ij}^{*} * 1_{\{\,If \;\; i \in N^{LVH}\}} \qquad (4)$$

Where $Distance_{ij}^{Post}$ is the distance between patient *i* and hospital *j* post centralization of care, $Distance_{i}^{Init}$ is the observed distance between patient *i* and the hospital chosen initially. Patient preferences are taken into account through the probabilities P_{ij}^{*}.

(iii) Lastly, the third step of our empirical strategy is to investigate whether the implementation of minimum volume thresholds might introduce socioeconomic and spatial inequalities in access to hospital care. Our variables of interest are the expected additional distance as described in equation *(4)*, and the total distance post-centralization (i.e., initial distance plus additional distance). We explore spatial inequalities first by mapping observed (i.e., before centralization) and simulated (i.e., post-centralization) hospital location and patient density per department individually for breast and ovarian cancer. Secondly, we map the observed and simulated average patient-hospital distance per department and for both conditions. There could also be socioeconomic inequalities in access to care through a pattern in the spread of additional distances caused by minimum volume thresholds that could be correlated to patients' socioeconomic characteristics. A natural way to explore these inequalities could be to regress additional distances on a set of socioeconomic characteristics as independent variables. However, we observe additional distances only for patients needing to be reallocated. Thus, an Ordinary Least Squares regression will be biased and inconsistent since it ignores the selection process through which patients are selected into the group of patients needing to be reallocated (Greene, 1981). In order to jointly model the selection process and the expected additional distance conditionally on the selection process, we estimated a Type 2 Tobit model (Tobin, 1958).

$$Reallocate_i = \begin{cases} 1, if\ y_1^* > 0 \\ 0, if\ y_1^* \leq 0 \end{cases} \qquad E(Add_distance)_i = \begin{cases} y_2^*, if\ y_1^* > 0 \\ 0, if\ y_1^* \leq 0 \end{cases}$$

Where $y_1^* = X_1'\beta_1 + \epsilon_1$; $y_2^* = X_2'\beta_2 + \epsilon_2$; and the error terms ϵ_1 and ϵ_2 are allowed to be correlated and assumed to follow a bi-variate normal distribution with co-variance matrix $\begin{pmatrix} 1 & \sigma_{12} \\ \sigma_{21} & \sigma_2^2 \end{pmatrix}$. The matrix of patient characteristics X_1' included age, length of stay, distance before centralization of

care, patient choice set size before centralization, information about patients' residential municipalities (e.g. population, median standard of living, number of drug stores, number of ambulances, number of households having a car), and information about patients' residential departments (e.g. number of emergency units, number of short-stay hospitals). The matrix of patient characteristics X_2' included the same characteristics as in X_1', exception made for patient age and length of stay. This exclusion restriction is required for identification purpose (see Appendix B for a discussion of the exclusion restriction).

In their report, the French National Health Insurance proposed a threshold of 150 cases per year for breast cancer and 10 cases per year for ovarian cancer (French National Health Insurance, 2018). To see the impact of the threshold chosen on patient access, we replicated the analysis for each threshold $k^{BC} = 2,3,\dots,160$ and $k^{OC} = 2,3,\dots,30$. However, analysis of inequalities is performed only at $k^{BC} = 150$ and $k^{OC} = 10$.

4. Results

4.1 Descriptive statistics

We identified 57,151 (4,001) patients surgically treated for breast cancer (ovarian cancer) in mainland France in 2017 who were treated in 511 (461) hospitals. The distribution of hospital volume activities for breast cancer varied from a minimum of 1 to a maximum of 1,911, with a median of 59 patients treated in 2017 per hospital. For ovarian cancer, the much smaller number of patients compared to the slightly smaller number of hospitals led to a distribution of hospital volume activities significantly below that for breast cancer. Indeed, the distribution varied from a minimum of 1 to a maximum of 110, with a median of 5 patients treated for ovarian cancer in 2017. A table of descriptive statistics on hospital attributes can be found in appendix C (Table 4).

Figure 1 shows the geographical distribution of hospitals in mainland France for breast and ovarian cancer. It can be seen that the geographical coverage is rather similar for both conditions, which is not surprising considering that 84% of hospitals treating ovarian cancer patients also have an authorization to treat breast cancer patients and cover the French territory relatively well.

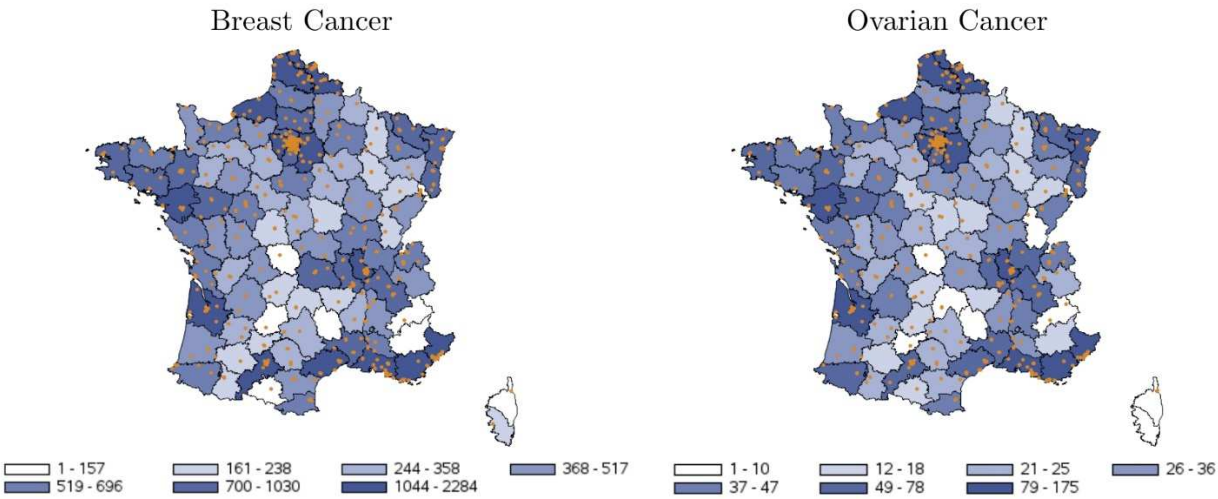

Figure 1 - Patient density per department (blue grid) and geographical breakdown of hospitals (dots) before centralization of care.

At the threshold proposed by the French National Health Insurance (i.e. $k^{BC} = 150$ and $k^{OC} = 10$), 401 hospitals (78.47%) among the 511 hospitals treating breast cancer patients, and 339 hospitals (73.54%) among the 461 hospitals treating ovarian cancer, would lose their authorization to treat the cancer concerned. Interestingly, among the 386 hospitals that treated both cancers in 2017, 237 hospitals (61.40%) would lose their authorization for both diseases at the same time. In terms of patient population, it would affect 35.51% of the breast cancer patients and 32.16% of ovarian cancer patients in 2017. Figure 2 illustrates on a map the simulated geographical spread of hospitals if these thresholds were strictly applied. If there was a good geographical coverage before centralization of care (see Figure 1), it can be seen that several French departments would suffer from medical desertification if care were centralized. It is possible to identify broadly the same two areas for breast cancer and ovarian cancer that would suffer the most from the centralization of

care, which are the center of France and the center south of France. It can also be seen on these maps that there is a wide variation in the rate of patients affected by the policy, in the sense that the initially chosen hospital would lose its authorization of treatment, by department. It is interesting to note that while we identify broadly the same two areas with no hospitals available for breast and ovarian cancer care, departments with the highest rates of patients affected by the policy are not always consistent between ovarian and breast cancer.

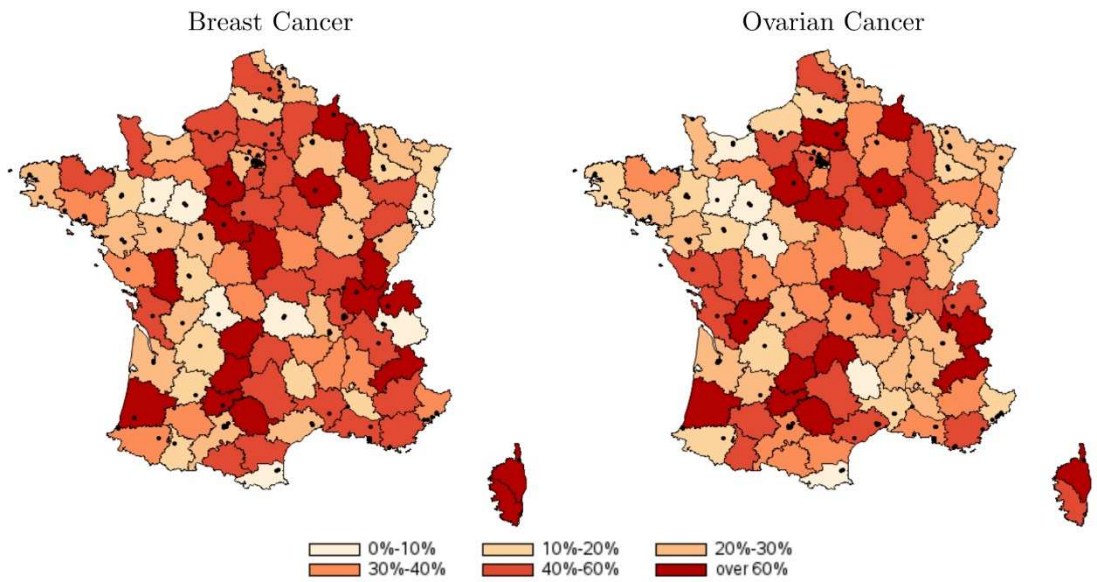

Figure 2 - Rate of patients affected by the policy and geographical breakdown of hospitals after centralization of care.

We also observed in our data strong variations in patients and patient residential location characteristics (Table 1). Indeed, patients who would need to be reallocated are living in municipalities with a far lower population density, a lower median standard of living and in departments with less general healthcare facilities (e.g., drug stores, ambulances, emergency units, short-stay hospitals). It should also be noted that patients needing to be reallocated have on average a lower choice set size, meaning they are living in areas already with fewer hospitals available for their cancer care within 50 kilometers. Interestingly, the average patient-hospital distance observed

initially is 17.74 (19.79) kilometers for patients who would be affected by the policy, compared to 30.93 (39.70) kilometers for patients already treated in a HV hospital initially for breast (ovarian) cancer.

Table 1: Descriptive statistics on patient, municipality, and department characteristics for the subgroups of reallocated ($R_i = 1$) and non-reallocated ($R_i = 0$) patients.

	Breast Cancer			**Ovarian Cancer**		
	$R_i = 1$	$R_i = 0$	P-value	$R_i = 1$	$R_i = 0$	P-value
Age	63.20	60.75	0.0001	65.13	62.17	0.0001
Length of stay	2.82	2.08	0.0001	11.20	10.99	0.5110
Choice set size	20.64	24.08	0.0001	19.79	39.70	0.0001
Initial distance	17.74	30.93	0.0001	19.79	39.70	0.0001
Municipality characteristics:						
- Population	33639.7	45901.6	0.0001	35897.7	44635.6	0.0001
- Median standard of living (€)	21391.6	27726.5	0.0001	21324.5	21696.7	0.0043
- # of drug stores	12.60	16.46	0.0001	13.94	16.01	0.0309
- # of ambulances	3.26	3.79	0.0001	3.29	3.81	0.04023
- # of households having a car	0.8529	0.8438	0.0001	0.8498	0.8433	0.0501
Department characteristics:						
- # of emergency units	10.12	10.74	0.0001	9.86	10.68	0.0001
- # of short stay hospitals	21.18	23.97	0.0001	20.35	24.09	0.0001
Frequency	18986	34472		1211	2554	
Share	35.51%	64.49%		32.16%	67.84%	

Note: number of (#) ; student's t-test of the difference between reallocated and non-reallocated patients (P-value).

4.2 Probabilities of patients' hospital choice

Table 2 displays the results of the Conditional Logit model of patient hospital choice estimated across all hospitals, regardless of their volume activities. The results of this model will be used to predict the probabilities P_{ij}^*, required for our evaluation strategy. It can be seen that our set of hospital-specific characteristics are strong predictors of patient choice. Patients were more likely to choose a hospital if it was the closest ($p < 0.001$), or closer ($p < 0.001$) to their home.

Table 2: Conditional Logit model of patient hospital choice on the full choice set.

	Breast Cancer	**Ovarian Cancer**
Closest	0.6991***	0.8998***
Distance	-0.0293***	-0.0167***
Age X Distance	-0.0004***	-0.0004***
Length of stay X Distance	-0.0004***	0.0003***
Type of hospital		
- Public	Ref	Ref
-Private	0.687***	0.2331***
- Private not for profit	0.8241***	0.4979***
Department of oncology	0.3241***	0.26***
# of hospital stays in oncology	0.0001***	0.0001***
# of surgical rooms	0.0173***	0.0273***
Bed occupational rate	0.0019***	0.0019***
# of employees for prevention of nosocomial infection	-0.0144***	0.0039
# patients	57151	4001
# observations	19166116	1202782
# hospitals	510	461
Log-Likelihood	-132733	-10337

Note: number of (#) ; modality in reference (Ref) ; significant at 1%, 5%, and 10% is indicated as ***, **, and *, respectively.

An interesting result is the heterogeneous impact of distance on the likelihood of hospital choice depending on patients' age and length of stay. Older patients tended to care more about distance when choosing where to be treated compared to younger patients ($p < 0.001$). Length of stay is used as a proxy for the severity of the disease, with the assumption that the more severely ill patients will receive more intense treatment requiring longer hospital stays. Interestingly, the most severely ill breast cancer patients (i.e. longer length of stay) tended to care even more about distance compared

to less severely ill patients (p < 0.001). Conversely, the most severely ill ovarian cancer patients tended to accept longer distance compared to less severely ill ovarian cancer patients (p < 0.001). Patients also tended to choose more often private for profit and most often private not for profit hospitals compared to public hospitals (p < 0.001), and hospitals specializing in oncology (i.e. having a department of oncology, with a higher number of hospital stays in oncology) (p < 0.001).

4.3 Expected hospital volume activities

Using the coefficient estimates of the Conditional Logit model, we estimated the individual probabilities P_{ij} that patient *i* chooses to be treated in hospital *j*. Then, as described in equation *(1)*, we computed the expected hospital volume activities for each volume threshold $k^{BC} = 2,3,\dots,160$ and $k^{OC} = 2,3,\dots,30$. To illustrate the effectiveness of each volume threshold in centralized care, Figure 3 displays the minimum, first quartile, and mean hospital volume at each threshold for breast cancer and ovarian cancer separately. Note that the uncertainty of the mean volume increases with the volume threshold, since the number of remaining HV hospitals decreases when the threshold increases.

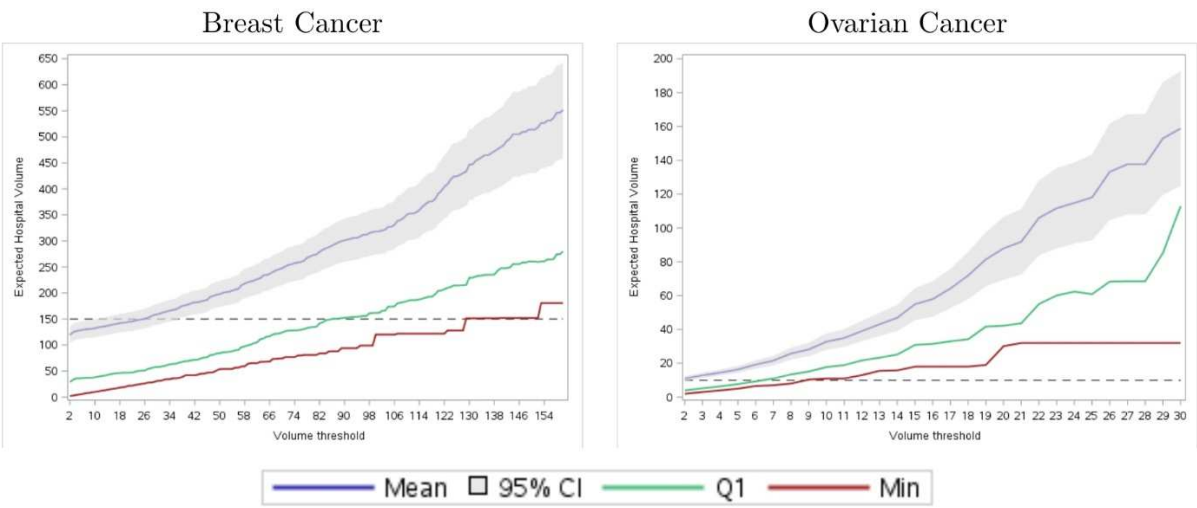

Figure 3 - Expected hospital-volume activities when varying the volume threshold.

As anticipated, the average expected hospital volume increases more than linearly when the volume thresholds increase. It can be seen that at the thresholds set by the national insurance (i.e., $k^{BC} = 150$ for breast cancer and $k^{OC} = 10$ for ovarian cancer), the average expected hospital volume activity would reach 514.05 patients (32.77 patients) if care were centralized, while we initially observed an average volume of 112.53 (8.79) breast cancer (ovarian cancer) patients. As a benchmark, we also computed hospital volume post-centralization when patients are assumed to choose their closest provider for each volume threshold. It can be seen in Figure 6 (Appendix D) that using the benchmark method or our evaluation strategy led to a broadly consistent distribution of expected hospital volume.

4.4 Additional patient-hospital distance

An implication of minimum volume standard regulation is that patients who were treated in LV hospitals (i.e. hospitals below the threshold) will have to be reallocated in one of the remaining hospitals after the application of a minimum volume threshold, and thus are likely to incur additional distances to be treated. As described in equation *(4)*, we estimated the expected additional distance for each volume threshold $k^{BC} = 2,3,\dots,160$ and $k^{OC} = 2,3,\dots,30$ (Figure 4).

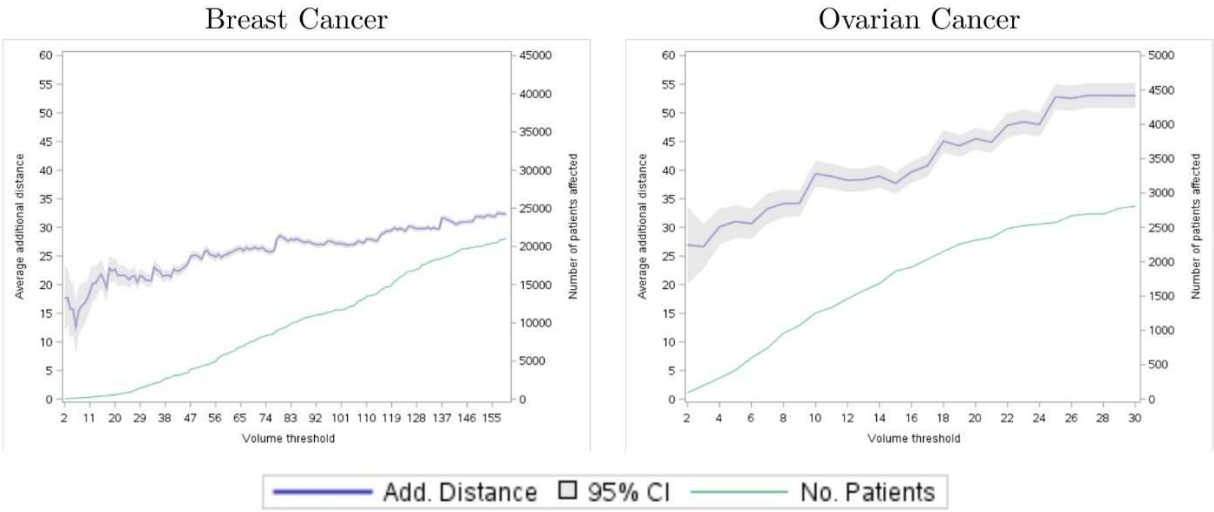

Figure 4 - Average additional distance and number of patients affected when varying the volume threshold.

In this figure, note that the uncertainty of the mean additional distance decreases with higher volume threshold, since the number of patients affected (i.e. for which we observe an additional distance) increases when the threshold increases, as illustrated by the green line. For breast cancer, a wide variation in the average additional distance when the volume threshold increases on the interval can be seen [2; 30[. The uncertainty of average additional distance within this interval could be caused by the volume threshold already in place for breast cancer treatment at 30 surgeries per year in France. It can be seen that this threshold has not been strictly applied, since we still observe patients treated in hospitals below this threshold. Then, on the interval [30; 160] a linear increasing trend of the average additional distance can be seen with the volume threshold ranging from 21 kilometers to 32 kilometers. For ovarian cancer, the mean additional distance is increasing almost linearly with the volume threshold ranging from 26 to 53 kilometers on the interval [2; 30]. Increasing the volume threshold translates into different degrees of centralized care, and the average additional distance patients initially treated in LV hospitals will have to travel increases slightly with the volume threshold for breast cancer, and increases more significantly for ovarian cancer. Understandably, the number of patients affected by the application of the minimum volume

threshold (i.e. in the sense that the initially chosen hospital will lose its authorization of treatment) drastically increases with the volume threshold, as illustrated by the green curve in Figure 4.

As a benchmark, we also computed additional distance post-centralization when patients are assumed to have chosen their closest provider (Figure 7, Appendix D). As expected, redirecting patients to the closest available provider leads to a distribution of additional distances far below the one from our evaluation strategy that takes into account patient preferences. Ignoring patient preferences undermine additional distances and leads to additional distances below zero for low volume thresholds, since not all patients were initially treated in their closest hospital.

4.5 Spatial inequalities

At the threshold required to reach the objective set by the French National Health Insurance (i.e. $k^{BC} = 150$ and $k^{OC} = 10$), patients will incur on average an additional distance of 32.45 kilometers for breast cancer and 38.89 kilometers for ovarian cancer to get to their hospital. To have an overview of the deterioration in patient access to hospital care caused by the volume threshold compared to the observed/initial situation, Figure 5 displays the average patient-hospital distance before centralization, the average expected distance post-centralization, and the average squared distance post-centralization per department. It can be seen that initially (i.e., maps on the top of Figure 5), patients living in departments in central France and in Corsica incurred longer distances compared to other French departments. A striking result is the increase in these spatial inequalities triggered by the introduction of a volume threshold. Indeed, it can be seen in the simulated maps (i.e., maps in the middle of Figure 5) that the distances post-centralization increase significantly for departments in central France, while remaining broadly constant for other departments. In other words, minimum volume standard tended to worsen spatial inequalities in access to hospital care for

breast cancer and ovarian cancer by increasing patient-hospital distances more significantly in departments that already have the highest average distances. For both diseases, two departments in the center of France will particularly be affected, with an average post-centralization patient-hospital distance of over 125 kilometers.

Note also that the inequalities already in place before centralization, and the degree of deterioration in patient access post-centralization are stronger for ovarian cancer care compared to breast cancer care. The two maps on the bottom of Figure 5 display the average squared patient-hospital distance. By taking square distances, more weight is put on long distances when computing the average by department (i.e. higher patient distance aversion). It can be seen that spatial inequalities across departments in square distances are even worse for both diseases, with even more differences between departments in the center of France compared to other locations.

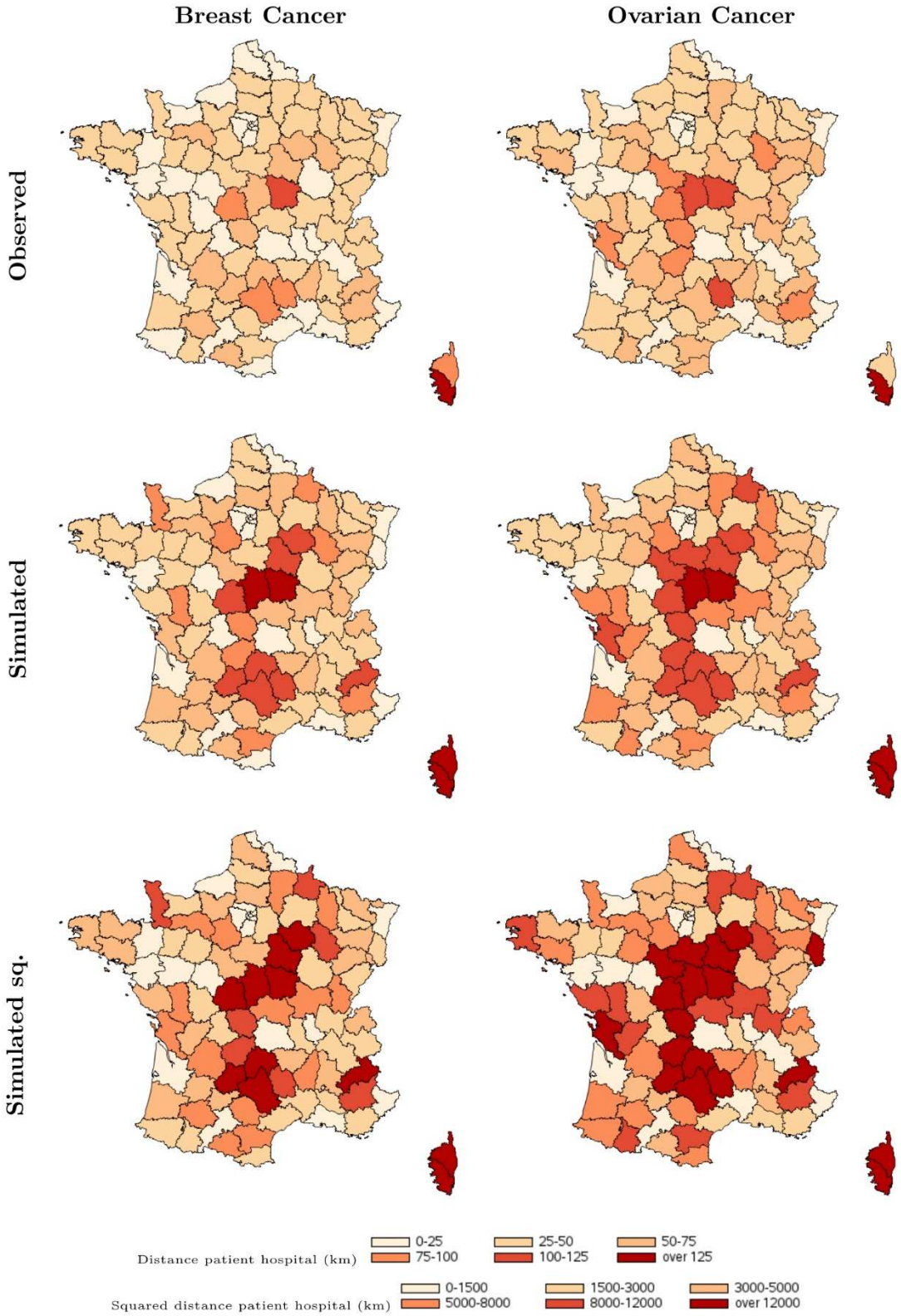

Figure 5 - Average of the observed, simulated, and simulated squared (i.e., Simulated sq.) patient-hospital distance.

4.6 Socioeconomic inequalities

Inequalities could also run through a correlation between patient characteristics (e.g. socioeconomic characteristics, municipality characteristics) and additional distances. To that end, we estimated a type 2 Tobit model for breast cancer and ovarian cancer patients separately (Table 3). It can be seen that for both cancers, older patients, patients living in departments with more emergency units and fewer short-stay hospitals, and patients living in less populated and poorer municipalities are more likely to be affected by the introduction of minimum volume thresholds, in the sense that they will need to be reallocated. Thus, in terms of probability of being affected by the policy (i.e., likelihood of seeing the hospital chosen for treatment withdrawn from the market), the most deprived and remote areas are more likely to be affected compared to patients living in richer and urban municipalities.

An interesting result is that patients who initially had a shorter distance to their hospital are also more likely to be affected by the policy ($p < 0.001$). Lower initial distances could either relate to patient distance aversion, but could also be caused by a limited choice set when patients did not have the opportunity to choose other hospitals at a moderate distance from their home. Since we also controlled for the choice set size as an independent variable in the model, this result could be interpreted as the more distance-averse patients (i.e. patients who initially chose a closer hospital) being more likely to be affected by the policy. Patients not affected by the policy are those already treated in a HV hospital initially. Our results agree with the idea that patients treated in HV hospitals are less distance averse, and thus more able to accept longer distances in order to be treated in a HV hospital. Note that while the effect of distance aversion is homogeneous whatever patient age for breast cancer, a higher age further increases the likelihood of being affected by the policy for distance averse ovarian cancer patients ($p < 0.001$). Furthermore, we identified a heterogeneous impact of the initial distance with patient choice set size of opposite sign for breast and ovarian cancer.

Table 3: Type 2 Tobit model of the additional distance conditional on the selection process.

	Breast Cancer		Ovarian Cancer	
	Reallocate	Additional Distance	Reallocate	Additional Distance
Intercept	-0.994***	33.9485***	-0.4539	11.5104
Age (std)	0.0673***		0.0596***	
Length of stay (std)	0.1477***		-0.0399**	
Choice set size	-0.1635***	-12.7201***	-0.0182	-14.6789***
Initial distance	-0.6009***	-34.8817***	-0.4611***	-60.6539***
Age X init. distance	0.0049		-0.1327***	
Choice set X init. distance	-0.3258***	-3.5605***	0.1134***	2.9195*
Municipality characteristics:				
- Population (std)	-0.1957***	-22.9751***	-0.2669**	-25.3535***
- Median standard of living (€,std)	-0.0609***	-3.6709***	-0.0723**	-3.1443**
- # of drug stores (std)	0.0128	16.4383***	0.1551	10.6537**
- # of ambulances (std)	0.0444***	-3.1779***	-0.0286	-1.0205
- # of households having a car	0.564***	-17.6132***	-0.1365	-41.3***
Department characteristics:				
- # of emergency units (std)	0.1771***	1.8508***	0.2762***	10.0967***
- # of short stay hospitals (std)	-0.3068***	-15.1861***	-0.5145***	-29.8196***
Rho	-0.0483		0.8866***	
Sigma	28.4539***		39.6759***	
Observations	53458		3765	
Log-Likelihood	-122688		-7837	

Note: number of (#) ; modality in reference (Ref) ; standardized variable (std) ; significant at 1%, 5%, and 10% is indicated as ***, **, and *, respectively.

For breast cancer patients, the most severely ill patients (i.e., having a longer length of stay at hospital) were also more likely to be affected by the policy ($p < 0.001$). Note that the severity of the disease included in the selection process had an effect of contrary sign for ovarian cancer, with the less severely ill ovarian cancer patients being more likely to be affected by the policy ($p = 0.0272$).

Conditional on the probability of being affected by the policy, it is interesting to see that for both cancers, patients living in municipalities with a lower population density, a lower median standard of living, a higher number of households having a car, and in departments with more emergency units

and fewer short-stay hospitals were more likely to incur higher additional distances. A remarkable result is that the most deprived and remote areas are simultaneously more likely to be affected by the policy and more likely to incur longer additional distances among the subgroup of patients affected.

5. Discussion

The centralization of care for complex procedures, such as surgeries in cancer care, is a major concern in health economics, and could offer an opportunity to substantially increase the quality of care through a reform of the organization of the supply side of the market. However, policy makers are facing a crucial trade-off between increasing the quality of care and decreasing patient access to care. In this study, we evaluate the impact of such a policy on patient access to care, and investigate how the burden of the policy would be distributed spatially and within socioeconomic subgroups.

Our findings tend to indicate that the application of minimum volume thresholds is very effective to achieve a centralization of care. At the threshold proposed by the French National Health Insurance (i.e. $k^{BC} = 150$ and $k^{OC} = 10$), the average expected hospital volume activity post-centralization will be four times higher for breast cancer and three times higher for ovarian cancer compared to the hospital volume distribution observed initially, which would substantially increase the quality of care. A question that still remains is what is the cost of this kind of centralized care in terms of patient access to hospital care? At these thresholds, breast cancer (ovarian cancer) patients affected by the policy will have to travel on average 32.45 (38.89) kilometers farther. In terms of patient population, it will affect 35.51% of breast cancer patients and 32.16% of ovarian cancer patients.

As expected, our findings tend to indicate that patient access to hospital care for breast and ovarian cancer care would be substantially reduced by the policy. What was more unpredictable was the impact of the policy on spatial and socioeconomic inequalities in access. We identified strong spatial

inequalities in the share of patients affected by the policy among French departments (Figure 2). While less than 10% of the patients would have to be reallocated in some departments, and thus would incur an additional distance, the share exceeds 60% in the most affected departments. Similarly, while the average patient-hospital distance would be lower than 25 kilometers in some departments, the average distance could exceed 125 kilometers in the most affected departments (Figure 5). Some departments, especially in the center of France, have longer average distances compared to other departments. After centralization, our results indicate that the average patient-hospital distances would drastically increase in these departments, while remaining broadly consistent elsewhere. In other words, the departments that would suffer the most from a centralization of care are those that already have less access to care. Note that spatial inequalities are even more significant if a higher degree of distance aversion is assumed by putting more weight to longer distances.

We identified substantial socioeconomic inequalities in the likelihood of being affected by the policy, as well as in variations in expected additional distance among socioeconomic subgroups (Table 3). Patients living in rural areas, with a lower standard of living, and who already have less access to non-specialized care are more likely to be affected by the policy, and also to incur longer additional distances. An interesting result is that distance-averse patients are more likely to be affected by the policy compared to less distance-averse patients. It should also be noted that for ovarian cancer, this effect was exacerbated for older patients. Similarly, older patients are more likely to be affected by the policy, while results from the Conditional Logit model indicate that they tended to attribute a more important weight to the distance in their preferences for hospital choice. The fact that more distance-averse patients would be more affected is a major concern in devising volume-based policies.

To the best of our knowledge, there are only three studies in the existing literature on this topic, and none in the French context (Hentschker et al., 2018; Hentschker and Mennicken, 2015; Kobayashi et

al., 2015). Overall, these studies found a moderate impact of centralized care on patient access to care. In comparison, our results indicate that the introduction of minimum volume thresholds in France could drastically deteriorate patient access to specialized care, and that the burden of the policy will be unequally distributed in spatial and socioeconomic terms. The divergence in this conclusion could stem from a differing evaluation strategy, the country or the disease analyzed. Among the three studies, only one explored inequalities among the population. They evaluate the impact of the centralization of care for ischemic heart disease and breast cancer on travel time in the Kyoto Prefecture in Japan, and assess unequal spread of travel time using a Gini coefficient (Kobayashi et al., 2015). Surprisingly, their main finding is that the centralization of care reduced inequalities in travel time for patients. However, in the Japanese context, the centralization of care is achieved by centralizing care to designated regional core hospitals, and thus does not rely on a minimum volume threshold. Therefore, the impact of centralization of care on travel time strongly depends on how these regional core hospitals are chosen. Moreover, in this study, we take into account the patients' choice of their provider based on their preferences in the evaluation strategy. Our evaluation strategy relates an implementation of a minimum volume threshold in a country where patients are free to choose their hospital, and is thus reflective of most healthcare systems, such as in the UK, USA, France, etc. In comparison, studies in the existing literature assumed that patients would be reallocated to their closest HV hospital after the centralization of care (Hentschker et al., 2018; Hentschker and Mennicken, 2015; Kobayashi et al., 2015). For the purpose of comparison, we employed the same strategy as a benchmark. As expected, ignoring patient preferences substantially underestimates the deterioration in patient access. While we found an average additional distance of 32.45 km for breast cancer and 38.89 for ovarian cancer when patient preferences are taken into account, results using the benchmark evaluation strategy indicate an average additional distance of 18.9 km for breast cancer and 21.57 km for ovarian cancer. Thus, following the benchmark evaluation strategy we might also have concluded that the introduction of a minimum volume threshold would have a moderate impact on patient access. In fact, assuming

patients will choose their closest hospital revert to estimating the lowest bound of the deterioration in patient access, or to assuming that distance is the only predictor of patient choice. Naturally, distance or travel time will be one of the most important factors in patient preferences, but other important factors are likely to be considered in the selection process as well. As an illustration, we observed in our data only 25.61% of breast cancer patients and 24.82% of ovarian cancer patients treated in the closest hospital to their home in 2017 in France. If the patient-hospital distance was the only predictor of patient choice, all patients would have been treated in their closest hospitals.

For that reason, we included in the Conditional Logit model variables we believed to be good predictors of patient choice (e.g. distance, hospital characteristics, heterogeneity with patient characteristics). It can be seen in Table 2 that these predictors are strongly significant, indicating that they are indeed good predictors. We have also performed further test of goodness of fit of our evaluation strategy as described in Appendix E. The Conditional Logit model shows a good predictive power in predicting patient probabilities of hospital choice. As a robustness check, we were also able to replicate the observed distribution of hospital volume activities using the probabilities P_{ij}^{*} with an average error of less than one patients.

This study also has several potential limitations. Calculating the distance from patient to hospital, we computed a straight-line on a map, while a superior alternative would have been to compute travel distance over a road network or travel time by car, to take into account the variation in travel time between rural and urban areas. Note that if these variations were strong, this would mean that our results are somewhat conservative. We also lack clinical information on the severity of the disease, as well as socio-economic characteristics at the level of the individual.

In this study, we evaluated the impact of a strict application of minimum volume thresholds on patient access. By retrieving from the market simultaneously hospitals not meeting the volume criteria, it does not allow the opportunity for LV hospitals slightly below the threshold to get off the volume threshold thanks to patient flows from even lower volume hospitals. The decision maker

could also choose to implement the minimum volume threshold progressively, until the distribution of hospital volume activities reached the desired level. In Appendix F, we determine in our data the minimum volume threshold that could be applied in order to still reach the goal that all hospitals post-centralization would have a volume activity higher than 150 for breast cancer and higher than 10 for ovarian cancer. Thanks to patient reallocation, we found that by reallocating patients treated in hospitals having a volume activity under 128 for breast cancer and under 9 for ovarian cancer, the remaining hospitals would all meet the volume criteria set by the French National Health Insurance. By doing this, 22 hospitals treating breast cancer and 21 hospitals treating ovarian cancer would be saved from closure. Naturally, we found a slightly lower degree of deterioration in patient access under these thresholds compared to the thresholds $k^{BC} = 150$ and $k^{OC} = 10$. However, it should be noted that the burden of the policy would still be unequally distributed through the same spatial and socioeconomic patterns. Understandably, the minimum thresholds we estimated for breast and ovarian cancer are not generalized out of our sample, and even less generalized to other countries. Nevertheless, they underline the importance of the dynamic of patient reallocation in devising volume-based policies.

Beside patient access to hospital care, a question that remains is how high-volume hospitals will handle additional patients. The average expected hospital volume activity will be four times higher for breast cancer and three times higher for ovarian cancer if care were centralized in France. There is a need for future research on the resources (e.g., medical personnel and infrastructure) required for the treatment of these two cancers, in order to identify whether high-volume providers would be able to handle the additional patients, as well as to assess the implication of a loss of activity for low volume providers.

6. Conclusion

Centralizing care to high volume hospitals is an opportunity to substantially improve the quality of care for diseases requiring complex procedures, such as surgeries in cancer care. However, policy makers are facing a trade-off between increasing the quality of care and decreasing patient access to care. In countries where patient choice of their preferred provider is effective, our findings underline the need to take into account patient preferences in order to have a complete picture of the impact of volume-based policies on patient access. Indeed, ignoring patient preferences drastically undermine the deterioration in patient access. Furthermore, policy makers should pay particular attention to the impact of centralizing care on inequalities in access. To conclude, our findings indicate that a strict application of such volume thresholds would be unsustainable in terms of patient access, mainly because of the resulting spatial and socioeconomic inequalities in access to care. To make the policy sustainable, policymakers could, for example, customize the volume threshold for areas where no hospitals would reach the national threshold within a reasonable distance, in order to reduce the burden of the policy for the most affected areas.

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