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Location dynamics of general practitioners in France

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ABSTRACT

Background: For several years now, the socio-political context in France has widened the territorial divide between metropolitan France and peripheral France. Access to healthcare is part of this divide, which harms small and medium-sized towns as well as rural fringes. This article focuses on these geographic dynamics in access to healthcare, with a focus on self-employed general practitioners (GPs), who are essential links in the care pathway as referring physicians.

Methods: This paper uses data from French public statistics from 2007 to 2017 to build spatial panels and to highlight the territorial factors that explain the dynamics of the locations of GPs.

Results: Over the period under review, the density of GPs has decreased and territorial disparity has increased. There is no trend towards a worsening of this isolation of either the periphery or deprived cantons with regard to the density of GPs in these areas. However, we note a clear trend towards the grouping together of different types of care within cantons, leading to a tendency towards the polarization of the healthcare supply in the territories of mainland France, which implies another type of geographical difficulty.

Conclusion: The increase in territorial disparities in accessibility to GPs does not really seem to correspond to the classical divides in France, but rather raises the issue of intra-metropolis and intra-periphery disparities.

1. Introduction

Access to healthcare is a legally guaranteed right in France. Indeed, article L. 1110–1 of law n°2002–303 of March 4, 2002 relating to the rights of patients and the quality of the health system (2002) stipulates that the State must "guarantee and ensure continuity of care." Despite this, inequalities in access to healthcare persist. The factors may be financial (Bras & Tabuteau, 2012; Castry et al., 2019; Dourgnon et al., 2012), organizational (Ellouze et al., 2018; Mauffrey et al., 2016; Twomey et al., 2020), discriminatory (Carde, 2007; Harris et al., 2019; Pfister, 2014) or territorial (Alfano et al., 2018; Goyder et al., 2006; Nemet & Bailey, 2000). This last factor has held an important place in public debates in France in previous years, in particular through the Yellow Vests (*Gilets Jaunes*) movement (Boyer et al., 2020), which symbolized the feeling within territories away from the large metropolises (Davezies et al., 2013) that people have been downgraded. Given this, when healthcare demand outstrips supply in a given French territory, this is considered as a breach of this principle of equality which is supposed to be legally guaranteed.

In the French healthcare system, there is a division between a mainly public hospital network and a liberal outpatient medicine (Cash, 2021). In this context, patients face financial inequalities in access to self-employed physicians (including GPs) depending on their agreement and their sector.[1] These financial inequalities can be coupled with those caused by territorial distribution. Moreover, general practice is defined in France as the specialty that ensures the proper monitoring of primary care (Gay, 2013). Indeed, the 2009 Hospital-Patient-Health-Territories (*Hôpital-Patient-Santé-Territoires*) law defines that general practitioners (GPs) have the mission of referring patients, coordinating care, contributing to prevention, screening, diagnosis, treatment and patient follow-up (Article L4130-1 of the Public Health Code, 2009). GPs are therefore essential actors in primary care, which the World Health Organization has highlighted as essential (Declaration of Alma-Ata International Conference on Primary Health Care, Alma-Ata, USSR, 6–12 September 1978, 2004). Therefore, it is appropriate to investigate the way in which city care supply (and particularly for GPs) is organized and

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[1] Self-employed physicians are paid on a fee-for-service basis, according to tariffs that may be set by the *Assurance Maladie* (the public service that takes charge of health risks in France) for physicians under agreement (Article L162-5 of the Social Security Code, 2011). Two sectors of agreement coexist: physicians in sector 1 apply the basic rates while those in sector 2 apply excess fees. In the non-agreement sector, fees are free and reimbursements are lower (Article L162-5 of the Social Security Code, 2011).

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regulated in French territories.

Until recently, this regulation was managed through the *numerus clausus* system. Established in 1971, the purpose of this system of selection, implemented at the end of the first year of health studies, was to regulate the population of medical professionals (GPs and specialists) in order to prevent medical under-density – which would harm access to healthcare – and medical over-density – which would induce an increase in expenditure without a significant improvement in the population's health (Huguier & Romestaing, 2014). This system therefore enabled the regulation of medical demography but did not contain a mechanism aimed at regulating working time or the geographical area in which health professionals worked (Samson, 2011). Therefore, increasing the *numerus clausus* would not be a solution to disparities in the territorial distribution of practitioners (Huguier & Romestaing, 2014). In this system, the regional distribution, defined by the Regional Health Agencies (RHA, in French, *Agences Régionales de Santé*), takes place at the end of the 6th year of study (Decree No. 2013–756 of August 19, 2013 on the regulatory measures of Books VI and VII of the Education Code, 2013). However, decree No. 2019–1125 of November 4, 2019 on access to training in medicine, pharmacy, odontology and midwifery (2019) indicates that from the start of the 2020 academic year, a new system, *numerus apertus*, is applied, allowing universities to define available places according to territorial needs at the regional level. In addition, since the 2000s a number of financial incentives have been put in place to encourage physicians to practice in rural areas (Bontron, 2012; Chevillard et al., 2018). However, their effectiveness has been assessed as limited (Cardoux & Daudigny, 2017; Munck et al., 2015).

Added to this is the fact that the *numerus clausus* was too low during the 1990s, down to its lowest level of 3500 in 1993 (Dormont & Samson, 2008; Langlois, 2004), sparking fears of a decline in the number of practitioners during the 2000s and 2010s (Barlet et al., 2009; Bessière et al., 2004; Darriné, 2002; Niel, 2002); at the same time, the French population was aging and therefore had growing care needs (Attal--Toubert & Vanderschelden, 2009; Breton et al., 2020). Moreover, many doctors from the baby-boom generation[2] were about to retire (Macé, 2014). Nevertheless, with the use of immigration (Hounsou, 2014; Séchet & Vasilcu, 2012) and the development of a system dovetailing employment and retirement, the National Council of the Order of Physicians (*Conseil National de l'Ordre des Médecins*) noted a relative stagnation of the number of practicing physicians over the 2007–2017 period. However, this should be put into perspective insofar as the density of GPs has decreased while that of specialists has increased. In addition, they work less than before on average, partly due to the fact that women physicians work on average less than their male counterparts and that the profession is becoming more feminized (Bouet & Mourgues, 2017). Thus, there are increasing difficulties in accessing GPs in France.

In these conditions of growing tension, it appears that the factors behind the choice of location among GPs are fundamental in determining to what extent these tensions may worsen for outpatient care according to the attractiveness of territories.

These factors have been widely studied. First, the arrival of doctors in a territory is influenced by prior healthcare supply, demand, and the potential presence of financial incentives (Barlet & Collin, 2009; Coufinhal et al., 2002; Dumontet et al., 2016; Goddard et al., 2010). Samson (2011) observes a negative ceteris paribus association between the density of GPs and their income. The choice of location of practitioners depends on the territory's economic attractiveness, particularly employment opportunities for partners (Rosenthal et al., 1992), and on the population's care needs. In this respect, supply responds to demand due to the population's socio-demographic structure and its health coverage (Vogt, 2016). Expected income, not only that of the doctor but more generally of the household, thus appears to be a key factor in location choice, although it is not the only determinant.

Indeed, various factors relating to quality of life (QoL) also play a role in location decisions (Carpenter & Neun, 1999; Mathews et al., 2012). The use of the expression "QoL" does not refer here to its medical meaning (Schalock, 1993), but to that of fulfillment in relation to one's natural and social environment (Bley & Vernazza-Licht, 1997; Mercier & Schraub, 2005). Thus, it is possible to link dissatisfaction with one's living environment and residential mobility (Lee et al., 1994). A territory is attractive when it gains more individuals and activities than it loses. Residential attractiveness is based on factors such as access to transport, education, employment and leisure (Poirot & Gérardin, 2010). The same is true for physicians, for whom these QoL factors have also been studied (Dionne et al., 1987; Foster & Gorr, 1992; Hingstman & Boon, 1989; Isabel & Paula, 2010; Scholz et al., 2015). This question of QoL therefore appears to be a factor in weakening the commitment of young doctors to rural areas, which are perceived as conferring a lower QoL due to more difficult access to public services and less opportunity for forming social relationships (Langlois, 2004).

The state of the art raises questions about the explanatory factors of the territorialization of GP and therefore of the territorial inequalities of accessibility to healthcare. What are the explanatory characteristics of these territorial evolutions? More specifically, what are the territorial characteristics that have attracted more GPs? Conversely, what is the typical profile of territories where this medical density is weakening? Based on the literature, we can hypothesize that these latter territories may be rural and/or poor. Does this hold true? Do territories outside the major cities push GPs away? Will what we observe in statics be found in dynamics? It is necessary to explore more precisely the way in which GP density interacts with the characteristics of the territory, but also to determine, using spatial models, whether the surrounding territories also have an impact. In this way, we will be able to understand how the location of GPs is changing in relation to QoL and to other care supply in the territory. Is there competition or complementarity in the interactions resulting in GPs locations? In addition, the use of spatial models is important from a methodological point of view, since the non-inclusion of spatial autocorrelation, if present, constitutes an omitted variable bias and induces biased coefficients. To our knowledge, no article deals with these questions using our proposed methods.

It is also interesting to add a demographic point of view to the studies on individual positions. In this way, we can describe territorial characteristics that have an impact on the changes in GP supply distribution and can thus put the spotlight on GP territorialization. To do so, it will be necessary to understand how location dynamics take shape according to the state of the healthcare market and the territorial interactions that may emerge. With a view to addressing all of these questions, the following section will present data as along with the quantitative methods used. Part 3 will focus on the results and the final section will discuss them and concludes.

2. Methods

2.1. Data

This work requires the use of three main types of variables: those on medical supply, those on households' expected income and those on QoL. These last two kinds of variables are used to understand the territorial characteristics that have an impact on the attractiveness of settling in a given territory.

We have already shown that expected household income depends on local demand for healthcare and on the opportunities for partners to find jobs. The literature on QoL indicates that the perception of whether living conditions are considered good or not is based on factors such as access to public and private services, living in metropolitan areas or

[2] Like other Western countries, France experienced a big jump in births after World War II and until the mid-1970s (ined.fr, consulted on 08/03/2021).

otherwise, and other factors relating to living conditions.

To understand these factors, the first data used come from the 2007, 2012 and 2017[3] French censuses. They provide us with the necessary information to understand the demographic and social structures of the territories. For territorial wealth indications, the Localized Social and Fiscal File (*Fichier Localisé Social et Fiscal*) of the same years (2007, 2012 and 2017) will also be used, as well as the Zoning in Urban Areas (ZUA, in French, *Zonage en Aires Urbaines*), to distinguish metropolises from peripheries and rural fringes.[4] Finally, in order to measure healthcare supply as well as the presence of public and private services, this work also relies on data from the Permanent Database of Facilities (PDF, in French, the *Base Permanente des Équipements*), listing all facilities available at the town level.

2.2. Variables

To find the data generating process (DGP) for GP supply in a given territory, the first task is to define what territorial scale should be considered. Therefore, we need to find territorial groups with a kind of homogeneity in terms of characteristics to be able to locate the phenomena of interest, but without having populations that are too small. In this respect, because of the rurality factor, the municipality scale is too small. The "community of municipalities" (*communauté de communes*) scale is larger, grouping together (sometimes several dozen) municipalities with very diverse characteristics, but is probably too diverse to correctly describe local specificities. Disparities of characteristics within these communities of municipalities mean that using this scale is not relevant here. One could use the "living area" (*bassin de vie*) scale, corresponding to the "smallest territory[ies] in [which] inhabitants have access to the most common facilities and services".[5] However, the DGP that we wish to produce will introduce access to these local services as an essential explanatory variable. Therefore, the use of such a geographical breakdown would limit this effect, which is one of the main effects requiring analysis, to changes within the living areas during the study period. From a diachronic perspective, this is therefore not satisfactory. The intermediate scale of pseudo-cantons[6] was thus chosen to achieve the required balance.

Next, the explained variable must represent cantonal GP supply. To this end, the density of GPs is used. This corresponds to the number of self-employed GPs[7] working within a canton per 1000 inhabitants.[8] Moreover, in order to normalize the distribution of the error term, the explained variable was changed to logarithmic form, and cantons with zero values were removed (representing 118 cantons out of 3490,[9] i.e., 3.38%). Removing these cantons may imply a selection bias[10]. However, the spatial panel estimation method requires that the distribution of the dependent variable is Gaussian (Lee & Yu, 2010). Therefore, it is necessary to remove these cantons.[11]

Among the explanatory variables, in addition to demographic structure variables, QoL variables will be introduced. In particular, the density of services (public and private)[12] will be used to reflect access to leisure, transportation, education, etc. This corresponds to the number of these services per 1000 inhabitants within a canton. The degree of integration in metropolises will be derived from the ZUA by the percentage of the population living in peripheral France. As the data are structured, this choice implies including within the same canton towns that do not necessarily belong to the same urban area. But in this way, the question of the heterogeneity of peri-urban areas is addressed. Indeed, this approach includes towns with weak or marginal links to major metropolises. Moreover, territorial deprivation will be measured using the following ad hoc index:

$$D = \frac{1}{ICU \times (100 - \%Unemp)} \tag{1}$$

with ICU the median income per consumption unit and %Unemp the percentage of unemployed people. In this way, the higher the index, the more deprived the canton is. In order to make the index between 0 and 1, its maximum (D_{max}) and minimum (D_{min}) values are used. Therefore, the deprivation index used in the models is D^*:

$$D^* = \frac{D - D_{min}}{D_{max} - D_{min}} \tag{2}$$

Finally, healthcare supply should be included to determine whether other types of care may have an impact on the territorialization of the GP market. The aim is therefore to understand how the locations of different types of care are associated ceteris paribus, and whether they are territorially complementary or competitive. For this purpose, the densities of various hospitals and medical establishments as well as specialized care (density and diversity) will be introduced. Density is the number of specialist physicians per 1000 inhabitants of the canton. The diversity of specialties is the number of specialties represented within the canton divided by the total number of specialties considered within the PDF (in order to have an index from 0 to 1).

All the variables presented above are summarized in Table 1.

[3] The analyses require a period of at least 10 years and the Permanent Equipment Database is only available from 2007. As the movements studied are very slow and the models used are very complex to compute, the panel is limited to five-year variations.

[4] The ZUA hubs correspond to a towns group where at least 40% of the active working population works within the same hub. A distinction is then made between large urban areas (more than 10,000 jobs), medium-sized areas (5000 to 10,000 jobs), small areas (1500 to 5000 jobs), multipolarized towns or those outside influence areas (insee.fr, consulted on 07/05/2021). Subsequently, we will distinguish large areas and multipolarized towns associated with them as being the metropolitan France, while the towns of the other categories will be apprehended as the peripheral France.

[5] Source: Definition available at insee.fr/fr/metadonnees/definition/c2060, consulted on 01/21/2022. There are 1641 in mainland France (Source: Base des bassins de vie, https://www.insee.fr/fr/information/2115016, consulted on 01/21/2022).

[6] Pseudo-cantons are created by the National Institute of Statistics and Economic Studies in line with the electoral cantons used for departmental elections in France. Large towns are included as a single canton. Smaller towns are clustered in groups that are large enough to avoid the presence of statistical individuals without any facilities (insee.fr, consulted on 06/16/2021). The cantons used are those prior to the NOTRe reform (reform of local authorities implemented from 2015), numbering 3665 in mainland France.

[7] In 2014, 58.2% of GPs were self-employed (Le Breton-Lerouvillois, 2014). This analysis therefore excludes almost 40% of GPs who are mostly employed. Their location is not totally free, since they have to work where there is employment, particularly in clinics and hospitals. This probably implies a slightly different location mechanism for them than for self-employed people. While the income issue may be less pronounced, the QoL issue may come into play in a similar way. However, this cannot be verified here.

[8] In the PDF, there is no information about hospital GPs.

[9] Because of missing data, the number of cantons in the database was reduced earlier from 3665 to 3490.

[10] A table of comparisons of the characteristic's means between retained and deleted cantons is available in Supplement A.

[11] The explained variable's density function is presented in Supplement B.

[12] All facility groupings indicated are detailed in Supplement C.

Table 1
Variables.

Dependent variable	
Log of GP density	Number of GPs per 1000 inhabitants working within a canton. Logarithm is used for normalization.
Independent variables (Part 1): Healthcare demand & supply	
Under 25 y.o. (%)	Percentage of the population within a canton aged 0–24. This variable is part of the demographic structure that influences healthcare demand.
75 y.o. & over (%)	Percentage of the population within a canton aged 75 and over. This variable is also part of the demographic structure that influences healthcare demand.
Density of specialists	Number of specialists per 1000 inhabitants within a canton.
Diversity of specialties	Number of specialties represented within the canton divided by the total number of specialties.
Density of hospitals & various medical establishments	Number of hospitals & various medical establishments per 1000 inhabitants within a canton.
Independent variables (Part 2): Quality of life	
Density of services	Number of services (public and private) per 1000 inhabitants within a canton.
Peripheral population (%)	Percentage of the population within a canton living in peripheral France.
Deprivation (D*)	Index (between 0 and 1) based on unemployment and income per consumption unit within a canton.

2.3. Empirical strategy

After presenting our descriptive statistics and running individual fixed-effects model to control for time-invariant confounders, we will show whether surrounding cantons have an impact on GP density and, if so, what forms it may take. To do this, we will use tests to determine whether there are spatial autocorrelation and spatial panel models in their different forms.[13] Indeed, spatial modeling is based on spatially referenced data, which means that one challenge is to deal with a spatial correlation between observations sharing local characteristics, a correlation that may be in the error term if it is not modeled otherwise. We refer to spatial autocorrelation, since the aim is to study links between observations and their neighborhoods within the error term or within the same variable.[14] A spatial pattern thus aims to describe the relationships of influence, diffusion, spillover, dependence or externality that exist between points in a spatial neighborhood (Anselin & Bera, 1998; Geary, 1954). To use Manski's terms (1993), this will make it possible to distinguish whether the factors affecting the neighborhood are endogenous or exogenous. In an endogenous effect case, the density of GPs in one canton would have an impact on the density of GPs in nearby cantons, leading to a negative endogenous factor if we assume that supply is concentrated in some cantons and leads to territorial competition, or a positive factor if, on the contrary, GPs tend to be located in clusters of cantons. For the exogenous effect, a canton's characteristics, whether observed or not, would have an impact on the density of GPs in nearby cantons. This method for producing the DGP therefore simultaneously gets rid of the omitted variable bias associated with spatial structure and time-invariant confounders. It also allows different models to be tested. For readability and following the procedure explained in Supplement D, a model was selected, the Durbin spatial error model (SDEM) with individual (i.e., canton) fixed effects:

$$y_{it} = \alpha_i + \beta x_{it} + \theta \Sigma_{i \neq j} w_{ij} x_{jt} + u_{it} \text{ with } u_{it} = \lambda \Sigma_{i \neq j} w_{ij} u_{jt} + \varepsilon_{it} \quad (3)$$

with y_{it} the value of the logarithm of the GP density for canton i at period t (with t = 2007; 2012; 2017);

α_i the canton fixed effect;
x_{it} the value of an explanatory variable (summarized in Table 1) for canton i at period t;
x_{jt} the value of an explanatory variable for canton j at period t;
u_{it} the error term for canton i at period t, which is function of the error term associated with cantons j at the same period;
ε_i the non-spatialized residual for canton i at period t.

This allows to capture explained and unexplained exogenous effects, whereas in the non-spatialized panel, $\theta = \lambda = 0$. However, the three types of effects (endogenous, exogenous, error) lead to different interpretations than standard models (LeSage & Pace, 2009). Once an exogenous effect is added, this implies that $\frac{\partial y_i}{\partial x_j} = \theta w_{ij}$. Thus, x_i and x_j jointly have a total effect on y_i which can be decomposed as the result of a direct effect $\frac{\partial y_i}{\partial x_i}$ and an indirect effect $\frac{\partial y_i}{\partial x_{kj}}$. These direct and indirect effects (the sum of which is the total effect) are presented following regression results.

3. Results

The statistics in Table 2 show the changes in variables. First, they show that over the 2007–2017 period, GP density clearly decreased, while disparities in its territorial distribution increased. These elements confirm and complement results already known. To complete these results, Fig. 1 maps changes in GP density and shows both the sub-departmental nature of these disparities and the growth of areas with poor access to GP care, particularly in the northern half of mainland France. In addition, territorial inequalities have emerged: it seems that the best-endowed cantons are spatially associated, like the least-endowed ones, in terms of medical density. This is confirmed by spatial tests (Supplement E) associated with the Moran (1948, 1950) and Geary (1954) statistics, both of which indicate positive spatial autocorrelations within the non-spatial panel model residuals.

At the same time, descriptive statistics confirm that the French population has aged (with fewer young people and more elderly people proportionally in the population), which once again implies more care needs. Since GP density has not evolved in the same direction as

Table 2
Descriptive statistics – evolutions in means and standard errors.[a].

Variables	Panel	2007	2012	2017
GP density (log)	−0.184	−0.134	−0.179	−0.238
	[0.0043]	[0.0069]	[0.0074]	[0.0078]
GP density (Gini)	0.229	0.216	0.228	0.240
Under 25 y.o. (%)	28.209	28.941	28.282	27.403
	[0.0419]	[0.0713]	[0.0708]	[0.0734]
75 y.o. & over (%)	10.323	9.711	10.471	10.789
	[0.0333]	[0.0564]	[0.0579]	[0.0572]
Density of specialists	0.300	0.296	0.297	0.308
	[0.0053]	[0.0091]	[0.0090]	[0.0096]
Diversity of specialties	0.226	0.229	0.226	0.223
	[0.0033]	[0.0059]	[0.0057]	[0.0056]
Density of hospitals & various medical establishments	4.490	4.129	4.437	4.905
	[0.0186]	[0.0293]	[0.0316]	[0.0341]
Density of services	21.808	20.186	21.917	23.321
	[0.0931]	[0.1629]	[0.1542]	[0.1622]
Peripheral population (%)	26.489	26.672	26.449	26.345
	[0.3631]	[0.6325]	[0.6283]	[0.6262]
Deprivation (D*)	0.401	0.431	0.399	0.372
	[0.0009]	[0.0018]	[0.0014]	[0.0013]

[a] More details in Supplement F.

[13] Spatial relationships are modeled by a standardized inverse distances matrix.

[14] In this respect, statistics attempting to measure it remain close to a correlation coefficient (Legendre, 1993).

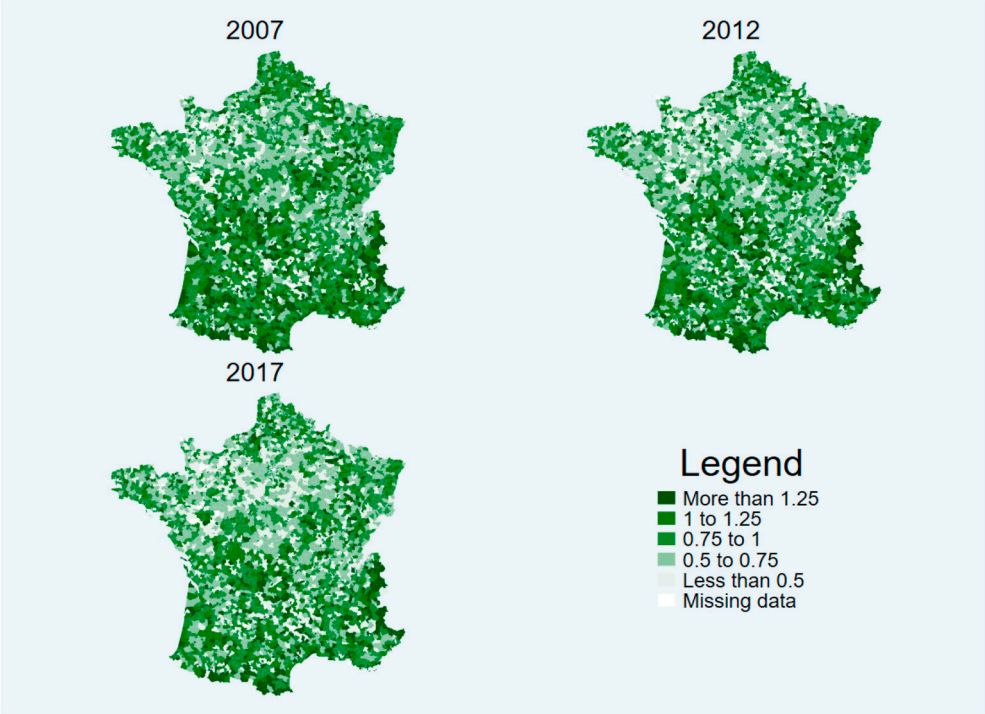

Fig. 1. Maps of changes in GP density in France (2007–2017).

Table 3
Models – Non-spatialized and spatialized determinants of GP density's dynamics.

	PANEL	SDEM
Non-spatialized coefficients		
Under 25 y.o. (%)	0.009**	−0.002
75 y.o. & over (%)	0.002	0.011*
Density of specialists	0.034*	0.034*
Diversity of specialists	0.243***	0.216***
Density of hospitals & various medical establishments	0.023***	0.034***
Density of services	−0.006***	0.004***
Peripheral population (%)	0.008**	0.005*
Deprivation (D*)	1.020***	0.069
Spatialized coefficients		
wU		0.326
wUnder 25 y.o. (%)		0.010
w75 y.o. & over (%)		0.100*
wDensity of specialists		0.307
wDiversity of specialties		−0.075
wDensity of hospitals & various medical establishments		−0.039
wDensity of services		−0.054***
wPeripheral population (%)		0.267**
wDeprivation (D*)		−0.702
Information and results of the regression tests		
N	10,314	10,314
Pseudo R^2	0.065	0.040
AIC	−9264.3	−3618.5
BIC	−9199.1	−3488.1

$*p < 0.05, **p < 0.01, ***p < 0.001$

demand, there are growing tensions surrounding needs.

As for changes within territories, overall, more services are available to the population (from 20 services for 1000 people to more than 23), deprivation has been reduced, and the population living outside the areas of influence of large metropolises has fallen slightly.

Some of the panel modeling, and more specifically that of the spatial panels, is presented in Table 3.[15] Table 4 shows the direct (X_i on Y_i), indirect (X_i on Y_j and X_j on Y_i) and total impacts of the different explanatory variables.

As with the reaction of the explained variable to healthcare supply, we can observe direct effects that are always significant and positive. In this respect, an increase in the density of specialists and diversity[16] of specialties, or even in the density of hospitals and various medical establishments within a canton, has a significantly positive impact on the GP density within this canton. On the other hand, no indirect impacts are observed between these same variables. In other words, changes in the density of specialists in the surrounding cantons do not impact the GP density within a canton. The same applies to hospitals and various medical establishments. In spatial terms, moreover, there are no endogenous effects.[17] Here, the increase in the GP density in nearby cantons also seems to have no impact on this same density within a canton. In terms of geographical phenomena, it seems to be neither a push nor a pull effect in the location of GPs at canton level. About the demographic structure, we first observe that changes in the age structure have an impact on GP density only for elderly people when the spatial autocorrelation bias has been removed. If the percentage of people aged

[15] In order to simplify the presentation of the results, Tables 3 and 4 only present the model selected by the procedure explained in Supplement D, whose results are presented in Supplement E. To consult all results, readers may refer to Supplements G and H.

[16] Results relating to the impact of variations in the diversity of specialties over time should be considered with the greatest caution, as they exclude almost three quarters of cantons. Readers can refer to Supplement I for further details.

[17] With the exception of the SAR model, see Supplement G.

Table 4
Direct, indirect and total impacts of territorial characteristics on GP density's dynamics.

	SDEM
Direct impacts	
Under 25 y.o. (%)	−0.002
75 y.o. & over (%)	0.011*
Density of specialists	0.034*
Diversity of specialties	0.216***
Density of hospitals & various medical establishments	0.034***
Density of services	0.004**
Peripheral population (%)	0.005*
Deprivation (D*)	0.069
Indirect impacts	
Under 25 y.o. (%)	0.010
75 y.o. & over (%)	0.100*
Density of specialists	0.307
Diversity of specialties	−0.075
Density of hospitals & various medical establishments	−0.039
Density of services	−0.054***
Peripheral population (%)	0.267**
Deprivation (D*)	−0.702
Total impacts	
Under 25 y.o. (%)	0.007
75 y.o. & over (%)	0.111*
Density of specialists	0.340
Diversity of specialties	0.141
Density of hospitals & various medical establishments	−0.005
Density of services	−0.049***
Peripheral population (%)	0.273**
Deprivation (D*)	−0.632

$*p < 0.05, **p < 0.01, ***p < 0.001$

75 and over increases by one point in a canton, then the density of GPs in the same canton increases by 1.1%. For the same variation in the surrounding cantons, the density of GPs in a canton increases by 10%.

Regarding QoL, the dynamics of peripheralization have a positive impact (whether direct or indirect) on GP density.[18] Next, changes in deprivation have no impact in the context of the spatial models, implying that an increase in poverty does not scare away GPs.[19] On the other hand, in the non-spatialized model, the dynamics of GP density are positive in impoverished areas. Added to all this is the density of services, whose direct impacts are positive and whose indirect ones are negative. Thus, an increase of one service per 1000 inhabitants in a canton is associated, ceteris paribus, with an increase in the density of GPs of 0.4%. When the same increase in the density of services occurs in neighboring cantons, this decreases the density of GPs within a canton by 5.4%. These services, which greatly contribute to daily life, therefore have a strong power of attraction, going so far as to empty the neighboring cantons that lack these services.

4. Discussion

Finally, which territorial characteristics have an impact on the location dynamics of GPs? To analyze this, it must first be kept in mind that the density of GPs decreased between 2007 and 2017 and that territorial disparities increased. One hypothesis from the literature might be that impoverished cantons isolated from metropolises should be the first victims of these inequalities. Our results indicate that this is not the case. Ceteris paribus, the deprivation dynamics of a canton and its neighbors have no impact on GP density. Regarding the percentage of the peripheral population, the effect is actually the opposite of what we might have expected, since where the peripheralization phenomenon occurs, the density increases. Consequently, this paper does not conclude that the isolation of peripheral and poor areas in terms of access to GPs is worsening. This does not mean that this isolation does not exist.[20] However, we do not find that it is aggravated because territories are excluded from large metropolises, nor that they are impoverished. The results therefore do not indicate the expected socio-territorial dynamics. It is not a simple opposition between the metropolitan France and the peripheral France. The mapping of the territorial dynamics of the GPs' location indicates intra-territorial, intra-metropolis and intra-periphery disparities. Defining policies on a regional scale does not therefore seem very relevant for dealing with these issues.

To what can the territorial evolutions be attributed? The cantons that have experienced an increase in available services attract GPs, leading to a centripetal effect distinguished by negative indirect effects. This once again underlines the importance of using spatial models, because in the conventional panel, the services effect is the opposite. Thus, not excluding spatial biases from the DGP would lead to a misunderstanding of these dynamics. Furthermore, the use of pseudo-cantons rather than "living areas" highlights the importance of the density of services among QoL factors. Proximity to stores, leisure activities, transport, public services, etc., thus appears to be an important factor in the location of self-employed GPs.

In addition, this care supply appears to be increasing where other care supply (whether outpatient or hospital-based) has itself increased. This means that there are grouping dynamics within cantons. Therefore, what we observe is territorial complementarity rather than competition. However, the scope of this attraction does not seem to extend beyond the canton itself since these same variables do not have any indirect effects. The magnet effect of specialists, hospitals and other medical institutions is therefore very localized. Nevertheless, the data do not show any competitive effects in location choices, but rather complementarity between different healthcare services, although this would perhaps be different with a much larger number of physicians. This leads to a polarization tendency of available care between cantons, with some enjoying more and more care and others less and less. Possibly, this phenomenon can be partly attributed to the growth of Multiprofessional Health Centers (MHCs, in French, *Maisons de Santé Pluriprofessionnelles*) or grouped professional practices (Chaput et al., 2019). Indeed, as well as the decline in the availability of GPs during the 2000s and 2010s in France, another phenomenon has been their tendency to group together,[21] particularly young practitioners within MHCs. These centers increased in number from 20 in 2008 to 1300 in 2020, and are spread across the whole French territory albeit mainly in peri-urban areas and rural fringes, thus offsetting the drop in city care, particularly in general practice[22] (Chevillard et al., 2013; Chevillard & Mousquès, 2020). In addition to supplying care in territories that were previously in deficit, MHCs allow doctors to work shorter hours on average (Aulagnier et al., 2007; Bourgueil et al., 2009). They therefore act as a tool in the fight against the scarcity of doctors. However, this form of healthcare leads to a polarization of the supply of healthcare, which can cause difficulties in terms of geographical access.

We can therefore highlight a clear trend toward the grouping

[18] However, this result should be considered with caution, as variations in the share of the population within the cantons living in peripheral territories only concern around a third of cantons.

[19] This could be attributed to the panel length and to the fact that over several decades the result would be different.

[20] We therefore do not contest pre-existing works on this point.

[21] In 2019, a proportion rising to 61% of private GPs practiced in a group (Chaput et al., 2019) compared to 54% in 2009 (Baudier et al., 2010).

[22] Although medical density is decreasing in the peri-urban and rural fringes, this is not for the same reasons. In peri-urban areas, it is because the population is increasing, whereas in rural fringes (where the population is not increasing and is aging) it is because there are fewer and fewer doctors (Chevillard & Mousquès, 2020).

together in cantons of doctors according to specialties, in areas that allow easy access to a whole range of services, and without any apparent disadvantage for rural areas compared with large cities or for areas that are becoming poorer. As the literature has argued, the fact that this isolation is not aggravated is probably also partly due to MHCs, but this article does not provide empirical evidence for this.

However, some of these interpretations remain questionable, as several variations are based on a relatively small proportion of cantons (particularly for the diversity of specialties and for peripheralization) or on a time period that may be too short to have a significant impact (particularly for deprivation). Consequently, a replication of this study over a longer period of time would be interesting in order to confirm or refute some results. However, as the PDF has only been available since 2007, it is currently impossible to conduct this kind of work in France. Moreover, the number of GPs, here used to establish the explained variable, does not perfectly reflect the healthcare supply. For this, more specific data would be needed, including the number of hours worked. This problem of data availability also implies that, at this stage, it is not possible to shift some of the explanatory variables (particularly medical supply) without ending up with a panel that is far too short. Indeed, our panel translates location dynamics, without being able to define perfectly clear causal links. To do so, it would be worth reproducing similar models, but using an explanatory variable of the previous period's healthcare supply. In this way, it could be determined whether the pre-existing care supply acts as a magnet for GPs to locate to. Finally, the constraint of removing cantons with zero values from the dependent variable prevented us from producing the same type of model with the adjusted supply of specialists as an explanatory variable. Making a spatial model requires both territorial continuity and a normality of dependent variables. As these conditions are not met, we hope that future researchers will be able to address this question and provide answers that we have not been able to give.

Authorship contribution

Iñaki Blanco-Cazeaux: conception & design of study, acquisition of data, analysis and interpretation of data, drafting the manuscript, revising the manuscript critically for important intellectual content, approval of the version of the manuscript to be published.

Declaration of competing interest

The author declares no competing interests.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101240.

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