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RESEARCH ARTICLE

Veterinarian shortage areas: what determines the location of new graduates?

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Abstract Over the past ten years, the number of veterinarians in rural areas has declined in many countries, giving rise to concerns about the geographical coverage of livestock health care. However, very little scientific work has been devoted to veterinarian shortage areas. This paper aims to shed light on this issue. Using econometric models based on count data, we test the effect of geographical and socio-economic characteristics of French living zones on the number of new veterinarians established in 2014. This work generated several findings. First, our study emphasises the importance of taking into account the heterogeneity of veterinarians. Indeed, the estimation results highly depend on the type of animals treated and gender. Second, we observed that the location of food animal practitioners depends on the characteristics of local demand (size and type of animal production) as well as on labour supply factors (natural or urban amenities, public service facilities). The results suggest that the risk of veterinarian shortages may be higher for areas specialised in animal production other than bovine (sheep, goats). They also suggest that maintaining public services may be a key issue for attracting food animal veterinarians in remote rural areas. Finally, our results show that veterinarians tend to cluster, which suggests that new veterinarians choose to establish themselves as employees or associates in already existing veterinary offices in order to share costs and minimise risks.

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Introduction

Over the past ten years, several studies and ministerial reports have shown a continuous reduction in the number of veterinarians in rural areas and a disaffection of new graduates with food animal practices in France. This double dynamic, also observed in other countries (Smyth et al. 2015), has raised concerns within the veterinarian community as well as within parts of the agricultural community (Wang et al. 2012).

The development of veterinarian shortage areas is an issue of major economic and social importance. A lack of veterinarians reduces disease prevention activities and leads to deterioration in sanitary supervision for livestock, thus favouring the development of livestock diseases. According to Mclnerney (1996) and Bennett (2003), the economic impacts of livestock diseases are numerous. The costs caused by the loss of production, the decrease in the quality of production and the higher consumption and waste of inputs must be added to the costs directly associated with the control and prevention of disease. Livestock diseases also generate externalities, in particular through their effects on animal welfare (Lagerkvist et al. 2011; Mangen and Burrell 2003). Given these different market- and non-market-related costs, livestock diseases have a negative impact on the profitability of farms and can threaten their sustainability (Lloyd et al. 2006). However, according to their severity and the extent of contamination, livestock diseases may also have impacts that go beyond the affected farm (Attavanich et al. 2011) or the sole agricultural sector (Dijkhuizen et al. 1991). As illustrated in the case of foot-and-mouth disease, such diseases can have disastrous macro-economic consequences due to the interdependence of economic sectors (Boisvert et al. 2012). The shortage of veterinarian services may also have repercussions on human health related to the spread of zoonoses or chemical substances used to treat sick animals (Teillant et al. 2015). Furthermore, the shortage of veterinarians increases the stakes in terms of regional development and land use planning. Without a sufficient number of veterinarians, equal access to health services, albeit for animals, may be jeopardised. The loss of veterinarians in rural areas is also a loss of high-skilled and wealthy inhabitants, which could deprive rural communities of human capital and potential vectors of development as well as of the financial and fiscal resources needed to maintain public services (Olfert et al. 2012).

Thus, the drop in the number of veterinarians may have deleterious socio-economic effects and may contribute to further reducing the appeal of already remote and isolated areas. Therefore, analysing the geographical distribution of veterinarians and its determinants is a crucial matter. The scientific literature addressing such questions is relatively limited. Among these works, some authors have considered the notion of veterinarian shortage areas and have noted the difficulties in identifying such areas (Wang et al. 2012). Very little research has attempted to assess the factors underlying veterinarian location. Smyth et al. (2015) showed that the geographic distribution of veterinarians does not exactly follow either that of the population or that of domestic animals. Olfert et al. (2012) even showed that veterinarian rural location has little sensitivity to cattle numbers. Thus, demand would not be sufficient to explain the location of veterinarians, and labour supply factors would also be decisive. Regarding the latter, Wang et al. (2015) showed that veterinarians tend not to locate in rural areas. Nevertheless, socio-economic characteristics, such as the presence of professional peers and a vibrant community, appear to enhance rural attractiveness (Olfert et al. 2012).

In line with this research, our article aims to clarify the determinants of the location of veterinarians. Following Olfert et al. (2012), our paper focuses on a regional economic approach and proposes an empirical application to the French case. Based on count data models, we test the effects of geographical and socio-economic characteristics in French living zones on the number of new veterinarians who have established themselves in 2014. This article contributes to the existing literature in two main ways. First, the heterogeneity of the veterinarian population is rarely taken into account. Distinguishing, on the one hand, three categories of veterinarians (food animal, companion animal or mixed practitioner) and, on the other, gender differences, this article shows that the location factors have different impacts according to the type of veterinarian. More specifically, the results reveal that the livestock demand influences the location of food animal veterinarians but not that of companion animal veterinarians. Thus, this work tends to qualify the conclusions of previous research on the relative importance of demand versus supply factors in veterinarian location choice. Furthermore, it shows that, when women and men are compared within the same professional practices, the men are more attracted to urban areas and are more sensitive to access to emergency services. Second, this article furthers the analysis of professional peer effects conducted by Olfert et al. (2012). These authors study peer effects through the share of the educated population. This variable captures both social interactions and potential agglomeration economies and does not enable conclusions about professional interactions among veterinarians. We propose to refine their work by analysing whether veterinarians tend to cluster.

The article is structured as follows. In Sect. 2, we review the literature and present our theoretical background. Section 3 describes the methodology and presents the data, the econometric model and the variables. The results of our estimates are presented in Sect. 4 and discussed in Sect. 5. Section 6 concludes.

Theoretical background

Urban versus rural location

In economic geography, the location of jobs and people is considered to be the result of a trade-off between agglomeration and dispersion forces (Fujita and Thisse 1996). Firms tend to cluster since geographic concentration brings economic advantages, referred to as agglomeration economies. Such economies depend on economies of scale within the firm (Krugman 1991). They also depend on diverse technological or pecuniary externalities generated by sharing, matching or learning mechanisms (Duranton and Puga 2004; Puga 2010). These externalities may be external to the firm but internal to the industry (economies of localisation), or they may be external to the industry and linked to the size of the entire economy (economies of urbanisation) (Henderson 1983; Nakamura 1985). As a result, firms tend to follow population in order to access greater market potential and labour pools; conversely, households tend to follow firms in order to access a wider job market and a greater range of goods and services (Abdel-Rahman 1988), including public goods. These agglomeration forces lead to a cumulative process wherein firms and people cluster geographically, which gives rise to the emergence and growth of cities.

The rural location of activities is therefore generally perceived as resulting exclusively from dispersion forces. Among such forces, fixed resources (such as land or mineral resources) are a strong restoring force and explain the rural location of activities such as farming, forestry and mining. Nevertheless, recent work in economic geography has shown that rural location depends on more than just dispersion forces and that agglomeration economies may also favour the market entry of new firms in rural areas (Artz et al. 2016). Other work in regional economics has ascertained the impact of natural amenities on rural development (Deller et al. 2001; Irwin et al. 2010). Indeed, amenities and quality of life play a major role in household migration (Graves and Linneman 1979; Partridge 2010). The endowments of natural amenities in rural areas encourage, from this very fact, demographic growth (Poudyal et al. 2008; Rickman and Rickman 2011). Throughout the population, rural amenities also strengthen local demand for goods and services and thus help to attract more population-based firms and jobs. Finally, rural amenities are resources for several economic activities (such as tourism) and thus may contribute more directly to attracting firms to rural areas (Gottlieb 1995).

Determinants of veterinarian location

Regarding location choice, the case of veterinarians is specific. Indeed, their high level of education and skills gives them geographic mobility. Veterinarians are even more mobile given that, as physicians, they are self-employed professionals.[1] Thus, one could expect that their location choice would be less constrained by the job market and would rather be a decision resulting from both residential and firm location considerations. Very little work in regional economics has examined the determinants of veterinarian location, and Olfert et al. (2012) stand somewhat as an exception. However, this question can be compared to the location of practitioners, which has generated an extensive body of literature (Bolduc et al. 1996; Correia and Veiga 2010; Dionne et al. 1987).

Following Goetz and Debertin (1996) and Olfert et al. (2012), we consider that a representative veterinarian locates so that he maximises his utility subject to an income constraint. His utility is a function of a composite good and a set of amenities. Furthermore, the veterinarian income constraint depends, on the one hand, on the price of the composite good and, on the other hand, on the income earned by the veterinarian. Following Olfert et al. (2012), we assume that it is mainly amenities and the income earned by the veterinarian that vary according to his location. As a result, the veterinarian location choice depends, on the one hand, on economic factors affecting income and, on the other hand, on hedonic factors linked to amenities.

The income earned by a veterinarian depends, first, on the demand for veterinary services. Within the work on physicians, Reskin and Campbell (1974) have shown that

[1] The number of employed practitioners, although increasing, remains low, with only 36% of veterinarians. A majority of them work as independent practitioners, whether by themselves (18%) or as a partner in a practice (46%).

the demand for medical services depends, of course, on the size of the population but also on its state of health. Similarly, we take for granted that the demand for veterinary services depends on the size of the animal population but also on qualitative factors, such as the type of animal treated (for instance, cattle or sheep) or the type of farming (i.e., intensive or extensive). Given agricultural demand, one might expect veterinarians to be more sensitive to dispersion forces than doctors would be and that veterinarians would be more likely to locate in rural areas. However, Olfert et al. (2012) showed that veterinarian location choice also strongly depends on the human population, yet the distribution of veterinarians does not exactly follow that of the population or that of domestic animals (Smyth et al. 2015). This is partly related to the fact that the relationship between demand and supply of veterinary services is not linear and that the increase in the population treated may lead to economies of scale at first and then to congestion effects (Olfert et al. 2012). However, it is also linked to the fact that veterinarians are a heterogeneous population. Indeed, we may distinguish between veterinarians according to whether they treat food animals (FA), companion animals (CA) or both categories. In addition to the lack of data on the type of animal treated, the existence of this latter mixed category makes the analysis of the link between supply and demand for veterinary services difficult. The income earned by a veterinary depends, secondly, on the professional environment and the presence of other veterinarians. The effect of geographic agglomeration remains ambiguous. Indeed, one might expect that a veterinarian would choose to move away from other veterinarians to avoid competition (Correia and Veiga 2010). However, work in economic geography suggests that the agglomeration of veterinarians may be a source of localisation economies. This may lead a veterinarian to locate near other veterinarians in order to share knowledge, experience, equipment and resources.

Amenities are also determining factors for veterinarian location. As they are particularly mobile from a geographic standpoint, one might expect veterinarians to be sensitive to the quality of life as well as to natural amenities and therefore to locate more in rural areas. Nevertheless, there are also amenities in urban areas, and research on the location of physicians has shown their preference for certain leisure facilities that are more numerous in cities, such as restaurants (Dionne et al. 1987; Goetz and Debertin 1996). Thus, it is unlikely that amenities are a dispersion force, and the appeal of rural amenities may be insufficient to counteract urban centres' attractiveness to veterinarians. Finally, quality of life also depends on social interaction and the socio-economic characteristics of the neighbourhood (Durlauf 2004). Olfert et al. (2012) showed that the level of education and the occupational structure of the population play a role in the location choice of veterinarians and that these are more attracted by vibrant rural communities.

Methodology

Data and dependent variables

Data on veterinarians were extracted from a database built up by the National Order of French Veterinarians. This database recorded all the active veterinarians in France in 2014 and contains individual information (location, skills, date of birth, etc.). Unfortunately, this database does not indicate the date on which the veterinarians located to their present location. This lack may generate simultaneity bias, as the veterinarian location choice might have been made prior to the independent variables. Thus, to guarantee no simultaneity bias, our analysis focuses on the veterinarians who graduated in 2014.

This sample includes 503 persons who are an average of 29 years old. To better take into account the heterogeneity of veterinarian practices, we have distinguished four different types of veterinarians (Table 1):

- CA practitioners: who treat solely companion animals (59% of our sample)
- FA practitioners: who treat mainly food animals (16%)
- Mixed practitioners: who treat both companion and food animals (14%)
- Other practitioners (11%)

Women are preponderant and represent 73% of the sample. They are not equally distributed across the veterinarian practices. More precisely, they are highly overrepresented in the CA category (78%), while they are underrepresented in the FA category (54%).

To analyse the influence of the location features, we have aggregated individual data and conducted our analysis at the French 'living zone' scale. This spatial unit is defined by the National Institute of Statistics and Economic Studies (INSEE) as the smallest spatial unit on which inhabitants have access to everyday facilities and services. It has the advantages of being a functional economic area and of being small enough to grasp the diversity of local situations and to analyse spatial interactions among veterinarians. There are 1666 living zones in France. Due to the availability of data, our analysis covers 1630 living zones in metropolitan France.

Our first dependent variable N_i corresponds to the number of veterinarians who graduated in 2014 in living zone i. This variable varies from 0 in a large number of living zones to 53.

The geographic distribution of N_i does not show specific regional patterns (Fig. 1). Nevertheless, new veterinarians are less likely to locate in the eastern part of France. Although fairly similar, the geographic distribution of these new veterinarians does not perfectly match the geographic distribution of the already settled veterinarians (Fig. 2).

To take into account the heterogeneity of the veterinarians and to analyse whether the living zone characteristics differently influence the veterinarians according to their practices, we also estimated models on subsamples and built three other dependent variables. N_{FA_i}, N_{CA_i} and N_{M_i} correspond to the number of veterinarians who

Table 1 Distribution of new veterinarians by gender and practice

	Companion animal practitioners (%)	Food animal practitioners (%)	Mixed practitioners (%)	Other practitioners (%)	All (%)
Women	78.3	54.2	70.8	73.6	72.8
Men	21.7	45.8	29.2	26.4	27.2
All	100.0	100.0	100.0	100.0	100.0

Pearson χ^2: 19.13; Pr = 0.00

graduated in 2014 and who treat FA, CA and both types of animals, respectively, within living zone *i*. Finally, to test the gender effect, we estimated models on six other dependent variables that differentiate the new veterinarians, the CA and FA practitioners according to their gender (F_i , M_i, F_{FA_i}, M_{FA_i} and F_{CA_i}, M_{CA_i}, respectively).

Econometric models

Poisson and negative binomial models

As with all count data, our dependent variables take only integer and positive values. They are also characterised by a non-normal distribution that includes a small number of distinct values. In that case, the linear regression model is not relevant, insofar as it can predict negative values. Furthermore, the log-transformation of the dependent variable is impossible due to the presence of zeros. Thus, it is necessary to switch to count data models, particularly to the standard Poisson regression. In this latter model,

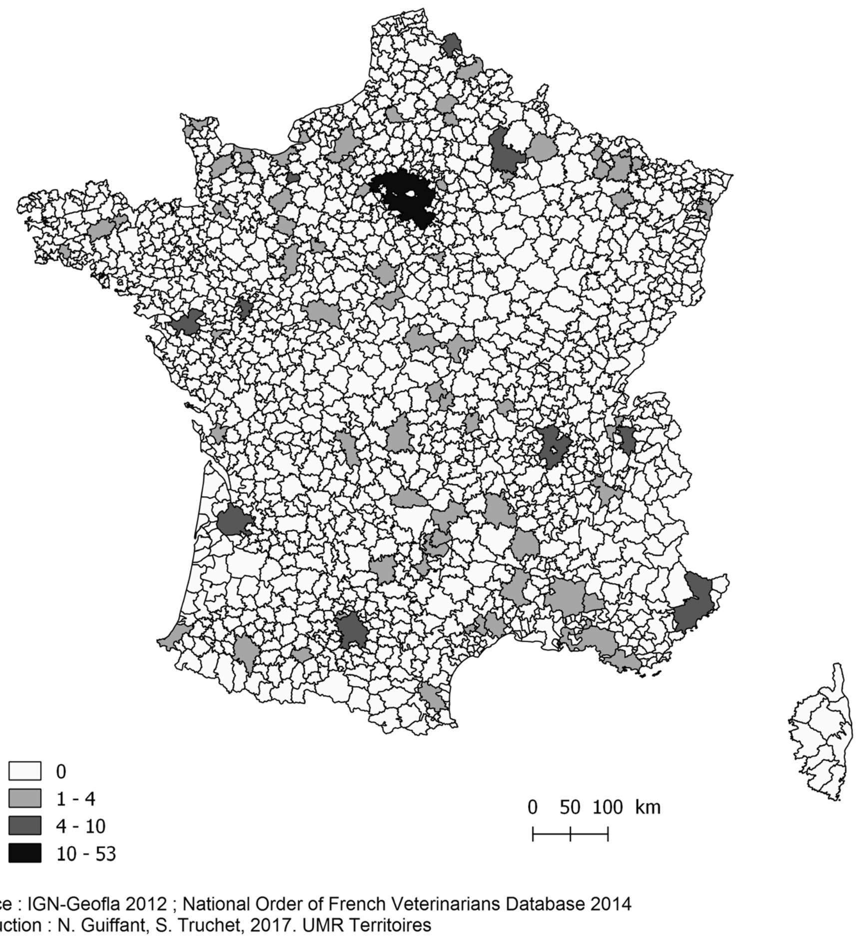
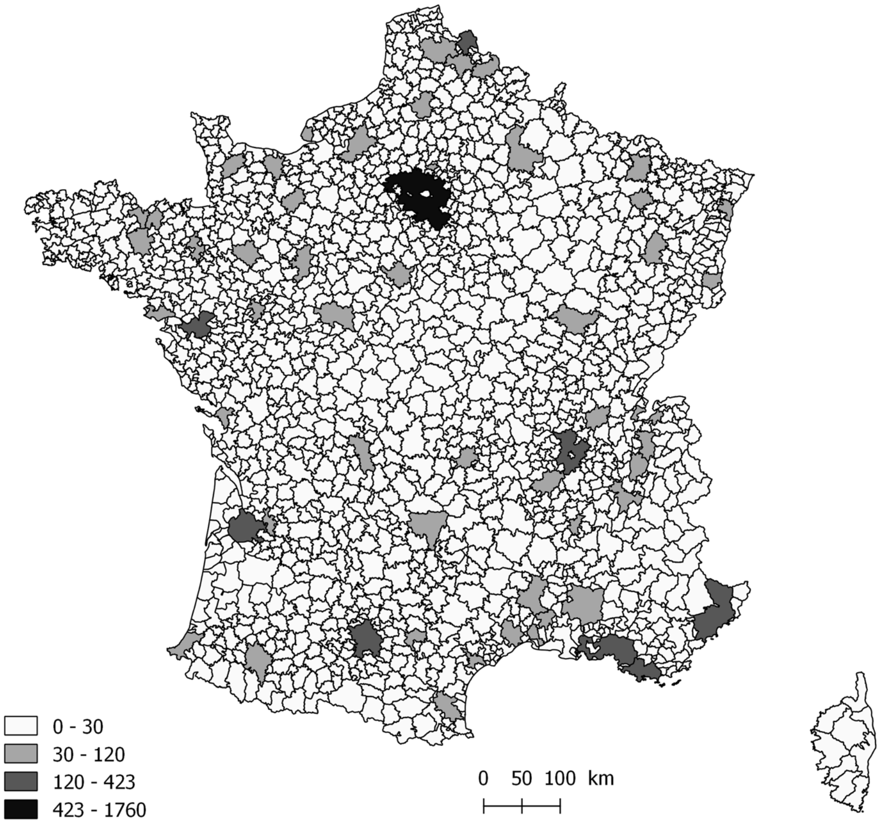


Fig. 1 Geographic distribution of veterinarians who graduated in 2014



Source : IGN-Geofla 2012 ; National Order of French Veterinarians Database 2014.
Production : N. Guiffant, S. Truchet, 2017. UMR Territoires.

Fig. 2 Geographic distribution of veterinarians settled before 2014

the density of the dependent variable N_i given a set of independent variables X_i can be written as follows (Wooldridge 2010; Winkelmann 2008):

$$\Pr(N_i = n_i | \mathrm{x}_i, u_i) = \frac{\mathrm{e}^{-\lambda_i u_i} (\lambda_i u_i)^{n_i}}{n_i!} \text{ where } \ln(\mu_i) = \beta \mathrm{x}_i + \epsilon_i = \ln(\lambda_i) + \ln(u_i)$$

The Poisson model suffers from an important drawback: it relies on a restrictive equidispersion assumption and is valid only if the variance μ_i, and the mean of the dependent variable are equal. In our case, the descriptive statistics show that this hypothesis is realistic for the dependent variablesN_{FA_i} N_{M_i}, F_{FA_i} and M_{FA_i} [2] (Table 2). However, the variances of N_i, N_{CA_i} , F_i and F_{CA_i} are respectively nearly eight, nine, seven and eight times higher than their means.

Therefore, the mean variance equality hypothesis is violated, and the Poisson model is not appropriate. We then need to resort to a negative binomial model (NB). This model is able to address the problem of the overdispersion of the dependent variables by introducing

[2] The variances of N_{FA_i}, N_{M_i}, F_{FA_i} and M_{FA_i} nearly equal their means.

Table 2 Descriptive statistics for the dependant variables (Obs. = 1630 living zones)

Variable	Definition	Mean	SD	Min.	Max.
N_i	Number of veterinarians who graduated in 2014	0.31	1.55	0.00	53.00
N_{FA_i}	Number of veterinarians who graduated in 2014 and reported as treating mainly FA	0.05	0.25	0.00	3.00
N_{CA_i}	Number of veterinarians who graduated in 2014 and reported as treating solely CA	0.18	1.27	0.00	44.00
N_{M_i}	Number of veterinarians who graduated in 2014 and reported as treating both CA (main species treated) and FA	0.04	0.23	0.00	3.00
F_i	Number of female veterinarians who graduated in 2014	0.22	1.20	0.00	41.00
M_i	Number of male veterinarians who graduated in 2014	0.08	0.44	0.00	12.00
F_{FA_i}	Number of female veterinarians who graduated in 2014 and reported as treating mainly FA	0.03	0.17	0.00	3.00
M_{FA_i}	Number of male veterinarians who graduated in 2014 and reported as treating mainly FA	0.02	0.16	0.00	3.00
F_{CA_i}	Number of female veterinarians who graduated in 2014 and reported as treating solely CA	0.14	1.05	0.00	37.00
M_{CA_i}	Number of male veterinarians who graduated in 2014 and reported as treating solely CA	0.04	0.29	0.00	7.00

an individual unobserved effect in the conventional Poisson model. As the variances of M_i and M_{CA_i} are respectively two and a half and two times higher than their means, their cases are more inconclusive. The overdispersion tests indicate that the negative binomial model is more adapted for M_i, whereas the Poisson model is more suitable for M_{CA_i}.

Zero inflated models

Count data are also very often characterised by the excess of zero. In the literature, there is a debate on the interpretation of zero counts and on the best models to treat this problem (Liviano and Arauzo-Carod 2013). The zero-inflated Poisson and the zero negative binomial models are the most often used. These two regime models include two latent groups that are treated differently by combining a binary process with a count process as in the following equation (Winkelmann 2008). In the ZINB case,

$$\Pr(N_i = n_i | \mathrm{x}_i, u_i, \mathrm{z}_i) = \mathrm{p}(1 - \min(n_i, 1)) + (1 - \mathrm{p})\mathrm{G}(\mathrm{x}_i\beta_2, \alpha) \qquad n_i = 0, 1, 2, \ldots$$

The probability function of the outcome n_i in the ZINB model is a mixture of $p = F(z_i\beta_1)$, the probability of belonging to the always 0-group from a logit specification, 1 the probability of the 0 outcome in the always 0-group and $G(x_i\beta_2, \alpha)$ the probability of each count (including zeros) in the not always 0-group from a NB model with the overdispersion parameter α (i.e., with conditional mean $\mu_i = \exp(x_i\beta_2)$ and conditional variance $\mu_i(1 + \alpha\mu_i)$.

The Vuong test comparing ZIP and Poisson models and ZINB and NB models, respectively, is used to choose between both specifications (Vuong 1989; Greene 2008). This statistic has a standard normal distribution. A value higher than 1.96 for the Vuong statistic favours the zero-inflated models, while a value less than − 1.96 favours the negative binomial distribution (the test is inconclusive for values between

− 1.96 and 1.96). In our case, this test suggests that the zero-inflated models better fit the data and are a significant improvement over the standard negative binomial model for N_i, N_{CA_i}, F_i and F_{CA_i}.

Thus, in the end, we have estimated:

- Poisson models on the mixed practitioner (N_{M_i}), the FA practitioner (N_{FA_i}), the male CA practitioner (M_{CA_i}) and the male (M_{FA_i}) and female FA practioner (F_{FA_i}) variables
- Negative binomial models on the male veterinarians (M_i)
- Zero-inflated negative binomial models on all the veterinarians (N_i), the CA practitioners (N_{CA_i}), the female veterinarians (F_i) and the female CA practitioners (F_{CA_i})

Independent variables

In line with the theoretical background presented in Sect. 2, four groups of independent variables have been introduced. Table 3 presents the main descriptive statistics regarding these independent variables.

The first group concerns the demand for veterinary services. As seen previously, the demand for veterinary services is heterogeneous and concerns FA, CA or both. Regarding CA, to the best of our knowledge, there are no data that would enable us to know the exact number of pets in municipalities or living zones. However, some research has shown that the CA geographic distribution corresponds to that of the human population (Smyth et al. 2015). Thus, given the lack of relevant data and following Olfert et al. (2012), we have chosen to use the human population as a proxy for the CA population. Based on the general census population data, the variable Population corresponds to the number of inhabitants within the living zones in 2013. The CA practitioners may also be influenced by the growth of the market. To test this assumption, we have also introduced the variable Δpop0813 corresponding to the change rate of the living zone population between 2008 and 2013. For FA, we have introduced the variable Livestock built from municipal data drawn from the French General Census of Agriculture of 2010. It corresponds to the number of livestock units[3] within the living zones. To take into account economies of scale and to identify potential congestion effects, we have introduced the quadratic forms of the population and livestock variables. In addition to the livestock units and given that the need for veterinary services differs greatly according to the type of herd, we have attempted to integrate qualitative aspects and to provide specific characteristics of the livestock. We have thus built six additional variables aiming to account for the living zones' agricultural specialisation. All the data used to build these agricultural variables were also drawn from the French General Census of Agriculture of 2010, which reports the predominant type of agricultural production for each French municipality.[4] More precisely, our six variables focus on the living zone specialisations of dairy cattle

[3] The livestock unit (Unité Gros Bétail in French) is a variable built from coefficients, enabling one to compare the different animals with one another and to sum them up in a single number.

[4] This method used by the French Ministry of Agriculture is based on the calculation of regional coefficients relative to the standard gross output (Orientation technico-économique or OTEX in French).

Table 3 Summary statistics for independent variables

Variable	Definition	Number	Mean	SD	Min.	Max.
Demand variables						
Population	Population in 2013 (10,000 inhabitants)	1630	3.87	28.10	0.19	1076.61
Population^2	Squared population in 2013 (10,000 inhabitants)	1630	804.18	28,727.20	0.04	1,159,091.00
Δpop0813	Change rate of the population between 2008 and 2014 (%)	1630	2.91	4.43	− 18.89	36.38
Livestock	Number of livestock units in 2010 (thousands)	1630	16.05	20.45	0.00	249.53
Livestock^2	Squared number of livestock units in 2010 (thousands)	1630	675.70	2409.71	0.00	62,263.72
Dairy	Share of municipalities specialised in dairy cattle production in the living zone in 2010	1630	0.06	0.15	0.00	1.00
Meat	Share of municipalities specialised in bovine meat production in the living zone in 2010	1630	0.04	0.12	0.00	0.89
Mixed bovine	Share of municipalities specialised in dairy cattle and bovine meat production in the living zone in 2010	1630	0.09	0.17	0.00	1.00
Sheep and goats	Share of municipalities specialised in sheep and goat production in the living zone in 2010	1630	0.03	0.10	0.00	0.91
Mixed crop–livestock	Share of municipalities specialised in mixed crop–livestock farming in the living zone in 2010	1630	0.35	0.26	0.00	1.00
Other animals	Share of municipalities specialised in other animal production in the living zone in 2010	1630	0.11	0.19	0.00	1.00
Professional environment variables						
N_density	Number of veterinarians who graduated before 2014 per 10,000 inhabitants	1630	3.58	2.97	0.00	30.03
Vet 60+	Share of veterinarians aged 60 years and over among those who graduated before 2014	1544	0.12	0.19	0.00	1.00
Vet indep.	Share of independents among the veterinarians who graduated before 2014	1544	0.70	0.23	0.00	1.00
Socio-economic characteristics variables						
Income	Average for the living zone of the annual municipal median incomes per consumption unit in 2013 (K€)	1630	19.84	2.80	13.48	41.58
Agri. 55+	Average for the living zone of the municipal shares of farmers aged 55 and over in 2011	1630	0.27	0.10	0.00	1.00
Amenities variables						
Altitude	Average municipal altitude in the living zone (hm)	1630	2.61	2.92	0.00	22.71
Coast	Dummy variable: 1 if presence of a coastline	1630	0.11	0.31	0.00	1.00
Emergency	Average time (in min) to reach the nearest municipality with emergency services by road	1630	22.80	8.85	0.00	84.63

Table 3 (continued)

Variable	Definition	Number	Mean	SD	Min.	Max.
Urban centre	Living zone with a large and medium-sized service centre according to zoning into urban area (ZAU)	1630	0.21	0.41	0.00	1.00
Suburban	Living zone where more than 70% of the population live in the periphery of a large, medium-sized or small urban centre or in a multipolarised municipality within a small or a medium-sized urban area according to ZAU	1630	0.43	0.50	0.00	1.00
Rural centre	Living zone where the service centre is a small urban centre according to ZAU	1630	0.24	0.43	0.00	1.00
Remote rural	Living zone where more than 70% of the population live in a remote rural municipality according to ZAU	1630	0.12	0.32	0.00	1.00

production (Dairy), bovine meat production (Meat), mixed dairy cattle and bovine meat production (Mixed bovine), sheep and goat production (Sheep and goats), mixed crop–livestock farming (Mixed crop–livestock) and other animal production (Other animals). As an example, the variable Dairy corresponds to the share of municipalities specialised in dairy cattle production within a living zone in 2010.

The second group of independent variables addresses veterinarians' professional environment. We have assumed that the number of veterinarians who graduated in 2014 in a living zone depends on the veterinarians already present in that area. As discussed above, this effect may be ambiguous because the geographical agglomeration of veterinarians not only may generate competition but may also be a source of localisation economies. Indeed, a veterinarian may locate near other veterinarians to share knowledge, experience, equipment and resources. To test this effect, we have constructed an independent variable related to veterinarian density within a living zone. The variable N_density corresponds to the number of veterinarians who graduated before 2014 per 10,000 inhabitants in the living zone. It varies from 0 to 30 veterinarians per 10,000 inhabitants, with a mean of nearly 4 veterinarians per 10,000 inhabitants. Assuming that newly graduated veterinarians may locate so that they could take over an existing practice of an elderly veterinarian who is about to retire, we have introduced Vet 60+. This variable is the share of veterinarians aged 60 years old or over among those who graduated before 2014 in the living zone. Furthermore, one might expect that new veterinarians choose to establish themselves as employees or associates in previously existing veterinary offices to share costs and minimise risks. The variable Vet indep., corresponding to the share of independent veterinarians among those who graduated before 2014 in the living zone, has been introduced to test this assumption. A negative effect is expected for this variable. These three variables have been calculated from the National Order of French Veterinarians database.

The third group of independent variables concerns the socio-economic dynamics. In accordance with Olfert et al. (2012), we assume that veterinarians find dynamic areas more appealing. Variables related to the population and to the degree of rurality have already enabled us to take into account some of the socio-economic dynamics. Two new variables have been added. The variable Income, expressed in K€, is based on the municipal median income, drawn from the General Census of Population in 2013 and averaged to the living zone. This variable enables us to capture the level of poverty or wealth of the population and indirectly the level of tax resources for the municipalities. The average share of farmers aged 55 and over (Agri. 55+) in the living zone was obtained from data of the General Census of Population conducted in 2011. This information provides a picture of the dynamics of the farming sector.

Finally, we have introduced variables dealing with urban and rural amenities. Research on household migration has highlighted the appeal of the coast (Stimson and Minnery 1998) and the influence of climate (Graves 1980). We have thus introduced into our regressions the average Altitude of municipalities in the living zones, which enables us to take into account both the topography and climate. The dummy Coast, which takes the value 1 if the living zone borders the ocean or the sea and 0 otherwise, has also been introduced. To evaluate the accessibility to urban amenities, we have chosen to use emergency services because of the key role health services play in household location choice. Furthermore, the presence of health services is often correlated with that of secondary schools, cinemas and theatres. Thus, accessibility to emergency services is a good indicator of the general accessibility of other urban amenities. The variable Emergency corresponds to the average time it takes to get from each municipality in the living zone to the nearest municipality with emergency services. We have constructed this variable using data drawn from the INSEE permanent database of municipal facilities in 2012[5] and municipal travel times.[6] We have also introduced dummies to take into account the geographic structure of the living zone and its degree of rurality. We differentiate the living zones on the basis of the characteristics of their municipalities according to the zoning into urban area (ZAU) defined by INSEE (Brutel et al. 2011). Four types of living zones are distinguished: the living zones with a large or a medium urban centre, which is the reference class in our regressions, the living zones that are suburban or under urban influence, those with rural centres and remote rural areas.

Results

Results of all veterinarians

The results of the estimates for all veterinarians are presented in Table 4. Model 1 corresponds to the ZINB model for the total number of veterinarians who graduated in 2014.

The results confirm the importance of demand in the location choice of recently graduated veterinarians. Indeed, both the number of inhabitants and the number of livestock units within the living zone have positive and significant effects on the number of veterinarians who graduated in 2014. The negative parameters of the quadratic forms of these two variables show that the relationship between supply and demand of veterinarian services is not linear. This supports the congestion effect hypothesis. Regarding the impact of the professional environment, veterinarians who graduated in 2014 are more likely to locate where there are already veterinarians. However, neither the share of elderly veterinarians nor the share of independent veterinarians among those already present in the living zone has a significant effect on the location of new veterinarians (Tables 6 and 7).[7] Among amenities, only the altitude has a significant impact on the veterinarian graduates from 2014, and this impact is negative. The degree of rurality of the living zones has a strong impact on their attractiveness to newly graduated veterinarians. Thus, the living zones structured around large and medium-sized urban centres are more attractive than remote rural living zones and, to a lesser extent, than living zones with rural centres. Furthermore, the living zones whose municipalities have on average a higher median income are more attractive to new graduates. For the dynamics of the agricultural sector, contrary to what might be expected, new veterinarians tend to locate in living zones with a greater share of older farmers.

[5] Base permanente des équipements (BPE)—2012, INSEE [producer], ADISP-CMH [disseminator].

[6] These are travel times by road and in off-peak hours, expressed in minutes, which were calculated using Odomatrix® software (Odomatrix, INRA UMR 1041 CESAER, from IGN Route 500®, RGC®).

[7] The variables Vet 60+ and Vet indep. show non-significant effects in any model. They also exclude, de facto from the regressions, the living zones without veterinarians before 2014 (i.e. 86 observations). Therefore, we decided to remove them from the final regression models. The complete models are presented in the appendices.

Table 4 Estimation results

	Model 1: all vet (ZINB)	Model 2: CA (ZINB)	Model 3: mixed (Poisson)	Model 4: FA Partial (Poisson)	Full (Poisson)
Intercept	−2.79***	−2.72***	−4.15***	−6.36***	−6.90***
	(0.66)	(0.90)	(1.34)	(1.38)	(1.53)
Population	0.03***	0.03***	0.02***	0.01*	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Population^2	−0.00***	−0.00***	−0.00***	−0.00	−0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	−0.01	0.03	−0.08**	−0.03	0.00
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Livestock	0.01**	−0.01	0.04***	0.09***	0.08***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Livestock^2	−0.00*	−0.00	−0.00	−0.00***	−0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.12***	0.08**	0.04	0.12***	0.10***
	(0.02)	(0.03)	(0.04)	(0.02)	(0.03)
Altitude	−0.07**	−0.13**	0.01	0.06	−0.02
	(0.03)	(0.05)	(0.05)	(0.04)	(0.05)
Coast	0.06	−0.36	0.83***	−0.33	−0.27
	(0.17)	(0.23)	(0.32)	(0.55)	(0.58)
Emergency	0.00	0.02*	0.01	−0.04**	−0.04**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Suburban	−0.30	−0.73**	0.14	0.50	0.57
	(0.20)	(0.35)	(0.37)	(0.38)	(0.41)
Rural centre	−0.38*	−0.26	−0.56	−0.11	−0.07
	(0.20)	(0.27)	(0.40)	(0.34)	(0.35)
Remote rural	−0.57*	−1.14*	−1.24*	0.19	0.19
	(0.33)	(0.66)	(0.68)	(0.52)	(0.53)
Income	0.05*	0.06	−0.03	0.07	0.08
	(0.03)	(0.04)	(0.06)	(0.06)	(0.06)
Agri. 55+	1.77***	1.38	2.45**	1.05	1.15
	(0.68)	(1.00)	(1.18)	(1.51)	(1.52)
Dairy					1.04
					(0.91)
Meat					1.99**
					(0.87)
Mixed bovine					1.59**
					(0.81)
Sheep and goats					0.36
					(1.51)
Mixed crop–livestock					0.36
					(0.77)
Other animals					−0.33

Table 4 (continued)

	Model 1: all vet (ZINB)	Model 2: CA (ZINB)	Model 3: mixed (Poisson)	Model 4: FA Partial (Poisson)	Full (Poisson)
					(0.90)
Log(α)	− 1.13***	− 1.59*	–	–	–
Log likelihood	− 876.38	− 537.88	− 261.11	− 270.22	− 262.97
Pseudo R^2	–	–	0.136	0.200	0.220
Vuong	3.03	3.14	–	–	–
AIC	1790.77	1113.77	552.21	570.43	567.95
BIC	1893.30	1216.30	633.16	651.38	681.27
Obs.	1630	1630	1630	1630	1630

Standard errors robust to heteroskedasticity are given in parentheses

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

Results according to the different types of veterinarians

Models 2, 3 and 4 correspond respectively to the ZINB model[8] on the CA practitioners, the Poisson model on the mixed veterinarians and the Poisson model on the FA practitioners. The comparison shows significant differences among these three models.

Regarding veterinarians who exclusively treat CA, they choose to locate solely according to human demand (model 2). Indeed, the number of livestock units has no significant effect on their choice of location. Moreover, they have a strong preference for urban living zones and are less attracted to remote rural and suburban living zones. Finally, they tend to cluster in areas where veterinarians are already settled.

Veterinarians who treat FA have quite an opposite profile (model 4, left column). Indeed, as might be expected, the effect of the population is less strong, whereas the number of livestock units plays a key role in their location choice. More surprisingly, the degree of rurality does not have a significant effect on the location of these veterinarians. However, access to health services seems to play a more important role. Thus, the longer the distance to emergency services, the fewer newly graduated veterinarians treating FA there are. This last result suggests that, although the FA veterinarians have to locate in rural areas to cope with the demand, they choose their location so that they can have access to certain urban amenities. Finally, the results show that their location choice also depends on the density of veterinarians already settled.

The profile of mixed veterinarians appears to be in between the two previous categories (model 3). Indeed, as in the case of veterinarians treating FA, mixed veterinarians choose their location according to the population and according to the number of livestock units. However, in line with veterinarians treating CA, these veterinarians seem to be particularly averse to remote rural areas and more attracted to urban living zones. More surprisingly, they are more attracted by living areas where the population has decreased. Finally, they also tend to locate where veterinarians are already present.

[8] We assume that the presence of zero in the first regime of the zero-inflated models relies mainly on the demand for veterinarian services and on the living area's size. Thus, we have included the two variables livestock and population as covariates z_i.

Table 5 Gender estimation results

	Model 1: all vet.		Model 2: CA	
	Female	Male	Female	Male
	(ZINB)	(NEGBIN)	(ZINB)	(Poisson)
Intercept	− 3.43***	− 3.95***	− 2.80***	− 3.65***
	(0.74)	(0.93)	(0.97)	(1.22)
Population	0.03***	0.03***	0.02***	0.03***
	(0.01)	(0.01)	(0.00)	(0.00)
Population^2	− 0.00***	− 0.00***	− 0.00***	− 0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	− 0.01	0.01	0.02	0.04
	(0.02)	(0.03)	(0.03)	(0.04)
Livestock	0.01	0.03***	− 0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.03)
Livestock^2	− 0.00	− 0.00**	0.00	− 0.00
	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.14***	0.11***	0.12***	− 0.17**
	(0.02)	(0.02)	(0.03)	(0.08)
Altitude	− 0.09**	− 0.03	− 0.16***	− 0.15
	(0.04)	(0.04)	(0.06)	(0.10)
Coast	0.08	− 0.15	− 0.34	− 1.07
	(0.19)	(0.33)	(0.23)	(0.65)
Emergency	0.01	− 0.01	0.02*	0.03
	(0.01)	(0.02)	(0.01)	(0.02)
Suburban	− 0.44**	− 0.49	− 0.75**	− 2.01***
	(0.22)	(0.35)	(0.37)	(0.50)
Rural centre	− 0.48**	− 0.61*	− 0.43	− 1.00**
	(0.22)	(0.36)	(0.31)	(0.45)
Remote rural	− 0.79**	− 0.62	− 1.41**	− 2.29**
	(0.40)	(0.46)	(0.72)	(1.14)
Income	0.06**	0.02	0.06	0.06
	(0.03)	(0.04)	(0.04)	(0.05)
Agri. 55+	2.09***	1.36	1.63*	− 0.43
	(0.72)	(1.09)	(0.99)	(1.75)
Log(α)	− 1.68***	− 0.15	− 13.70**	–
Log likelihood	− 693.27	− 396.71	− 439.79	− 200.30
Pseudo R^2	–	0.14	–	0.31
Vuong	3.15	–	3.54	–
AIC	1424.54	825.41	917.58	430.61
BIC	1527.08	911.75	1020.11	511.55
Obs.	1630	1630	1630	1630

Table 5 (continued)

	Model 3: FA			
	Partial		Full	
	Female	Male	Female	Male
	(Poisson)	(Poisson)	(Poisson)	(Poisson)
Intercept	− 7.64***	− 6.23***	− 8.36***	− 6.53***
	(1.75)	(2.05)	(1.73)	(2.42)
Population	0.04**	0.02*	0.05**	0.02*
	(0.02)	(0.01)	(0.02)	(0.01)
Population^2	− 0.00**	− 0.00	− 0.00**	− 0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	− 0.05	− 0.01	− 0.02	0.03
	(0.03)	(0.05)	(0.04)	(0.05)
Livestock	0.08***	0.11***	0.07***	0.11***
	(0.02)	(0.02)	(0.02)	(0.03)
Livestock^2	− 0.00**	− 0.00***	− 0.00**	− 0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.09***	0.16***	0.07**	0.14***
	(0.03)	(0.04)	(0.03)	(0.04)
Altitude	0.03	0.11	− 0.06	0.05
	(0.04)	(0.08)	(0.06)	(0.09)
Coast	− 0.72	0.10	− 0.71	0.25
	(0.73)	(0.61)	(0.77)	(0.65)
Emergency	− 0.03	− 0.05*	− 0.03	− 0.05*
	(0.02)	(0.03)	(0.02)	(0.03)
Suburban	0.00	1.15**	0.04	1.35**
	(0.59)	(0.58)	(0.62)	(0.67)
Rural centre	0.16	− 0.17	0.22	− 0.13
	(0.43)	(0.62)	(0.45)	(0.65)
Remote rural	0.78	− 0.43	0.80	− 0.53
	(0.65)	(0.83)	(0.68)	(0.86)
Income	0.13*	− 0.02	0.14**	− 0.02
	(0.07)	(0.09)	(0.06)	(0.10)
Agri. 55+	0.03	2.12	0.35	2.04
	(1.76)	(2.29)	(1.71)	(2.48)
Dairy			0.90	0.89
			(0.96)	(1.64)
Meat			2.24**	1.58
			(1.08)	(1.41)
Mixed bovine			1.96*	0.97
			(1.00)	(1.41)
Sheep and goats			1.20	− 1.90
			(1.74)	(2.55)
Mixed crop–livestock			0.46	0.07
			(0.83)	(1.42)

Table 5 (continued)

Other animals			0.43	− 1.56
			(0.97)	(1.68)
Log likelihood	− 171.50	− 143.66	− 168.20	− 138.18
Pseudo R^2	0.18	0.21	0.19	0.24
AIC	373.01	317.32	378.40	318.36
BIC	453.95	398.26	491.73	431.69
Obs.	1630	1630	1630	1630

Standard errors robust to heteroskedasticity are given in parentheses

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

Effect of the regional agricultural specialisation

The previous results confirm our hypothesis regarding the tendency towards agglomeration among veterinarians. This mechanism may be due to the interaction among veterinarians and to the existence of localisation economies or complementary effects. As previously noted, this agglomeration effect may be explained by the fact that the new veterinarians choose to succeed elderly veterinarians who are about to retire, to integrate into existing veterinarian practices and to associate with other veterinarians. However, it may also be due to the unobserved characteristics of the living zones that affect both the density of veterinarians who settled before 2014 and the number of veterinarians who graduated in 2014. Thus, regarding veterinarians treating FA, the effect attributed to localisation economies may be linked mainly to the agricultural specialisation of the living zones. To confirm this, the full model 4 (right column) introduces variables related to agricultural specialisation. The results show that, even when we control for the agricultural specialisation effect, the effect of the density of veterinarians already settled remains significant and positive. As a result, the agglomeration effect does not seem to be linked solely to the agricultural characteristics of the area and may result from a process influenced by localisation economies. In addition, these results reveal the greater attractiveness of living zones specialised in bovine meat production or mixed dairy cattle and bovine meat production.

The gender effect

Table 5 presents the results for the male and female subsamples. Model 1 concerns the female (left column) and the male (right column) veterinarians, regardless of practice. These first two models show significant differences between men and women. Indeed, the location choice of the female veterinarians is only influenced by the human demand, whereas the male veterinarians also locate in response to the number of livestock units. Furthermore, the female veterinarians seem to be more sensitive to the degree of rurality than the male veterinarians. More precisely, the former seem to be much more attracted to urban living zones than to remote rural areas and, to a lesser extent, than to rural centre living zones or suburban living zones, whereas the results confirm only the male veterinarian preference for urban living zones over rural centre areas.

The descriptive statistics indicate that women are highly overrepresented among CA practitioners and underrepresented among FA practitioners (Sect. 3.1). Consequently, these differences may be due to the different practices rather than gender. Models 2 and 3 allow further analysis by differentiating the male and female veterinarians according to their practices. The results in model 2 show that the female and male CA practitioners are generally influenced by the same location determinants. However, there are slight differences in the influence of the degree of rurality. Indeed, unexpectedly, the male CA practitioners are much more attracted to urban areas than to remote rural areas and suburban living zones than the female CA practitioners. With regard to the FA practitioners, the results are also surprising, as they show that men are more influenced by access to emergency services than women. Men are also more attracted to suburban areas than to urban living zones, whereas the degree of rurality has no significant effect on the location of the female FA practitioners.

Discussion

Beyond the possible bias that is specific to count data models, which we have already evoked in Sect. 3.2, our models may face problems identical to linear regression models. Thus, to test the robustness of our results, we have conducted several other tests. First, we have tested for the absence of multicolinearity by successively introducing the different covariates that might be correlated. These estimates confirm the robustness of our results. Moreover, the correlation matrix shows no sign of multicolinearity. Second, we have used regression methods calculating standard errors robust to heteroskedasticity. Finally, the problem of endogeneity remains a major issue in our estimates. To guarantee no simultaneity bias, we have chosen to focus our analysis on newly graduated veterinarians, whose choice cannot therefore affect the independent variables. The main limit of our models derives from a possible specification bias and the potential existence of omitted variables that may play a key role in the mechanisms of veterinarian location. Using panel data, we could have better controlled for the effect of the living zones' unobserved characteristics. Unfortunately, the database of the National Order of French Veterinarians registered the information on the French veterinarians in 2014 but does not provide an historical record of the veterinarians' location or of the species that they treat.

Despite these limitations, our study provides several original findings. Our main contribution to the very sparse literature devoted to veterinarian shortage areas and veterinarian location choice is threefold. First, Olfert et al. (2012) showed that veterinarians locate more in response to the population than to the livestock concentration within an area. The authors conclude that the geographic distribution of veterinarians is more linked to factors of labour supply than to the imperatives of labour demand. However, in this work, the authors considered all the veterinarians regardless of their practices. By differentiating new veterinarians according to the type of animals they treat, our study tends to qualify this conclusion and highlight the influence of labour demand on location choice. Our results reveal that livestock has an impact on the location of both food animal veterinarians and mixed practitioners, unlike companion animal veterinarians. It also appears that the type of demand is a determining factor and that food animal veterinarians are more attracted by areas specialised in bovine meat or mixed dairy cattle–bovine meat productions. These results may suggest that the risk of veterinarian shortages may be higher for areas specialised in animal productions other than bovine (such as the areas characterised by sheep and goat farming and present for instance in the Alps or the

Pyrenees) or for low specialised areas characterised by mixed crop and livestock farming. Second, we have observed that factors of labour supply (i.e., amenities, socio-economic environment) may also have different effects according to the veterinarian profile. Indeed, the different categories of veterinarians are not responsive to the same aspect of rurality. Unlike companion animal veterinarians, food animal practitioners are more repelled by the lack of public services than by the remoteness from cities. Therefore, even if they have to locate in rural areas in order to meet the demand, FA practitioners seem to locate so that they can have relatively good access to services and urban amenities. Mixed veterinarians constitute an intermediary profile between those who treat livestock and those who treat companion animals. This category, which represents 14% of new graduates, could compensate for the lack of veterinarians treating food animals in certain areas. However, our results indicate that this may not be the case everywhere, insofar as it would seem more difficult to attract these veterinarians to remote rural areas. Furthermore, with respect to gender, our study revealed that, contrary to what previous studies concluded (Wang et al. 2015), men are more attracted to urban areas and are more sensitive to access to emergency services than women within the same professional practices. Thus, the feminisation of the veterinary profession may have an effect on the abandonment of rural areas because they move towards CA practice rather than because of their aversion for rural areas. Finally, our study also refines the findings of Olfert et al. (2012) on the agglomeration of human capital and the professional peer effect. Focusing on the localisation economies, our results have shown that the veterinarians, regardless of gender or practice, tend to locate in areas where veterinarians are already established. This finding could suggest that new veterinarians choose to establish themselves as employees or associates in already existing veterinary offices in order to share costs and to minimise risks. This interpretation of the results is consistent with the fact that the National Order of French Veterinarians notes an increase in the size of veterinarian practices.

This study calls for future research in two directions. At an individual level, our work takes into account the heterogeneity of preferences in the veterinarian population according to gender and professional practice. Complementary works could be pursued in order to better understand the determinants of new veterinarian location choice. Research applied to doctors has shown the influence of individual characteristics, such as nationality (Bolduc et al. 1996), socio-professional status or rural background (Ward et al. 2004), on location choice. Other researches applied to entrepreneurs or higher-education graduates have also revealed the influence of the distance to college (Faggian and Franklin 2014) or of geographical origin (Krupka 2009; Figueiredo et al. 2002). The collection of more detailed individual data would allow for a better analysis of the influence of individual factors on veterinarian location. Furthermore, our analysis reveals the specificity of mixed veterinarians, who constitute an intermediary profile between food animal and companion animal practitioners. However, this category of veterinarians is neither well identified nor well known and raises many questions. Thus, further research is needed to better determine the share of the livestock care in the veterinarian services they provide and to better understand their choices with respect to practice and location. At the territorial level, our study suggests that veterinarians tend to cluster, which may lead to a cumulative process of veterinarian agglomeration in certain areas to the detriment of others; this phenomenon may lead to veterinarian shortage areas. However, our work does not allow us to completely capture this shortage problem. Our analysis shows, for instance, that new veterinarians are less attracted by areas more specialised in sheep and goat production, but the need for veterinarian services is also less important for these production types than for bovine production. Therefore, this existing situation does not necessarily correspond to a shortage. Thus, future research is needed to better understand the gap between demand and supply for veterinarian services and to better identify veterinarian shortage areas.

Conclusion

The development of veterinarian shortage areas is an issue of major economic and social importance, especially for FA practitioners. Despite this, the scientific literature addressing this question and the location of veterinarians is relatively limited. Thus, our article contributes to this literature and clarifies the determinants of the location of veterinarians. Following Olfert et al. (2012), this paper focuses on a regional economic approach applied to the French case. Based on count data models, we tested the effects of geographical and socio-economic characteristics in French living zones on the number of new veterinarians who established themselves in 2014.

This work provides several findings that may have policy implications at two different levels. At the individual level, our results show that veterinarians' choice to live in urban areas rather than in rural areas mainly depends on their professional practice. Moreover, gender may have an effect on the abandonment of rural areas because women move more towards CA practice and not because of their aversion for rural areas. Consequently, it seems necessary to better understand why women neglect FA practice and to identify how to remove these deterring factors. Specific actions should also be conducted to promote FA practice during veterinarian education or the traineeship period.

At the territorial level, our analysis also shows that certain geographical and socio-economic characteristics are determinants of FA veterinarian location choice. First, even if FA practitioners have to locate in rural areas in order to meet the demand, they locate so that they can have relatively good access to services and urban amenities. Thus, maintaining public services should be a key issue for attracting FA veterinarians in rural areas. Second, our results reveal that the new veterinarians, regardless of practice or gender, tend to locate where other veterinarians are already present. This finding is convergent with the National Order of French Veterinarians, which observes that new veterinarians choose to establish themselves as employees or associates in already existing veterinary offices in order to minimise risks. As a consequence, promoting the creation of veterinary practices in certain remote areas could be a means of coping with veterinarian shortage areas and of ensuring equity of access to veterinarian services. Finally, our analysis shows that FA practitioners are less attracted by areas specialised in animal production other than bovine and by low specialised areas characterised by mixed crop and livestock farming. These results may suggest that animal production farms located in such areas may face a greater lack of veterinarian services. Thus, specific supervision might be needed for such areas to ensure geographical coverage of veterinarian services.

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Appendix

Table 6 Estimation results including all the professional environment covariates

	Model 1: all vet (ZINB)	Model 2: CA (ZINB)	Model 3: mixed (Poisson)	Model 4: FA Partial (Poisson)	Full (Poisson)
Intercept	− 2.67***	− 2.58***	− 3.43**	− 6.73***	− 7.48***
	(0.71)	(0.98)	(1.47)	(1.42)	(1.47)
Population	0.03***	0.03***	0.02***	0.01*	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Population^2	− 0.00***	− 0.00***	− 0.00***	− 0.00	− 0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	− 0.01	0.02	− 0.08**	− 0.04	− 0.01
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)
Livestock	0.01**	− 0.01	0.04***	0.09***	0.08***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Livestock^2	− 0.00**	− 0.00	− 0.00	− 0.00***	− 0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.12***	0.08**	0.02	0.12***	0.10***
	(0.02)	(0.03)	(0.05)	(0.03)	(0.03)
Vet 60+	− 0.38	− 0.63	0.07	0.09	0.04
	(0.39)	(0.53)	(0.62)	(0.75)	(0.79)
Vet indep.	− 0.15	− 0.12	− 0.63	0.22	0.02
	(0.29)	(0.40)	(0.54)	(0.55)	(0.54)
Altitude	− 0.07**	− 0.13**	0.01	0.06	− 0.02
	(0.03)	(0.05)	(0.05)	(0.05)	(0.05)
Coast	0.06	− 0.38	0.80**	− 0.32	− 0.28
	(0.17)	(0.24)	(0.32)	(0.56)	(0.59)
Emergency	0.00	0.02**	0.01	− 0.04**	− 0.04**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Suburban	− 0.35*	− 0.86**	0.18	0.53	0.59
	(0.20)	(0.39)	(0.37)	(0.39)	(0.42)
Rural centre	− 0.38*	− 0.31	− 0.54	− 0.09	− 0.04
	(0.20)	(0.31)	(0.40)	(0.34)	(0.36)
Remote rural	− 0.59*	− 1.25*	− 1.11	0.23	0.24
	(0.33)	(0.68)	(0.68)	(0.51)	(0.52)
Income	0.05*	0.06	− 0.04	0.08	0.09*
	(0.02)	(0.04)	(0.06)	(0.05)	(0.05)
Agri. 55+	1.92***	1.60	2.47**	1.10	1.27
	(0.69)	(1.02)	(1.17)	(1.54)	(1.53)
Dairy					1.37
					(0.91)
Meat					2.34***
					(0.86)

Table 6 (continued)

	Model 1: all vet (ZINB)	Model 2: CA (ZINB)	Model 3: mixed (Poisson)	Model 4: FA Partial (Poisson)	Full (Poisson)
Mixed bovine					1.96**
					(0.80)
Sheep and goats					0.71
					(1.51)
Mixed crop–livestock					0.81
					(0.75)
Other animals					0.08
					(0.90)
Log(α)	− 1.18***	− 1.76*	–	–	–
Log likelihood	− 858.83	− 526.98	− 258.67	− 263.77	− 256.37
Pseudo R^2	–	–	0.133	0.200	0.223
Vuong	2.87	2.92	–	–	–
AIC	1759.66	1095.95	551.33	561.54	558.73
BIC	1871.85	1208.14	642.15	652.36	681.60
Obs.	1544	1544	1544	1544	1544

Standard errors robust to heteroskedasticity are given in parentheses

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

Table 7 Gender estimation results including all the professional environment covariates

	Model 1: all vet.		Model 2: CA	
	Female (ZINB)	Male (NEGBIN)	Female (ZINB)	Male (Poisson)
Intercept	− 3.41***	− 3.65***	− 2.72***	− 3.01**
	(0.80)	(1.18)	(1.01)	(1.36)
Population	0.03***	0.03***	0.02***	0.03***
	(0.01)	(0.01)	(0.00)	(0.00)
Population^2	− 0.00***	− 0.00***	− 0.00***	− 0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	− 0.02	0.01	0.02	0.04
	(0.02)	(0.03)	(0.03)	(0.04)
Livestock	0.01	0.04***	− 0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.03)
Livestock^2	− 0.00	− 0.00**	0.00	− 0.00
	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.14***	0.10***	0.11***	− 0.20***
	(0.02)	(0.03)	(0.03)	(0.07)
Vet 60+	− 0.30	− 0.37	− 1.04	− 0.20
	(0.45)	(0.73)	(0.63)	(0.83)

Table 7 (continued)

Vet indep.	0.05	− 0.47	0.09	− 0.89
	(0.30)	(0.52)	(0.45)	(0.68)
Altitude	− 0.09**	− 0.03	− 0.16***	− 0.16
	(0.04)	(0.05)	(0.06)	(0.10)
Coast	0.08	− 0.12	− 0.35	− 1.03
	(0.19)	(0.33)	(0.23)	(0.65)
Emergency	0.01	− 0.01	0.02*	0.04**
	(0.01)	(0.01)	(0.01)	(0.02)
Suburban	− 0.44**	− 0.54*	− 0.80**	− 2.13***
	(0.22)	(0.31)	(0.37)	(0.52)
Rural centre	− 0.46**	− 0.63**	− 0.42	− 0.99**
	(0.23)	(0.31)	(0.31)	(0.45)
Remote rural	− 0.76*	− 0.60	− 1.42**	− 2.03*
	(0.40)	(0.46)	(0.69)	(1.14)
Income	0.06**	0.02	0.06	0.04
	(0.03)	(0.05)	(0.04)	(0.06)
Agri. 55+	2.11***	1.80	1.73	0.28
	(0.73)	(1.19)	(1.05)	(1.81)
Log(α)	− 1.72***	− 0.28	− 14.58***	–
Log likelihood	− 683.84	− 382.78	− 433.99	− 189.17
Pseudo R^2	–	0.14	–	0.32
Vuong	3.10	–	3.73	–
AIC	1409.67	801.56	909.99	412.33
BIC	1521.86	897.72	1022.17	503.15
Obs.	1544	1544	1544	1544
	Model 3: FA			
	Partial		Full	
	Female	Male	Female	Male
	(Poisson)	(Poisson)	(Poisson)	(Poisson)
Intercept	− 7.62***	− 7.09***	− 8.22***	− 8.10***
	(1.88)	(1.96)	(1.83)	(2.08)
Population	0.04**	0.02*	0.05**	0.02*
	(0.02)	(0.01)	(0.02)	(0.01)
Population^2	− 0.00**	− 0.00	− 0.00**	− 0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Δpop0813	− 0.05	− 0.02	− 0.02	0.01
	(0.03)	(0.05)	(0.04)	(0.05)
Livestock	0.08***	0.12***	0.07***	0.11***
	(0.02)	(0.02)	(0.02)	(0.03)
Livestock^2	− 0.00**	− 0.00***	− 0.00**	− 0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
N_density	0.09***	0.16***	0.06*	0.15***
	(0.03)	(0.04)	(0.04)	(0.04)

Table 7 (continued)

Vet 60+	0.79	− 1.23	0.85	− 1.73
	(0.84)	(1.43)	(0.82)	(1.73)
Vet indep.	0.08	0.38	− 0.12	0.24
	(0.70)	(0.82)	(0.67)	(0.84)
Altitude	0.03	0.11	− 0.06	0.06
	(0.05)	(0.08)	(0.06)	(0.10)
Coast	− 0.74	0.17	− 0.75	0.31
	(0.73)	(0.62)	(0.78)	(0.67)
Emergency	− 0.03	− 0.05*	− 0.03	− 0.05*
	(0.02)	(0.03)	(0.02)	(0.03)
Suburban	0.03	1.19**	0.07	1.36**
	(0.59)	(0.59)	(0.61)	(0.69)
Rural centre	0.15	− 0.17	0.22	− 0.14
	(0.43)	(0.64)	(0.45)	(0.68)
Remote rural	0.77	− 0.39	0.82	− 0.48
	(0.62)	(0.85)	(0.66)	(0.87)
Income	0.12*	0.01	0.14**	0.02
	(0.06)	(0.09)	(0.06)	(0.09)
Agri. 55+	− 0.11	2.28	0.21	2.30
	(1.77)	(2.42)	(1.72)	(2.58)
Dairy			0.87	1.69
			(0.96)	(1.73)
Meat			2.27**	2.46*
			(1.07)	(1.44)
Mixed bovine			2.04**	1.74
			(1.00)	(1.47)
Sheep and goats			1.17	− 1.07
			(1.72)	(2.62)
Mixed crop–livestock			0.49	1.11
			(0.84)	(1.46)
Other animals			0.44	− 0.73
			(0.98)	(1.85)
Log likelihood	− 170.54	− 136.67	− 167.17	− 130.89
Pseudo R^2	0.17	0.23	0.19	0.26
AIC	375.09	307.34	380.35	307.78
BIC	465.90	398.15	503.22	430.65
Obs.	1544	1544	1544	1544

Standard errors robust to heteroskedasticity are given in parentheses

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

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