SPATIAL HEDONIC ANALYSIS OF VETERINARIAN INCOME

Jasper Fanning[a] and Thomas L. Marsh[b]

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[a]Phd candidate, Agricultural Economics, Kansas State University, email: jasperfanning@urnrd.org; [b]Associate Professor, School of Economic Sciences, IMPACT Fellow, PO Box 646210, Washington State University; Pullman, WA, 99164-6210, phone: 509-335-8597, fax: 509-335-1173, email: tl_marsh@wsu.edu.

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Abstract: We investigate a hedonic model for veterinarian income using survey data from the American Veterinarian Medical Association. Diagnostic testing indicates the presence of spatial autoregression in the hedonic income model, which is accounted for by incorporating a spatial component into the regression model. The results provide unique empirical findings about determinants of veterinarian income and spatial patterns, as well as insight useful for governments and academic institutions planning programs and the veterinarian industry.

Key Words: spatial autoregression, veterinarian income, hedonic model

Introduction

Veterinarians and veterinary practices have demonstrated little or no growth in real income over the past two decades (AVMA). Veterinarian income averages about $20 per hour worked. Not surprisingly the income of an individual veterinarian remains lower than that of comparable medical professions, which impacts the ability of veterinarians to repay student loans and reduces the ability to attract quality individuals to the profession. Moreover, and although veterinarian support of livestock production has always played an effective role in the productivity of the US agricultural sector, recent concerns of animal disease outbreaks (e.g., foot and mouth disease) and bioterroism acts across the world have highlighted the importance of veterinarian expertise. An effective supply of quality veterinarian labor is a necessary and important means by which to prevent and combat unintentional or intentional disease outbreaks. Our interests are in quantifying determinants of veterinarian incomes in the US to better understand labor issues and spatial relationships influencing their incomes. Identifying key determinants is necessary for government, industry and academic programs to plan future marketing and education strategies.

Previous research on veterinarian income is limited, focusing on only descriptive analysis. Indeed, no economic study has been identified that rigorously analyzes key determinants influencing veterinary earnings. We investigate cross-sectional data from the AVMA – 2001 Biennial Economic Survey on veterinary income and returns to veterinary practice. The 2001 survey contains 6,600 veterinary income responses and 979 veterinary practice responses available to analyze. The survey elicited information on practice type, ownership status, size of city, size of practice, benefits received, income, equity in practice, education level, gender, and experience. Respondents also provided other demographic information such as age, marital status, state of residence, year of graduation from veterinary school, and degrees earned.

Preliminary analysis of the AVMA data began with a standard hedonic model of veterinarian income across alternative employment categories. If earnings are determined under competitive market conditions, then veterinary income should be a function of attribute values.[1] Indeed, significant income determinants include practice type, location, hours worked, gender, experience, education, and other factors. For instance, regression results indicate that male private practice associates with no experience who enter a mixed animal practice should expect an income of roughly $51,500. Small animal and equine associates earn roughly $5400 and $7800 more per year than mixed animal associates. An associate's income increases with years of experience, with an additional year of experience worth about $897. Female associate income is lower than male associates by approximately $10,800 per year. Interestingly, associates are compensated very little for work beyond 40 hours per week.

The AVMA data offered sufficient geographical detail (i.e., zip code level) with which to posit, test, and correct for selected spatial hypotheses in the framework of a hedonic income model. Diagnostic testing of the standard hedonic model indicated persistent presence of first order spatial autoregression.[2] Evidence of spatial autoregression remained persistent in the regression models except for university and industry employed veterinarians. Spatial results from the owner, associates, and government models are statistically significant and have an insightful interpretation. For instance, the income of private practice associates is influenced by observations across a much wider geographic area than that of private practice owners.

This paper proceeds in the following manner. First, we highlight specific aspects of veterinarian incomes from the AVMA data. Second, we specify a hedonic income model derived from a dual cost function with quality differentiated inputs. Third, the spatial hedonic model is introduced and discussed. Fourth, empirical results are presented and discussed. Finally, concluding comments are provided.

Data

The survey on veterinary income in 2001 elicited information on practice type, practice location, ownership status, size of city, size of practice, benefits received, income, equity in practice, education level, and experience. Respondents provided demographic information such as age, gender, marital status, state of residence, year of graduation from veterinary school, and degrees earned. Professional accreditation of respondents was provided by indicating which if any AVMA recognized specialty boards of which the respondent was a diplomat in 2001. Respondents also indicated whether or not they had completed a veterinary internship, residency, or both. Years of veterinary experience, excluding time spent in an internship, residency, specialty certification program, or advanced degree program, was provided. Veterinarians not employed in private practice were asked to select their employer type from the following: College/University, Federal Government-Civil Services, Federal Government-Uniformed Services, State or local government, Industry or commercial firm, or other.

Tables 1-5 provide descriptive statistics by employment category (private practice, private practice associates, university, government, and industry, respectively).

For illustrative purposes, and to further motivate the analysis, tables 6 and 7 provide descriptive statistics of income by employment category and gender.

Quality Differentiated Inputs

The situation we consider is a veterinarian firm where one input, labor, has a vector of characteristics that are chosen by the firm. The reason why labor input is quality differentiated relates to alternative skill levels and possibly other factors that offer different products to clients or enhance the productivity a veterinarian clinic. Below we follow Kolstad and Turnovsky (1998) in specifying a dual cost function, focusing on multiple labor markets in the veterinarian sector that includes nonlinear pricing because wages depend on endogenous quality from the multiple markets.

Let **y** be a vector of outputs for the veterinarian clinic, **x** be a vector of conventional inputs (capital, services, energy, or equipment) and *q* be the single input (labor) that is available with a vector of characteristics **z**. Consider the production set expressed implicitly as

(1) $$g(\mathbf{x}, q, \mathbf{z}, \mathbf{y}) \leq 0$$

In (1), *g* is quasi-convex, the level sets are convex, and the production frontier defined when the above equation holds with equality. Assume further that producers face a single price vector $\mathbf{p}_x$ for inputs **x**.

For the differentiated labor product *q*, clinic owners face a nonlinear price function $\rho(\mathbf{z};\boldsymbol{\alpha})$ for labor with characteristics **z** where $\boldsymbol{\alpha}$ is a vector of parameters. If a single market is under consideration, then $\boldsymbol{\alpha}$ is constant and it can be suppressed in the notation of the nonlinear price function. Alternatively, if there are multiple labor markets then there are multiple price functions that can be identified as a family of functions by

$\boldsymbol{\alpha}$. In the case of veterinarian practices, multiple labor markets arise because of a myriad of reasons including skill level, skill type, and location.

The veterinarian firm's problem can be formulated as a dual cost minimization problem

(2a) $$C\left(\mathbf{p}_x,\boldsymbol{\alpha},\mathbf{y}\right)=\min_{q,\mathbf{z},\mathbf{x}} q\rho\left(\mathbf{z},\boldsymbol{\alpha}\right)+\mathbf{x}\mathbf{p}_x$$

subject to

(2b) $$g(\mathbf{x},q,\mathbf{z},\mathbf{y})\le 0$$

(2c) $$q,\mathbf{z},\mathbf{x}\ge 0$$

The objective function in (2a) identifies the minimum cost of producing output **y** from a choice of inputs **x** and *q* and characteristics **z**. If $\rho\left(\mathbf{z};\boldsymbol{\alpha}\right)$ is convex in $\left(\mathbf{z},\boldsymbol{\alpha}\right)$, then the objective function is convex, and thus *C* is concave in prices and $\boldsymbol{\alpha}$ over the region where solutions exit.

Demand functions can be derived from (2) using the envelope theorem as

(3a) $$\frac{\partial C}{\partial \mathbf{p}_x}=x^*$$

(3b) $$\nabla_\alpha C=q^*\nabla_\alpha\rho\left(\mathbf{z}^*,\boldsymbol{\alpha}\right)$$

where $\mathbf{x}^*,\mathbf{z}^*,q^*$ denote optimal values. From the first order conditions

(3c) $$\rho\left(\mathbf{z}^*,\boldsymbol{\alpha}\right)=\mathbf{p}_x\frac{g_q}{g_x}$$

(3d) $$\nabla_z\rho=\frac{\mathbf{p}_x\nabla_z g}{q\ g_x}$$

In (3c) the nonlinear price function is equal to the marginal rate of technical substitution between q and $\mathbf{x}$, while in (3d) the marginal nonlinear price function with respect to characteristics is equal to the marginal rate of substitution.

Our empirical approach is to follow Kristofersson and Ricertsen (2004) by specifying the hedonic price function as linear in functional form. We do this for several reasons. First, the parameter estimates of the linear hedonic model are the marginal prices. Second, there is no clear choice for the "best" functional form. Third, our interest is to focus on estimating a spatial hedonic model. Convergence of a spatial model, which is nonlinear in nature, is much more difficult if the hedonic model itself were nonlinear.

Spatial Hedonic Model

The empirical approach proposed is a spatial hedonic model. In a typical hedonic wage model, wages are regressed on characteristics of the employee, the employing firm, and the location or environment. For the case of the veterinarian clinic, veterinary income is regressed on appropriate characteristics discussed above.

Under the assumption of a linear hedonic model, the regression model is more parsimonious and the regression coefficients can be interpreted as implicit marginal prices of the respective characteristics (Feldstein; Freeman); provided the standard assumptions of the classical linear regression model are satisfied (Greene). The hedonic model for veterinarian income can be specified as follows

(4) $$\mathbf{Y}_j = \mathbf{X}_j \boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_j$$

where $\mathbf{Y}_j$ is a $N \times 1$ vector of veterinarian income, $\mathbf{X}_j$ is a $N \times K$ matrix of continuous dependent variables or discrete variables, $\boldsymbol{\beta}_j$ is a $K \times 1$ vector of parameters to be estimated, and $\boldsymbol{\varepsilon}_j$ is a $N \times 1$ vector of unknown residuals. In (4) the hedonic models are differentiated by employment *j* = {private practice owners, private practice associates, university, government, and industry}. This specification provides separate parameter estimates for each organizational structure, rather than explaining differences between employment structures solely with, say, intercept terms.

Spatial Regression

To account for direct influences of spatial neighbors, the classical regression model in (4) can be reformulated as a first order spatial autoregressive model (see Cliff and Ord; Anselin)[3]

(5) $$\mathbf{Y} = \rho \mathbf{W_1 Y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

In (5), $\mathbf{W_1}$ is a $N \times N$ proximity matrix and ρ is a scalar interpreted as the spatial autoregressive parameter of the spatially lagged dependent variable.[4] The spatial autoregressive parameter implies positive spatial autoregression if $\rho > 0$, negative spatial autoregression if $\rho < 0$, and no spatial autoregression if $\rho = 0$. Positive (negative) spatial autoregression is characterized by similar (different) y_i values in areas identified by nonzero w_{ij} values.

Spatial correlation caused by misspecification of the regression function (e.g., omitted variables) can be accounted for by imposing structure on the error terms of the regression model. In the spatial statistics literature a standard structure imposed on the error terms is the first order spatial autoregressive error process (see Cliff and Ord; Anselin)

(6) $$\boldsymbol{\varepsilon} = \lambda \mathbf{W_2} \boldsymbol{\varepsilon} + \mathbf{u} = \left(\mathbf{I} - \lambda \mathbf{W_2}\right)^{-1} \mathbf{u}$$

yielding the modified regression model

(7) $$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \left(\mathbf{I} - \lambda\mathbf{W_2}\right)^{-1}\mathbf{u} \quad .$$

In (6) and (7), **u** is a (N×1) vector of *iid* error terms, $\mathbf{W_2}$ is a N×N proximity matrix, and λ is the scalar interpreted as the spatial residual autoregressive parameter.

The joint spatial model combining (5) and (7) can be expressed as

(8) $$\mathbf{Y} = \rho\mathbf{W_1}\mathbf{Y} + \mathbf{X}\boldsymbol{\beta} + \left(\mathbf{I} - \lambda\mathbf{W_2}\right)^{-1}\mathbf{u}$$

The advantage of estimating the joint spatial model, when feasible, is that the spatial lag model in (5) and the spatial error model in (7) are nested in (8). This facilitates hypothesis testing among the alternative spatial models.

Spatial Weighing Matrix

Our spatial weight matrix $\mathbf{W}_k$ for k=1,2 is specified to capture exponential distance decay (see Bodson and Peeters; Cliff and Ord; Dubin; Garrett and Marsh). The elements of the contiguity matrix $\mathbf{W}_k = \{w_{ij^*}\}$ are defined as $w_{ij}^{*} = \exp\left(-d_{ij}/\phi\right)$ where d_{ij} = the absolute difference between any two observations (i.e., zip codes identifying veterinarian practice locations). As the distance difference d_{ij} increases (decreases), w_{ij}* exponentially decreases (increases), thus giving less (more) spatial weight to that pair when $i \neq j$. For i=j, w_{ij}* =0 by standard convention. The positive parameter ϕ, which moderates the exponential decay, is estimated as a parameter in the regression model. Although $\mathbf{W}_k$ is a function of ϕ, for convenience it is suppressed in the notation $\mathbf{W}_k$=$\mathbf{W}_k$ (ϕ).

Maximum Likelihood Estimation

In general, the ordinary least squares (OLS) estimator applied to (7) will be unbiased and consistent, but inefficient in the presence of spatial *residual* correlation. It will be biased and inconsistent for the case of a spatially lagged dependent variable in (5). The maximum likelihood estimator, for the case of normally distributed errors, is discussed in Anselin.[5]

The log-likelihood function of the ML estimator for the joint spatial model with $\mathbf{A} = \mathbf{I} - \rho \mathbf{W}_1$ and $\mathbf{B} = \mathbf{I} - \lambda \mathbf{W}_2$ is

(9) $$\ln L = -(N/2)\ln(\pi) - (1/2)\ln|\mathbf{\Omega}| + \ln|\mathbf{B}| + \ln|\mathbf{A}| - (1/2)\boldsymbol{\varepsilon}'\boldsymbol{\varepsilon}$$

where $\boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}(\phi)$ is a vector of residuals conditioned on ϕ and $\mathbf{\Omega}$ defines the covariance structure. Hence, (9) is optimized to find $\hat{\boldsymbol{\beta}} = \hat{\boldsymbol{\beta}}(\phi)$ using MAXLIK in GAUSS. Then a grid search is used to optimize the likelihood function over a range of ϕ values to determine $\hat{\hat{\boldsymbol{\beta}}} = \hat{\boldsymbol{\beta}}(\hat{\phi})$.[6]

Estimation and Hypothesis Testing Procedures

The estimation and hypothesis testing proceeded in several steps. First OLS models were estimated for each employment category. Then, OLS residuals were used to calculate Lagrange multiplier (LM) tests for spatial autoregression in the error and dependent variable.[7] Second, maximum likelihood models of (5), (7), and (8) were estimated for each employment category. Nested likelihood ratio (LR) test statistics were used to compare the spatial lag model in (5) and the spatial error model (7) relative to the joint spatial model in (8). Finally, in addition to the LM and LR tests, asymptotic z-tests were calculated for the hedonic coefficients and the spatial autoregressive parameters. These sets of hypotheses tests provided the basis by which to choose *preferred* hedonic models for private practice owners, private practice associates, university, government, and industry veterinarians.

Results

A summary of hypothesis tests are provided in Table 8. Spatial effects are different across veterinary employment categories. Spatial autoregression is neither statistically significant in either the spatial lag model [equation (5)] nor the spatial error model [equation (7)] for university and industry employed veterinarians. Private practice owners and associates and government veterinarian's models exhibit significant spatial autoregression. Results indicate that the source of spatial dependence is consistent with a spatial lag on the dependent variable for private practice owners and private practice associates, implying a direct neighborhood effect. The source of spatial dependence among government employed veterinarians is consistent with spatial error dependence, implying an omitted variable or spillover effect.

Table 9 presents the preferred model for each employment type. Hedonic models with a spatial lag component on the dependent variable include private practice and associates. For example, in the analysis of private practice veterinarians, spatial lag dependence arises because of the existence of underlying spatial relationships within the cross-sectional data. The apparent spatial lag dependence refers to the interdependence of private practice veterinarian income across observations, due to factors associated with location and proximity. In the context of the private practice veterinary market, the existence of spatial lag dependence means that the income of a particular private practice veterinarian is partly determined by the income of veterinarians at other locations in addition to their own inherent characteristics. Spatial lag is apt to exist within the population of private practice veterinarians due to regional market characteristics of the veterinary industry. Hedonic models with a spatial error component include government employed veterinarians. Spatial error dependence may arise due to the omission of unobserved variables.[8] For university and industry veterinarians, the OLS regression is the preferred model. Next, we discuss results of each preferred model in detail and compare spatial patterns across models.

Private Practice

The preferred spatial lag model indicates that private practice owners of small animal exclusive and equine practices earn $13,124 and $26,912 more than mixed animal practice owners, respectively. Private practice owners earn roughly 10.6% return on practice equity. Female practice owners earn $25, 848 less than male practice owners, when other factors are considered in the model. Each hour worked beyond 40 hours per week increases practice owners income by approximately $528. Results indicated that leveraging owner's labor with that of associate veterinarians and veterinary labor with technician labor increased owner income. For each associate per owner, an owner's income increased by roughly $9,628. For each technician (non-veterinarian) per veterinarian, an owner's income increased by about $1,165. Practice owners who had attained a masters degree earned about $9,306 less than those who had no advanced degree other than their Doctorate of Veterinary Medicine. The population of the city in which the practice is located is significantly related to owner income. Owner's income increased by roughly $9,840, 21,837, $24,059 when the population was 2,500 to 49,999, 50,000 to 499,999, or 500,000 or more, relative to an owner whose practice was in a city with a population less than 2,500, respectively. The spatial lag parameter estimate, ρ, was 0.4785, with a probability of 0.0000. The optimal value of the spatial weight decay parameter, ϕ , was 54.08.

Associates

Like practice owners, the preferred model is spatial lag. Private practice associates working in small animal exclusive and equine practices earn roughly $5,405 and $7,752 more than mixed animal associates, respectively. It appears that as associate income increases so does the number of fringe benefits offered. For each fringe benefit received associate income increases by about $688. Unlike practice owners, the coefficient associated with years of experience is statistically significant. Each year of experience increases associate earnings by roughly $897. Like female practice owners, female associates earn less than their male counterparts, approximately $10,841 less. Associates earn more in larger practices, $468 more per veterinarian in the practice, in practices that have higher associate to owner ratios, $1,087 for each associate per owner, in practices that leverage veterinary labor with non-veterinary labor, $915 for each non-veterinary employee per veterinarian. Associates who have attained Board Certification or a M.S. have incomes of $19,996 and $12,722 less than those with only a D.V.M., respectively. Interestingly though associates who have completed a residency are indicated to earn $57,134 more than those who have not. Unlike owners, whose income was positively related to city population, associates in cities with a population from 2,500 to 49,999 earn $5,446 less than those in cities with less than 2,500 people. Coefficients for larger city populations were not statistically significant. The spatial lag coefficient, ρ, was .577, which was significant at the 0.0000 level. The optimal weight decay parameter, ϕ, was 133.43.

Government

Spatial error results for government employed veterinarians indicate that advanced education in addition to the D.V.M. is more advantageous to the government veterinarian than to veterinarians in private practice. A Ph.D. increases a government veterinarians income $11,126, completing a residency increases it $6,503, and Board Certification increases it $8,608. Experience for a government veterinarian is worth about $694 per year. Civil services federal veterinarians earn $12,112 more, while uniformed services federal veterinarians earn $9,874 less, than state and local government veterinarians. Within the government, female veterinarians do not earn significantly less than their male counterparts, as they do in private practice. Logically, results indicate government veterinarians in a management role earn significantly more than those in a clinical or technical position. The spatial error coefficient, λ, was .3044. The optimal weight decay coefficient, ϕ, was 1.00, which indicates the weight decay for government veterinarians is quite rapid with respect to distance.

University

Ordinary least squares results for university employed veterinarians indicate that board certification and gender are the only variables that are statistically significant other than those related to status level within the university system. Board certification increases income by $16,687 and females earn $16,508 less than their male counterparts. University veterinarians whose primary function is research or management earn $10,543 and $30,245 more than those whose primary function is teaching, respectively. Deans, assistant deans, and professors earn significantly more than assistant professors, $32,718, $26,638, and $20,609, respectively.

Industry

Our preferred OLS results for industry veterinarians indicate that the most significant factors that influence income are related to position on the corporate ladder. The only significant coefficients were related to CEO, vice president, Ph.D., consulting, and vacation weeks. CEO and vice president veterinarians earn about $49,766 and $28,891 more than research veterinarians in industry, respectively. The number of vacation weeks is related to an increase in income of $14,369 per week of vacation, indicating that those who get paid more also receive additional time off. Industry veterinarians whose primary function is consulting earn $37,419 less than researchers.

Practice Mix

The common perception among veterinarians is that small animal veterinarians earn more than large animal and mixed animal practitioners. These results indicate that perception is correct with respect to practice owners, with the exception that equine practitioners earn even more than small animal veterinarians. Mixed animal practices have difficulty efficiently utilizing both large and small animal equipment investment, unless the practice is quite large. Large animal practices provide services to relatively low value (food animals) compared to small animal and equine practices that provide services to companion type animals. Results also indicate that practice owners income increases with population. The positive correlation between owner income and population is likely due to two phenomena. First, the average income of individuals is higher in larger cities. Second, the regional market within which a practice competes contains more potential customers in larger cities.

The perception that small animal veterinarians earn more than large animal veterinarians does not however hold true among associate veterinarians. Only equine associates earn significantly more than mixed animal associates. Also, the income of associate veterinarians is not statistically different across city populations. Thus, it is evident that while owner income may be lower for large and mixed animal practice owners and for owners of practices in smaller cities, this does not result in the associates working in these practices earning less as well. The competitive associate market requires even those owners who earn below average income to compete for associates in the competitive market.

Spatial Factors

The spatial lag models used to draw inference on the private practice owner and associate samples further indicate that associate income is not as limited by local spatial conditions such as owner income. The estimate of ϕ for private practice associates, 133.60, is considerably larger than the estimate of ϕ for practice owners, 54.08. Loosely speaking, the income of associates is influenced by observations across a much wider geographic area than that of owners. The income of owners is influenced by the local spatial conditions, however the income of associates is not as directly tied to local area. The associate is relatively free to move around compared to the owner, who is somewhat geographically restricted. Thus, it appears practices must compete for associates in a region that is larger than the local area within which the practice owner competes.

Conclusions

Our research investigated a hedonic model for veterinarian income across employment categories using 2001 survey data from the American Veterinarian Medical Association. Significant income determinants included practice type, location, hours worked, gender, experience, and education. For instance, regression results indicate that male private practice associates with no experience who enter a mixed animal practice received an income of roughly $51,500. Small animal and equine associates earned roughly $5400 and $7800 more per year than mixed animal associates. An associate's income increased with more years of experience, with an additional year of experience worth about $897. Gender did matter, especially in private practice. Female associate income was lower than male associates by approximately $10,800 per year. Interestingly, associates were compensated very little for work beyond 40 hours per week.

Factors that influence veterinarian income varied by type of employment, however there was some commonality across employment types. As expected, income increases with advancement or promotion within an organization. Income and fringe benefits are positively correlated, as those veterinarians with a larger number of benefits were indicated to have higher incomes. Female veterinarians earned less than their male counterparts, however the disparity was more pronounced in private practice than in industry, university, and government. The disparity in private practice is unexplained by this research. An analysis of revenue, costs, and management practices by gender would be required to identify factors related to the gap between male and female practice owners' income.

Diagnostic testing of the standard hedonic income model indicated persistent presence of first order spatial autoregression. Evidence of first order spatial autoregression remained persistent in the regression models except for university and industry employed veterinarians. Spatial results from the owner, associates, and government models were highly significant. For instance, the income of associates is influenced by observations across a much wider geographic region than that of owners. However, parameter estimates did not change dramatically relative to OLS results. The results provided unique empirical results on determinants of veterinarian incomes and spatial patterns influencing veterinarian incomes, as well as insight useful for governments and academic institutions planning programs and the veterinarian industry.

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Table 1. Descriptive statistics of private practice owners, only for observations in regression model.

Variable	N	Mean	Std Dev	Minimum	Maximum
Income	1203	112523	59698	15000	296000
Large animal exclusive	1203	0.114	0.318	0.000	1.000
Large animal predominant	1203	0.144	0.351	0.000	1.000
Small Animal Predominant	1203	0.162	0.369	0.000	1.000
Small animal exclusive	1203	0.185	0.389	0.000	1.000
Equine	1203	0.132	0.339	0.000	1.000
Owner equity	1203	128034	162594	0	1500000
Years of experience	1203	20.630	9.295	0.000	46.000
Female	1203	0.172	0.378	0.000	1.000
Hours per week over 40	1203	13.327	10.613	-10.000	45.000
Number of veterinarians in practice	1203	2.726	2.125	0.500	20.500
Number of associates per owner	1203	0.553	0.827	0.000	10.500
Number of non-vet employees per vet	1203	3.080	2.538	0.000	21.333
Board Certified	1203	0.025	0.155	0.000	1.000
Ph.D.	1203	0.011	0.107	0.000	1.000
M.S.	1203	0.082	0.275	0.000	1.000
Residency	1203	0.033	0.178	0.000	1.000
Internship	1203	0.053	0.225	0.000	1.000
Population 2,500 to 49,999	1203	0.555	0.497	0.000	1.000
Population 50,000 to 499,999	1203	0.184	0.387	0.000	1.000
Population 500,000 or more	1203	0.072	0.259	0.000	1.000

Table 2. Descriptive statistics of private practice associates, only of observations in regression model.

Variable	N	Mean	Std Dev	Minimum	Maximum
Income	638	62697	27440	17000	256884
Large animal exclusive	638	0.069	0.254	0.000	1.000
Large animal predominant	638	0.088	0.283	0.000	1.000
Small Animal Predominant	638	0.139	0.347	0.000	1.000
Small animal exclusive	638	0.373	0.484	0.000	1.000
Equine	638	0.136	0.343	0.000	1.000
Years of experience	638	8.821	7.854	0.000	45.000
Female	638	0.509	0.500	0.000	1.000
Hours per week over 40	638	10.113	10.092	-10.000	40.000
Number of veterinarians in practice	638	4.165	4.162	1.000	44.500
Number of associates per owner	593	1.887	1.735	0.000	19.000
Number of non-vet employees per vet	638	3.352	2.369	0.000	25.000
Board Certified	638	0.028	0.166	0.000	1.000
Ph.D.	638	0.003	0.056	0.000	1.000
M.S.	638	0.075	0.264	0.000	1.000
Residency	638	0.031	0.174	0.000	1.000
Internship	638	0.114	0.319	0.000	1.000
Weeks of vacation	638	1.871	1.061	0.000	6.000
Number of benefits	638	7.009	2.721	0.000	14.000
Population 2,500 to 49,999	638	0.476	0.500	0.000	1.000
Population 50,000 to 499,999	638	0.293	0.456	0.000	1.000
Population 500,000 or more	638	0.100	0.301	0.000	1.000

Table 3. Descriptive Statistics of university employed veterinarians, only of observations in regression model.

Variable	N	Mean	Std Dev	Minimum	Maximum
Income	279	96863.63	36850.54	15000	240000
Professor	279	0.329749	0.470967	0	1
Associate Professor	279	0.222222	0.416487	0	1
Dean	279	0.010753	0.103322	0	1
Assistant Dean	279	0.078853	0.269994	0	1
Department Head	279	0.039427	0.194957	0	1
Section Head	279	0.021505	0.145322	0	1
Clinician	279	0.039427	0.194957	0	1
Researcher	279	0.075269	0.264299	0	1
Clinical	279	0.27957	0.449594	0	1
Consulting	279	0.014337	0.119089	0	1
Extension	279	0.039427	0.194957	0	1
Management	279	0.168459	0.374946	0	1
Research	279	0.258065	0.438356	0	1
Years of experience	279	19.11111	10.63684	0	46
Female	279	0.290323	0.454727	0	1
Hours per week over 40	278	11.84892	8.982063	-10	45
Weeks of vacation	278	2.636691	1.294679	0	6
Board Certified	279	0.637993	0.481445	0	1
Ph.D.	279	0.412186	0.493113	0	1
M.S.	279	0.458781	0.499194	0	1
Residency	279	0.580645	0.49434	0	1
Internship	279	0.050179	0.218707	0	1

Table 4. Descriptive Statistics of government veterinarians, only of observations in regression model.

Variable	N	Mean	Std Dev	Minimum	Maximum
Income	198	80798	23548	28000	175000
Federal—Civil Services	198	0.212	0.410	0.000	1.000
Federal—Uniformed Services	198	0.384	0.488	0.000	1.000
CEO	198	0.071	0.257	0.000	1.000
Vice President	198	0.126	0.333	0.000	1.000
Department Head	198	0.182	0.387	0.000	1.000
Section Head	198	0.298	0.459	0.000	1.000
Clinician	198	0.172	0.378	0.000	1.000
Clinical	198	0.187	0.391	0.000	1.000
Consulting	198	0.020	0.141	0.000	1.000
Management	198	0.540	0.500	0.000	1.000
Teaching	198	0.010	0.100	0.000	1.000
Years of experience	198	19.283	10.054	0.000	45.000
Female	198	0.293	0.456	0.000	1.000
Hours per week over 40	198	7.540	7.520	-15.000	30.000
Weeks of vacation	198	2.990	1.318	0.000	6.000
Board Certified	198	0.409	0.493	0.000	1.000
Ph.D.	198	0.141	0.349	0.000	1.000
M.S.	198	0.475	0.501	0.000	1.000
Residency	198	0.217	0.413	0.000	1.000
Internship	198	0.045	0.209	0.000	1.000

Table 5. Descriptive statistics of veterinarians employed in industry, only of observations in regression model.

Variable	N	Mean	Std Dev	Minimum	Maximum
Income	173	138235	63018	27500	290000
CEO	173	0.064	0.245	0.000	1.000
Vice President	173	0.266	0.443	0.000	1.000
Department Head	173	0.173	0.380	0.000	1.000
Section Head	173	0.162	0.369	0.000	1.000
Clinician	173	0.104	0.306	0.000	1.000
Clinical	173	0.064	0.245	0.000	1.000
Consulting	173	0.092	0.291	0.000	1.000
Management	173	0.214	0.411	0.000	1.000
Manufacturing	173	0.012	0.107	0.000	1.000
Marketing	173	0.040	0.198	0.000	1.000
Sales	173	0.092	0.291	0.000	1.000
Years of experience	173	18.682	9.124	1.000	43.000
Female	173	0.289	0.455	0.000	1.000
Hours per week over 40	173	10.740	8.118	-5.000	40.000
Weeks of vacation	173	2.763	1.292	0.000	6.000
Board Certified	173	0.382	0.487	0.000	1.000
Ph.D.	173	0.283	0.452	0.000	1.000
M.S.	173	0.306	0.462	0.000	1.000
Residency	173	0.341	0.475	0.000	1.000
Internship	173	0.046	0.211	0.000	1.000

Table 6. Professional income of veterinarians in private practice by ownership status, 2001[a]

	Large Animal Exclusive	Large Animal Predominant	Mixed Animal	Small Animal Predominant	Small Animal Exclusive	Equine	Other	Total Private Practice
Mean ($)								
Owner	91,787	78,374	81,392	89,064	103,270	128,442	131,731	98,520
Associate	60,929	56,082	55,399	60,363	68,804	69,349	75,191	66,841
Median ($)								
Owner	81,280	65,500	65,500	68,500	89,500	101,500	77,500	80,500
Associate	58,000	53,500	53,500	56,500	62,500	56,500	64,000	59,500
Standard Error ($) / Usable Responses								
Owner	3,274	3,123	3,137	3,435	3,356	5,529	22,080	1,529
	(286)	(289)	(472)	(307)	(364)	(345)	(40)	(2,103)
Associate	2,586	1,507	1,146	1,516	1,340	3,511	7,881	818
	(88)	(90)	(202)	(167)	(438)	(177)	(34)	(1,196)

[a] Weighted estimates based on the total population of veterinarians in private practice. Owner's income excludes 12% return on owner's equity in practice (fair market value of fixed assets less long-term debt).

Table 7. Professional income of veterinarians in private practice by gender, 2001[a].

	Large Animal Exclusive	Large Animal Predominant	Mixed Animal	Small Animal Predominant	Small Animal Exclusive	Equine	Other	Total Private Practice
Mean ($)								
Male	87,455	75,977	79,148	91,625	97,583	127,932	116,960	94,975
Female	64,146	54,447	55,727	58,980	67,990	70,667	85,065	66,318
Median ($)								
Male	75,100	62,620	65,500	73,600	80,500	95,500	85,000	74,500
Female	53,500	53,500	50,500	55,120	59,500	53,500	59,500	59,500
Standard Error ($) / Usable Responses								
Male	2,831	2,776	2,815	3,425	2,751	5,527	17,555	1,352
	(327)	(328)	(515)	(290)	(446)	(344)	(48)	(2,298)
Female	7,197	2,609	2,632	2,166	1,762	3,703	16,485	1,135
	(47)	(51)	(158)	(184)	(356)	(178)	(26)	(1,000)

[a] Weighted estimates based on the total population of veterinarians in private practice. Owner's income excludes 12% return on owner's equity in practice (fair market value of fixed assets less long-term debt).

Table 8. Summary of spatial diagnostic tests.

	Practice Owners	Practice Associates	University	Government	Industry
Number of Observations	1203	638	279	198	173
Ordinary Least Squares Model					
LM Spatial Error	94.358179*	10.02609*	0.005239626	8.9864502*	0.33768781
LM Spatial Lag	98.544799*	15.540914*	0.48246804	1.0551519	3.4985109
Joint Spatial Dependence Model					
Lambda	-0.0554	-0.1155	0.0907	0.4928*	-0.3470*
Rho	0.3054*	0.2366*	-0.0906	-0.3472*	0.3167*
Mean log-likelihood	-12.1926	-11.4263	-11.4476	-11.1743	-12.1582
Spatial Lag Model					
Rho	0.2699*	0.1587*	-0.0411	0.0753	0.1429*
Mean Log-Likelihood	-12.1927	-11.4443	-11.4484	-11.2037	-12.1681
LR Test vs. Joint Spatial Model	0.1203	11.484*	0.2232	5.8212*	1.7127
Spatial Error Model					
Lambda	0.2894*	0.1489*	-0.0056	0.2320*	0.0741
Mean log-likelihood	-12.1965	-11.4474	-11.4491	-11.1899	-12.1755
LR Test vs. Joint Spatial Model	4.6917*	13.4618*	0.4185	3.0888	2.9929
Spatial Lag Model-Optimal Phi					
Rho	0.4785*	0.5769*	-0.9475*	0.2653	0.4207*
Phi[1]	54.08362	133.59927	500	181.95237	207.72073
Mean log-likelihood	-12.1861	-11.4263	-11.4431	-11.201	-12.1621
Spatial Error Model-Optimal Phi					
Lambda	0.5546*	0.6861*	0.1797	0.3044*	0.1444
Ph [a]	55.0267	160.6800	161.6580	1.0000	1.0000
Mean log-likelihood	-12.1889	-11.4312	-11.4479	-11.18	-12.1697

[a] Optimal values of phi found via iterative grid search

Table 9. Preferred Models.

	Practice Owners	Practice Associates	Government	University	Industry
	Spatial Lag	Spatial Lag	Spatial Error	OLS	OLS
Constant	5,231*	13,213*	42,763*	59,840*	48,158*
Ph.D.	-21,113	4,910	11,126*	1,601	24,718*
M.S.	-9,306*	-12,840*	-13	-508	10,265
Weeks of vacation		-1,740*	2,118*	-1,268	14,369*
Years of experience	210	897*	694*	749*	902*
Board Certified	14,643	-19,942*	8,608*	16,687*	13,823
Female	-25,848*	-10,841*	-3,610	-16,508*	-4,782
Hours per week over 40	528*	166	143	-151	938*
Residency	663	57,134*	6,503*	5,859	18,311*
Internship	-3,828	4,668	7,072	7,851	13,915
Number of benefits		688*			
Large animal exclusive	-936	-952			
Large animal predominant	-3,962	-573			
Small Animal Predominant	6,685	3,157			
Small animal exclusive	13,124*	5,405*			
Equine	26,912*	7,752*			
Number of veterinarians in practice	2,581*	468*			
Number of associates per owner	9,628*	1,087*			
Number of non-vet employees per vet	1,165*	915*			
Population 2,500 to 49,999	9,840*	-5,446*			
Population 50,000 to 499,999	21,837*	-4,120			
Population 500,000 or more	24,059*	-920			

* 0.05 level of significance

Table 9. Preferred Models (cont.).

Owner equity	0.1062*				
Dean/CEO			34,161*	32,718*	49,766*
Assistant Dean/V.P.			16,743*	26,638*	28,891*
Dept. Head			2,303	13,808	7,102
Section Head			8,095	-5,063	1,246
Professor				20,609*	
Associate Professor				4,704	
Researcher				-27,154*	
Clinician			10,555	-3,363	-10,107
Clinical			-1,326	4,241	-19,815
Consulting			-5,962	15,838	-37,419*
Management			6,352	30,245*	877
Research				10,543*	
Manufacturing					14,466
Marketing					-42,088*
Sales					-28,496*
Federal—Civil Services			12,112*		
Federal—Uniformed Services			-9,874*		
Rho	0.4785*	0.5773*			
Lambda			0.3044*		
Phi [a]	54.0836	133.4296	1.0000		
Mean log-likelihood	-12.1861	-11.4262	-11.1800		
R^2				0.9519	0.9043
Adj. R^2				0.9442	0.8803

* 0.05 level of significance

[a] Optimal values of phi found via iterative grid search

Endnotes

[1] Hedonic analysis has been used extensively to define implicit prices of wages, land, housing, and market goods (Rosen; Taylor and Smith; Ekeland, Heckman, and Nesheim).
[2] Correction for spatial autoregression has been incorporated into numerous empirical economic applications, but has only recently been considered in hedonic regression models (e.g., Bowen, Mikelbank, and Prestegaard).
[3] In (5) and the remaining equations below, we suppress the index *j* of employment structure for simple convenience.
[4] For instance, the elements of the proximity matrix $\mathbf{W_1}=\{w_{ij}^*\}$ may be defined as a standardized joins matrix where $w_{ij}^* = w_{ij} \big/ \sum_j w_{ij}$ with w_{ij}=1 if observations *i* and *j* are from an adjoining spatial region (for $i \neq j$) and w_{ij}=0 otherwise.
[5] Consistent generalized two stage least squares and generalized method of moments estimators are discussed in Kelejian and Prucha (1998, 1999). Lee (2002, 2003) examined consistency and efficiency of least squares estimation for mixed regressive, spatial autoregressive models and investigated best two-stage least squares estimators for a spatial model with autoregressive disturbances. Marsh and Mittelhammer discuss maximum entropy estimators of the spatial regression model.
[6] Here, we do a grid search over an interval with a lower bound of 1 and an upper bound of 500.
[7] See Anselin for derivations of LM test statistics and their robustness relative to alternative hypothesis testing procedures.
[8] Spatial error dependence may arise as the result of omitting variables, which are not otherwise fundamental to the model (Anselin).