9-2010

Where Are the Veterinarian Shortage Areas Anyway?

Tong Wang
Iowa State University, tongwang@iastate.edu

David A. Hennessy
Iowa State University, hennessy@iastate.edu

Annette M. O'Connor
Iowa State Univresity, oconnor@iastate.edu

Where Are the Veterinarian Shortage Areas Anyway?

Abstract
This paper describes an econometric model to evaluate factors associated with a county's likelihood of being designated as a private practice shortage area under the United States' Veterinary Medicine Loan Repayment Program (VMLRP). Study determinants of equilibrium food animal veterinarian location choices were also evaluated and used as a benchmark to assess the shortage designation process. On the whole the program appears to perform quite well. For several states, however, VMLRP shortage designations are inconsistent with the model of food animal veterinarian shortages. Comparative shortage is generally more severe in states that have no VMLRP designated private practice shortage counties than in states that do.

Keywords
economic externalities, food animal veterinarians, loan repayment program

Disciplines
Health Economics | Health Policy | Large or Food Animal and Equine Medicine

Where Are the Veterinarian Shortage Areas Anyway?

Tong Wang, David A. Hennessy, and Annette M. O’Connor

Working Paper 10-WP 513
September 2010

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Tong Wang is a PhD candidate in the Department of Economics, David A. Hennessy is a professor in the Department of Economics and Center for Agricultural and Rural Development, and Annette M. O’Connor is an associate professor in Veterinary Diagnostics and Production Animal Medicine in the College of Veterinary Medicine, all at Iowa State University.

Questions or comments about the contents of this paper should be directed to David Hennessy, 578C Heady Hall, Iowa State University, Ames, Iowa 50011-1070; Ph: (515) 294-6171; Fax: (515) 294-6336; E-mail: hennessy@iastate.edu.

Abstract

This paper describes an econometric model to evaluate factors associated with a county's likelihood of being designated as a private practice shortage area under the United States' Veterinary Medicine Loan Repayment Program (VMLRP). Study determinants of equilibrium food animal veterinarian location choices were also evaluated and used as a benchmark to assess the shortage designation process. On the whole the program appears to perform quite well. For several states, however, VMLRP shortage designations are inconsistent with the model of food animal veterinarian shortages. Comparative shortage is generally more severe in states that have no VMLRP designated private practice shortage counties than in states that do.

Keywords: economic externalities, food animal veterinarians, loan repayment program.

1. Introduction

Food animal veterinarian (FAV) service value extends beyond value derived as an input into food production. The consequences of infectious exotic and/or zoonotic animal disease outbreaks for the agricultural sector as a whole underline the positive economic externalities arising from a FAV's work. For example, some highly contagious diseases may immediately pass on to animals in spatially contiguous areas, followed by depopulation of infected animals and a large loss. This is especially true when profitable export markets are threatened. The devastating effect of foot and mouth disease (FMD) on Taiwan's pork industry is an example. Before the 1997 FMD outbreak, pork export had been Taiwan's most valuable agricultural export. Between March and July 1997, more than 4 million out of nearly 11 million hogs died. Of these, 0.18 million died from the disease itself, while 3.85 million were depopulated from infected farms (Huang, 2000). The disease outbreak, and especially depopulation through euthanasia, is also likely to create animal welfare concerns for society as a whole.

In the event that a FAV shortage causes delays in controlling an infectious disease, the consequences are not constrained to animal welfare and the agricultural sector alone. Using a computable general equilibrium (CGE) model of the United Kingdom economy, Blake et al. (2003) have shown that the 2001 FMD outbreak in the UK had a much larger adverse effect on the UK tourism and outdoor leisure sectors than on its agriculture sector. FAV work also provides positive externalities to human health through increasing the probability of detecting zoonotic disease early. As health care professionals working with animals and their owners, veterinarians are likely to be the first to detect the disease and call attention to impending zoonotic disease problems.

Therefore a society's willingness to pay for farm animal veterinary services is likely to exceed the farmer's private willingness to pay. Stated differently, a farmer is likely focused primarily on using veterinary services so as to increase farm profit. While the grower is obviously very concerned about quickly detecting exotic disease, the private benefits to the grower of hiring veterinary services that devote some time to checking for exotic diseases on own farm premises are far smaller than are the benefits to society. Absent other external effects, the private market for FAV services is likely to support a level of activity below the socially optimal level.

The issue of whether the United States has a shortage of FAVs has been addressed previously, with divergent conclusions. Pointing out the profession's low salaries when compared with comparably trained professionals, Getz (1997) infers the existence of excess supply. Using econometric analysis, Brown and Silverman (1999) have forecasted a decrease in demand (-1.7%) during the 18 year forecast period, 1997 to 2015. They have also predicted a large surplus of veterinarians in large animal practice.

However, other papers on the issue suggest that a shortage exists and will persist through the near future. Prince et al. (2006) point to two sets of factors that significantly affect the supply of FAVs. One is the trend toward "less emphasis on food animal practice" and career opportunities during training. The other is a "lack of spousal career options, limited lifestyle and career opportunities, and lack of cultural and recreational opportunities." Narver (2007) concludes that the demographic shift in the profession toward females with non-food animal practice preferences is likely to create a shortage. Walker (2009) comments that factors contributing to the shortage include the need to repay student debt. Most significantly, she detects an uneasy relationship between professionals disposed, acculturated and trained to care for animals at the individual level and food production systems that have increasingly emphasized herd health, profit and analytic approaches to effective treatment.

One way to reconcile these divergent perceptions is to point to the wedge between the social value of FAVs and the private sector's willingness to pay. Farmers have insufficient incentive to pay for the public health benefits that private practice veterinarians can provide through identifying, reporting and assisting in the control of endemic infectious, exotic and zoonotic diseases. Those who see a surplus base their views on market salaries, the existence of tuition subsidies and large public contributions to veterinary college infrastructure. Those who point to shortage view the sum of private and unmet social needs. Correct diagnosis of the problem is an important first step. As both views may be valid, if attention and resources are to be channeled into clarifying and solving problems in this market then both sides of the debate need to recognize the foundations upon which alternative views in the debate are built.

Perceiving a FAV shortage in light of positive externalities generated, state and federal governments in the United States have offered subsidies for veterinarian students entering food animal practice. This market intervention can be defended as economic policy because the subsidy seeks to incentivize resource allocation toward providing public goods that the market fails to provide (Varian, 1992).[1]

According to AVMA state legislative resources[2], 19 states offer state veterinary loan programs. The perceived FAV shortage, especially in rural areas has also been addressed at the federal level. In January 2003, the Veterinary Medicine Loan Repayment Program (VMLRP) was established under the National Veterinary Medical Service Act. For qualified veterinarians who agree to serve in certain high-priority veterinary shortage areas for a period of three years, the U.S. Department of Agriculture's (USDA) National Institute of Food and Agriculture (NIFA) will repay a maximum of $25,000 of student loans per year. The focus of our inquiry is

---

[1] The extent of intervention (e.g., size of subsidy), choice of instruments and efficiency in providing these services are other matters. In order to reduce transactions costs and hasten response, since 2001 the U.S. Department of Agriculture has operated the National Animal Health Emergency Response Corps. It is intended to organize volunteer veterinary professionals in preparation for an emergency disease outbreak event. In other countries, more public sector veterinarians are employed throughout the country while private sector veterinarians are employed to make farm visits motivated by disease eradication schemes. In the context of detecting biosecurity and other problems that are ill-defined and very rare, it would be difficult for a government to evaluate and monitor job performance.

[2] http://www.avma.org/advocacy/state/loan_repayment_programs/default.asp, visited on 8/16/2010.

the set of counties that has been identified as short of private practice veterinarians.

NIFA determines private veterinary shortage areas according to the following steps:[3] 1) "NIFA will release a Federal Register (FR) notice soliciting nominations for veterinary shortage situations from all State Animal Health Officials (SAHOs)"; 2) "SAHOs will prepare nominations corresponding to the highest priority veterinary shortage situations within their entities and then submit completed nomination forms by email to NIFA"; 3) "A review panel composed of Federal and State animal health experts will be convened by NIFA to evaluate the submitted nomination packages." Then "final decisions regarding recommendation status will be made by the NIFA Program Manager, on behalf of the Secretary of Agriculture. Designated shortage situations will be made accessible to the public in list and/or map form." We will refer to Program Designated (PD) and Program Non-Designated Shortage Counties (PN).

In this paper we present two econometric models to investigate what factors determine the number of FAVs in any given county, and also the counties that have been designated as shortage areas. In the first model we estimate the relationship between the location of FAVs and the stock of different species served by such veterinarians. In the second model we study factors that might affect the odds that a county is designated as a shortage area. We then provide an objective designation of FAV shortage as the presence of a negative deviation from the first model's predicted FAV value. If the deviation is negative, then we refer to the county as a model-designated shortage county (MD). Otherwise we refer to the county as model non-designated shortage county (MN). We then compare MD counties with PD counties. We also consider comparative shortages in states that either did not nominate any counties or had their nominations rejected by the NIFA program manager.

[3]http:www.nifa.usda.gov/nea/animals/in_focus/an_health_if_vmlrp_nomination_and_designation_of_veterinary_shortage_situations.html, visited on 8/17/2010.

2. Materials and Methods

2.1. Data collection and management

The VMLRP private practice shortage situations are posted at NIFA Web site http://www.nifa.usda.gov/nea/animals/in_focus/vmlrp/vmlrp_shortage_situation_usmap.html.[4] Based on these data, all counties in the US were categorized as either private practice Program Designated (PD) or Program Non-Designated (PN) shortage counties. The AVMA website http://www.avma.org/fsvm/maps/default.asp[5] provided the number of FAVs for each county. Data used to identify FAV needs at the county level include the number and composition of species in the county. Data for livestock, namely all cattle (labeled cattle), all hogs (hogs), all sheep (sheep) and all horses (horses), were obtained from the 2007 USDA Census of Agriculture. Horses have been included because FAVs may include them in their practice, especially in shortage counties where specialist equine practices are unlikely to locate. The study includes all counties in the contiguous 48 states (i.e., excluding Alaska and Hawaii). Ten states do not have a designated shortage area, either because "no shortage situation nominations were submitted," or "shortage situation nominations were submitted, but the external review panel did not recommend them for official designation."[6] These are Alabama, Connecticut, Georgia, Massachusetts, Mississippi, Nevada, New Jersey, Tennessee, Washington and Wyoming.

Consistent and reliable data are not available concerning pet populations at the county level of analysis. Therefore demographic variables are used to proxy for possible demand on veterinarian time from serving pets in the county. These include the county's total population

---

[4] Last visited on 8/16/10.
[5] Visited on 3/8/10. Data are from the American Veterinary Medical Association database, as of December 31, 2008.
[6] In an e-mail dated July 10, 2010, Gary Sherman at NIFA has communicated to us that 181 of the 249 nominations received were recommended. Further details on the rejected nominations were considered to be confidential, and were not made available to us.

in 2000 and average per capita income in 1999, where census forms ask about income in the preceding year. These data were extracted from the most recent available decennial census conducted by the U.S. Census Bureau. Population and income should be important factors in determining the number of pets in a county and the population's willingness to pay for veterinary services.

A rurality index was included in the model to accommodate several possible issues. These include *i*) a preference for a rural lifestyle, such as keeping large or many animals as pets; *ii*) the effect of rurality on spousal career constraints; *iii*) the relationship between rurality and cost of making calls to food animal premises. Because of these multiple, and likely opposing, effects and because true shortages are likely to be correlated with rurality, we will interpret the variable with some caution. The rurality index is measured by Purdue University's Center for Regional Development and Indiana University's Indiana Business Research Center (http://www.ibrc.indiana.edu/innovation/maps.html.[7]) The index is based on four dimensions: population, population density, extent of urbanized area and distance to the nearest metro area.

Distance to veterinary college was considered as there may also be inertia in that a student may prefer to locate where he/she externed, and that may be near the student's veterinary college. In addition, the graduate or spouse may have already established personal and professional roots in the region. Distance is calculated by CDXZipStream software,[8] which calculated the distance between each county and each of the 27 veterinary colleges using zip code information and chose a minimum distance.

We also seek to capture any distinctive effects associated with counties in which a veterinary college is located, including the aforementioned inertia and career opportunities that can arise for FAVs from being near a major teaching and clinical facility. We do so by use of a

[7] Visited on 1/6/10.
[8] See http://www.cdxtech.com/CDXZipStream/Overview.aspx, visited 6/7/2010.

veterinary college dummy (college), assigned the value 1 if a veterinary college is located in the county and the value 0 otherwise.

Table 1 provides descriptive statistics for all the variables in models I and II. Here, cattle, sheep, hogs and horses are in units of ten thousand. Human population is in 1,000 head while income is in units of $1,000.

2.2. Models and statistical analyses

Model I seeks to identify factors associated with the number of veterinarians in a county. Model II seeks to identify factors associated with designation of a county as a veterinarian shortage county under the VMLRP. We used Model I to predict the number of veterinarians, and then computed the residual, i.e., the difference between the observed and predicted veterinarian count. PD should have fewer veterinarians than the number predicted by Model I. So we use the results of Model I as a benchmark to check the Model II estimates, and also to check whether the shortage map published under VMLRP is correlated with shortages identified by Model I.

2.2.1. Model I

In Model I we follow Getz’s (1997) state-level analysis on early 1990s data, but do so at the county-level on table 1 data, and are more comprehensive in the chosen explanatory variables. The variable to be explained is the number of farm animal veterinarians. We applied a Poisson regression to model the veterinarian count. However, due to the over-dispersion problem often associated with the Poisson regression, we also evaluated a Negative Binomial regression as a method of modeling the data.

Both Poisson and negative binomial specifications have the general form

$$\log\left(\text{vet}_i\right) = \hat{b}_0 + \hat{b}_1\text{cattle}_i + \hat{b}_2\text{sheep}_i + \hat{b}_3\text{hogs}_i + \hat{b}_4\text{horses}_i + \hat{b}_5\text{population}_i + \hat{b}_6\text{distance}_i + \hat{b}_7\text{college}_i + \hat{b}_8\text{rurality}_i + \hat{b}_9\text{income}_i, \quad \text{(TMI)}$$

where the subscript i denotes the county identifier and TMI stands for Tentative Model I.

2.2.2. Comments on Model I

Before progressing further, some comments are in order concerning the interpretation of TMI and related models to follow. They are equilibrium models depicting how FAVs choose location of practice. They characterize neither the willingness to supply food animal veterinary services at a given price nor the willingness to pay for these services at a given price. It will be noted that price and salary are not included in TMI. Rather, TMI characterizes how supply and demand interact to provide an equilibrium allocation of FAVs across the counties of the United States. This is not a structural econometric model of the market. By contrast, a structural econometric model would seek to separate supply and demand sides of the market. A comprehensive structural model would also need to include the closely related companion animal, public service and industry components of veterinarian labor markets.[9]

Ideally a structural model would be preferred because it might enable a clearer understanding of such matters as how rurality affects demand and supply, as well as the extent to which a subsidy would promote supply. Data limitations preclude the estimation of a comprehensive structural model. Our purposes are to assess which counties have comparatively few FAVs given the animals to be served, and then to evaluate the VMLRP in this light. For these purposes, TMI and related models are well suited.

[9] It has been pointed out (e.g., Walker, 2009) that FAVs can often quite readily reallocate their services to companion animal and other service sub-markets.

2.2.3. Model II

In Model II, a logistic regression model was used as the response variable only takes two values, either 1 whenever the county is a PD or 0 whenever it is not a PD. A tentative Model II can be specified as the logistic specification:

$$\log\left(\frac{p}{1-p}\right)_i = \hat{b}_0 + \hat{b}_1\text{vet}_i + \hat{b}_2\text{cattle}_i + \hat{b}_3\text{sheep}_i + \hat{b}_4\text{hogs}_i + \hat{b}_5\text{horses}_i + \hat{b}_6\text{population}_i + \hat{b}_7\text{distance}_i + \hat{b}_8\text{college}_i + \hat{b}_9\text{rurality}_i + \hat{b}_{10}\text{income}_i. \quad \text{(TMII)}$$

Here p is the probability that a county is designated as the private veterinarian shortage county.

3. Results

3.1. Model I results

For the negative binomial distribution, variance is constrained to equal $\text{mean} + \kappa \times (\text{mean})^2$ where $\kappa \geq 0$. This reduces to the Poisson distribution when $\kappa = 0$. So to test whether we should use Poisson regression or negative binomial regression, we first tested the null hypothesis that $\kappa = 0$ (page 743 of Greene, 2003). The log likelihood statistics for Poisson and negative binomial models are 2045.26 and 3079.78, respectively. The log likelihood ratio test statistic is 2069.04, which corresponds to a p-value < 0.0001. Hence, we reject the null hypothesis to conclude that the mean and variance are not equal. Henceforth the negative binomial regression is used for Model I.

From the estimated results of model TMI, we found that sheep and population regressors were not statistically significant at the 10% level. Sheep are a low valued livestock of limited presence in the United States. The demand for veterinarian care is low, and so the species is unlikely to have a significant impact on veterinarian location choices. We may think of population as a control variable for the possibility that serving pets is a significant component of a practice. The veterinarians under scrutiny designated themselves as serving primarily food animals, so it is reassuring and not surprising to learn that the population control for pets does not matter. That the county income control does matter may reflect the companion animal nature of horses, i.e., it is not just the number of horses that matters as there may also be income effects in leisure horse owner consumption preferences. Sheep and population regressors were excluded from the final model.

The updated Model I, MI1, is:

$$\begin{aligned}\log\left(\text{vet}_i\right) = \hat{b}_0 + \hat{b}_1\text{cattle}_i + \hat{b}_2\text{hogs}_i + \hat{b}_3\text{horses}_i + \hat{b}_4\text{distance}_i + \hat{b}_5\text{college}_i + \hat{b}_6\text{rurality}_i \\ + \hat{b}_7\text{income}_i.\end{aligned} \qquad \text{(MI1)}$$

As previously discussed, rurality can have multiple effects on the number of FAVs in a county. Given the intent of the loan program, including it may explain away the shortage. For this reason we also consider Model I without rurality and refer to it as MI2:

$$\log\left(\text{vet}_i\right) = \hat{b}_0 + \hat{b}_1\text{cattle}_i + \hat{b}_2\text{hogs}_i + \hat{b}_3\text{horses}_i + \hat{b}_4\text{distance}_i + \hat{b}_5\text{college}_i + \hat{b}_6\text{income}_i. \qquad \text{(MI2)}$$

3.2. Model II results

Upon running tentative Model II we find that the *sheep*, *population*, *college* and *income* variables are not significant at the 0.1 level. Therefore these four variables are excluded from the final model. Reasons for the insignificance of *sheep*, *population* and *income* effects have been discussed in section 3.1. *College* indicates whether or not a county has a veterinary college. The existence of a veterinary college is more likely to impact the county's probability of being selected as a public shortage area, rather than a private practice shortage area, so it is not surprising that the variable is not found to be significant. The finalized Model II is as follows:

$$\log\left(\frac{p}{1-p}\right)_i = \hat{b}_0 + \hat{b}_1\text{vet}_i + \hat{b}_2\text{cattle}_i + \hat{b}_3\text{hogs}_i + \hat{b}_4\text{horses}_i + \hat{b}_5\text{distance}_i + \hat{b}_6\text{rurality}_i. \qquad \text{(MII)}$$

3.3. Model estimates and interpretation

The estimated negative binomial regression coefficients for both Model MI1, with rurality, and Model MI2, without rurality, are shown in table 2. The rurality variable is removed in MI2 because it may conceivably be the cause of the shortage that the loan program is intended to address. In that case, including rurality would provide residuals that had already accounted for the shortage so that one might not expect to see a relationship between the model residuals and perceptions of veterinarian shortage. So, upon holding the other model variables constant, a unit (ten thousand) increase in the cattle population will increase the log of veterinarians by 0.084 in Model MI1 and by 0.080 in MI2. In both MI1 and MI2 factors such as more livestock, having a veterinary college and higher income were associated with increases in the predicted number of veterinarians in the county. Factors associated with decreases in the predicted number of veterinarians include longer distance to veterinary college and a higher rurality index.

The estimated logistic regression coefficients for Model MII are given in table 3. The values of $\hat{b}_i$, $i \in \{1, 2, \ ... \ , 6\}$, are shown in the estimate column. For example, for an increase of one in the veterinarian count the log odds of being designated a shortage county decreases by 0.079. Interpretation is easier if the coefficients are exponentiated, as shown in the point estimate column. When the veterinarian number increases one unit then the odds ratio for being listed as PD decreases to 0.924. This means that when the number of veterinarians increases then the county is less likely to be listed under the VMLRP as a veterinarian shortage area. When cattle count increases one unit (i.e., 10,000 cattle) then the odds ratio for being listed increases to 1.065. The corresponding odds ratio is 1.009 for hogs and 1.989 for horses. So, having controlled for the number of FAVs in the county, more valuable livestock will increase the odds ratio for being a PD county more than will less valuable animals, where hogs are generally the least valuable species and horses the most valuable.

As distance from the nearest veterinary college increased by one mile, the odds ratio for being a PD county increased to 1.004. If the distance increased from 0 to the maximum 601.9 miles, the odd ratio was increased to $(1.004)^{601.9} = 11.05$. Further, as rurality increased by one unit (i.e., when a county changes from purely urban to purely rural) the odds ratio for being listed as a PD county increased to 6.375. This suggests that rurality has played a key role in deciding whether a county is listed as a veterinarian shortage county.

Comparing the predicted shortage situation (i.e., the county has a negative residual in model) with the published USDA NIFA shortage situation, percent concordance is 71%. This measures the specification for Model MII. In other words, this measures the proportion of non-designated counties for which both models agreed with this designation.

3.4. Comparing PD with MD shortage counties

We compared the residuals from Model MI2 with the shortage designations that Model MII studies.[10] Model I residuals are calculated as $r_i = y_i - \hat{y}_i$ where y_i is the *i*th county observed number of veterinarians and $\hat{y}_i$ is the corresponding predicted value. We refer to a county as being model designated, or MD, whenever the Model I residual is negative. This is because there are fewer veterinarians than Model I predicts. The hypothesis is that negative, rather than positive, residual counties are more likely to be identified by loan program administrators as being comparatively short of FAVs. The county is said to be model non-designated, or MN, whenever the residual is positive. Overall, 413 out of 657 (63%) PD counties and 964 out of 2412 (40%) PN counties are MN under Model MI2.[11]

From now on we will refer to the ratio of PD counties that are MD over all PD counties as

---

[10] Comparison of residuals of model MI1 with MII shortage counties generate very similar results. Results are available upon request.
[11] 406 (62%) PD and 971 (40%) PN are MD.

sensitivity and the ratio of PN counties that are MN over all PN counties as specificity. That is, we take the model to be the truth and seek to understand how the program performs in identifying counties that do and do not have shortages. In equation form, we write:

$$\text{Sensitivity} = \frac{\#(\text{PD} \cap \text{MD})}{\#(\text{PD})}; \qquad \text{Specificity} = \frac{\#(\text{PN} \cap \text{MN})}{\#(\text{PN})}; \qquad \text{(SS)}$$

where $\cap$ means that both conditions must apply.

In table 4, we compute sensitivities for the 38 states (excluding Alaska and Hawaii) that have designated private practice shortage counties. This provides us with a rough way of knowing how many counties in each state have been appropriately designated, where the column ‘total’ gives the number of counties in the states. Table 5 shows the specificities for the same states. In other words, table 4 demonstrates how good the program is at identifying the counties that are shortage counties, based on Model I. It signals the agreement between Model 1 and NVLRP designations. Table 5 shows how good the program is at tossing out counties that are not shortage counties, again according to our model. Low sensitivity could arise from two reasons: *i*) MD counties were not chosen as PD, and *ii*) too many counties were PD. Low specificity could also arise for two reasons: *i*) MN counties were chosen as PD, and *ii*) too few counties were PD.

3.5. Comparing state-level shortage situations with the national average

To obtain a sense of which states may have a more ‘dire’ veterinarian shortage situation when compared to the national average, we provide in table 6 the percentage of counties with negative residuals arising from MI2. The average across all 38 states is 57% and the standard deviation is 19%. So we can say a state has a less ‘dire’ veterinarian shortage situation than the national average if the state’s percentage of negative residuals is no more than 57-19=38, and a state has a more ‘dire’ shortage situation if this percentage is at least 57+19=76. Any percentage in between is referred to as about average.

According to table 6, six states (Iowa, Maine, New Hampshire, New York, Vermont, Wisconsin) have a less severe veterinarian shortage situation than the country’s average, if a shortage exists in those states at all. Of these, Maine, New Hampshire and Vermont do not provide even an undergraduate program but are small states proximate to colleges in Massachusetts and New York states. Six states (Delaware, North Carolina, Rhode Island, South Carolina, Virginia, West Virginia) have a more serious shortage situation. Of these, both North Carolina and Virginia have veterinary colleges. Delaware, Rhode Island, South Carolina and West Virginia do not provide even an undergraduate program but are comparatively small states. It is difficult to discern a pattern here, except perhaps that the South East appears to be least well-served and the Midwest may be quite well-served. Notice that Idaho (54.5%), Kansas (56.2%), Montana (46.4%), Nebraska (53.8%), New Mexico (39.4%), North Dakota (52.8%), Oregon (41.7%) and South Dakota (43.9%) have below average (57%) shortage levels.

4. Discussion

4.1. Overall justification of the designation process

From table 3 we can see that a county is more likely to be categorized as a shortage area if one or several of the following apply: 1) fewer veterinarians, 2) more livestock, 3) further from veterinary college, 4) more rural. This result is consistent with the result in Table 2, where we show that there are fewer veterinarians whenever the county is farther from a veterinary college and is more rural. Also, results in table 3 show that, upon fixing the number of veterinarians, a unit increase in more valuable livestock increases the odds that a county is listed as a shortage county more than does a unit increase in less valuable livestock. This is consistent with results in table 2, where we find that more valuable livestock require more veterinarian time. As market demand for veterinarian time will be higher for more valuable livestock, a shortage situation is more likely. On the whole, this comparison between results of models I and II suggests to us that the process of designating shortage counties has performed reasonably well.

From table 4 we can see that for over 40% of the states program designation sensitivity exceeds 70%.[12] For another 50%, this sensitivity is between 30% and 70%. Also, from table 5, program designation specificity exceeds 60% for 20% of the states and is between 30% and 70% for about 60%. Upon acknowledging measurement errors in the data and specification errors in the model itself, the results are generally consistent with appropriate shortage designations on the part of VMLRP administrators. Those states with sensitivity or specificity around or below 30% warrant further scrutiny to better establish possible reasons for the poor match between MD and PD procedures.

4.2. Justification of designation process at the state level

At the individual state level, tables 4 and 5 compare the residual from Model MI2 with the shortage designations that Model MII studies.[13] This provides us with a rough way of knowing how many shortage counties in each state have been appropriately designated, and also how many non-shortage counties have been successfully screened out of the program.

In table 4, only three states have sensitivities less than 30%. These states are Arkansas, New Hampshire and New York. For these states, and assuming our model designation is correct, the low sensitivity may arise for two possible reasons. Those states may have a less

[12] The 30% and 70% cutoffs in the table are somewhat arbitrary, being chosen to assist in organizing and interpreting the results.

[13] Replacing residuals from Model MI2 with those from MI1 would generate very similar results. Results are available upon request.

dire veterinarian shortage situation when compared to the nation as a whole. Alternatively, the designated counties in these states may not be the state's real shortage counties. From table 6 we can conclude that the low program designation sensitivities of New Hampshire and New York are because they do not face a very serious veterinarian shortage situation and too many counties have been designated. However, Arkansas has a shortage situation that is about the national average. For it, the low program designation sensitivity could be because the wrong counties have been designated.

California, Delaware, Illinois, Missouri, North Carolina, Rhode Island and Virginia are the seven states where sensitivities are above 90%. Among these, Rhode Island and Delaware are small states with few counties and all the counties in both states were designated. High sensitivity could mean that these two states have fewer FAVs when compared with the nation as a whole, as table 6 suggests. Or it could be due to random error in the model. California, Illinois, Missouri, North Carolina, Virginia are large states with more than 50 counties. So, as far as selecting the true shortage counties goes, we are quite confident that the program has worked well in those states.

In table 5 it can be seen that for some of those high sensitivity states, such as North Carolina, Virginia and West Virginia (87%), the specificities are low. In table 6, we find that these low specificities are accompanied by a more serious shortage situation than the country average. This suggests that although the PD counties are indeed comparative shortage counties, many other shortage counties were omitted. In other words, efficient use of a given program budget would probably involve funding the inclusion of more counties from those states.

Combining tables 4 and 5, we find 12 states that have both sensitivity and specificity above 50%. Those are Arizona, Idaho, Illinois, Iowa, Kansas, Maryland, Michigan, Minnesota, Missouri, Montana, Ohio and Wisconsin. When compared with other states, these states have chosen well in that they chose the appropriate number of shortage counties and also did a fairly good job of identifying the counties to assign as shortage counties.

Table 7 gives us a sense of what the shortage situation might be for those states that do not have a designated private practice shortage area. Our model suggests that Connecticut, where 25% of counties have negative residuals under Model I, is the only state among the ten that does not have a comparative shortage issue. Alabama, Georgia, Massachusetts and New Jersey clearly register as having more dire comparative shortage situations than the nation's average. So our model suggests that any shortage problem is generally more severe for those states that do not have any VMLRP designated private practice shortage counties than for those that do.

5. Conclusion

This paper studies the factors that might affect a county's likelihood of being listed as a shortage area by the VMLRP. To study whether veterinary loan program shortage assignments are justified, we also consider an alternative model, which studies the factors that determine the number of food animal veterinarians in one county. Overall we found that a designated shortage area is typically a county that is characterized by fewer food animal veterinarians, has more livestock, is further from a veterinary college and is more rural. These are consistent with our model of determinants for food animal veterinarian presence and the goals of the VMLRP. In addition to livestock populations as determinants, veterinarians would appear to prefer to locate close to a veterinary college and in less rural areas. Suppose that the program's intent is to promote the presence of food animal veterinarians in proportion to the number of livestock. Suppose too that the extent of non-market social benefits provided in the form of detecting and reporting exotic diseases, outbreaks of controlled endemic diseases, and so on, are in proportion to the number of animals in a county. Then this model suggests that more rural counties and counties distant from veterinary colleges should be targeted.

So as to develop a more detailed picture, for each state we also evaluated the percentage of program designated shortage counties (PD) that our model also designated as shortage counties (MD). Conversely, we evaluated the percentage of program omitted counties (PN) that our model also designated as non-shortage counties (MN). And to develop a better understanding of the reasons behind low sensitivity and specificity levels, we also compare each state's veterinarian shortage situation with the national average. These analyses provided us with a rough sense of whether state designations are consistent with our model. We have also pointed to the states where too few or too many counties have been designated, where the wrong counties may have been designated, and where the designation process seems to have been appropriate. Most strikingly, we suggest that any comparative shortage is generally more severe in states that received no funding under the VMLRP than in states that did receive funding.

References

Blake, A., Sinclair, M.T., Sugiyarto, G. 2003. Quantifying the impact of foot and mouth disease on tourism and the UK economy. Tourism Economics 9(4), 449–465.

Brown, J.P., Silverman, J.D. 1999. The current and future market for veterinarians and veterinary medical services in the United States. Journal of the American Veterinary Medical Association 215(2, July 15), 161–183.

Getz, M. 1997. Veterinary Medicine in Economic Transition. Iowa State University Press, Ames IA.

Greene, W.H. 2003. Econometric Analysis, 5th edn. Prentice Hall, Upper Saddle River, NJ.

Huang, S. 2000. Taiwan's hog industry—3 years after disease outbreak. Agricultural Outlook AGO-275(October), 20-23.

Narver, H.L. 2007. Demographics, moral orientation, and veterinary shortages in food animal and laboratory animal medicine. Journal of the American Veterinary Medical Association 230(12, June 15), 1798–1804.

Prince, J.B., Andrus, D.M., Gwinner, K.P. 2006. Future demand, probable shortages, and strategies for creating a better future in food supply veterinary medicine. Journal of the American Veterinary Medical Association 229(1, July 1), 57–69.

Varian, H.R. 1992. Microeconomic Analysis, 3rd edn. W.W. Norton, New York.

Walker, J.B. 2009. Food animal medicine in crisis. Journal of the American Veterinary Medical Association 235(4), 368–374.

Table 1. County descriptive statistics[a]

Variable	Year	Mean	Std Dev	Minimum	Maximum
Shortage $\in \{0,1\}$	2010	0.210	0.408	0.000	1.00
Veterinarians	2008	2.804	3.676	0.000	49.00
Cattle ($\times 10^4$)	2007	3.134	4.876	0.000	107.2
Sheep ($\times 10^4$)	2007	0.189	0.690	0.000	19.001
Hogs ($\times 10^4$)	2007	2.208	8.871	0.000	228.52
Horses ($\times 10^4$)	2007	0.131	0.150	0.000	3.113
(Human) Population ($\times 10^3$)	2000	89.5	292.5	0.067	9519.3
Distance (miles)	-----	140.95	94.34	0.000	601.9
Veterinary College $\in \{0,1\}$	2010	0.009	0.093	0.000	1.000
Rurality $\in [0,1]$	See text	0.500	0.177	0.000	1.000
Income ($\times \$10^3$)	1999	17.13	3.916	4.963	44.30

[a] Data sources are explained in the text.

Table 2. Parameter estimates for models MI1 and MI2

	MI1		MI2	
Variable	Estimate	p-value	Estimate	p-value
Intercept	0.026	0.8555	-0.714	<0.0001
cattle	0.084	<0.0001	0.080	<0.0001
hogs	0.019	<0.0001	0.018	<0.0001
horses	2.052	<0.0001	2.362	<0.0001
distance	-0.001	<0.0001	-0.001	<0.0001
college	0.589	0.0002	0.698	<0.0001
rurality	-0.921	<0.0001	-----	-----
income	0.047	<0.0001	0.065	<0.0001

Table 3. Parameter estimates for Model MII

Effect	Estimate	Pr >ChiSq	Point Estimate	95% Wald Confidence Limits	
vet	-0.079	0.0001	0.924	0.887	0.961
cattle	0.063	<0.0001	1.065	1.042	1.088
hogs	0.009	0.058	1.009	1	1.019
horses	0.687	0.058	1.989	0.977	4.047
distance	0.004	<0.0001	1.004	1.003	1.005
rurality	1.852	<0.0001	6.375	3.395	11.97

Table 4. VMLRP sensitivity

	Total # counties	PD $\cap$ MD	PD	Sensitivity	$\geq$70%	30-70%	$\leq$30%
Arizona	15	7	10	70.00	x		
Arkansas	75	0	2	0.00			x
California	58	2	2	100	x		
Colorado	64	10	14	71.4	x		
Delaware	3	3	3	100	x		
Florida	66	10	18	55.6		x	
Idaho	44	19	34	55.9		x	
Illinois	102	5	5	100	x		
Indiana	92	20	28	71.4	x		
Iowa	99	3	6	50		x	
Kansas	105	28	32	87.5	x		
Kentucky	120	33	48	68.7		x	
Louisiana	64	10	15	66.7		x	
Maine	16	5	16	31.3		x	
Maryland	23	2	4	50		x	
Michigan	83	39	46	84.8	x		
Minnesota	87	10	18	55.6		x	
Missouri	114	5	5	100	x		
Montana	56	22	44	50		x	
Nebraska	93	14	26	53.8		x	
New Hamp.	10	2	8	25			x
New Mexico	33	12	29	41.4		x	
New York	62	2	8	25			x
N. Carolina	100	23	25	92	x		
N. Dakota	53	3	7	42.9		x	
Ohio	88	6	9	66.7		x	
Oklahoma	77	7	12	58.3		x	
Oregon	36	2	6	33.3		x	
Pennsylvania	67	2	6	33.3		x	
Rhode Island	5	5	5	100	x		
S. Carolina	46	7	9	77.8	x		
S. Dakota	66	29	66	43.9		x	
Texas	254	28	39	71.8	x		
Utah	29	5	6	83.3	x		
Vermont	14	3	9	33.3		x	
Virginia	98	18	19	94.7	x		
W. Virginia	55	7	8	87.5	x		
Wisconsin	72	5	10	50		x	
Count (%)					16 (42)	19 (50)	3 (8)

Table 5. VMLRP specificity

	PN ∩ MN	PN	Specificity	≥60%	30-60%	≤30%
Arizona	3	5	60	x		
Arkansas	23	73	31.5		x	
California	19	56	33.9		x	
Colorado	18	50	36		x	
Delaware	0	0	-----			
Florida	16	48	33.3		x	
Idaho	5	10	50		x	
Illinois	50	97	51.6		x	
Indiana	26	64	40.6		x	
Iowa	62	93	66.7	x		
Kansas	42	73	57.5		x	
Kentucky	17	72	23.6			x
Louisiana	16	49	32.6		x	
Maine	0	0	-----			
Maryland	11	19	57.9		x	
Michigan	19	37	51.3		x	
Minnesota	36	69	52.2		x	
Missouri	57	109	52.3		x	
Montana	8	12	66.7	x		
Nebraska	31	67	46.3		x	
New Hamp.	1	2	50		x	
New Mexico	3	4	75	x		
New York	34	54	62.9	x		
N. Carolina	22	75	29.3			x
N. Dakota	21	46	45.6		x	
Ohio	49	79	62	x		
Oklahoma	28	65	43		x	
Oregon	17	30	56.7		x	
Pennsylvania	34	61	55.7		x	
Rhode Island	0	0	-----			
S. Carolina	6	37	16.2			x
S. Dakota	29	66	43.9		x	
Texas	72	215	33.5		x	
Utah	9	23	39.1		x	
Vermont	4	5	80	x		
Virginia	13	79	16.5			x
W. Virginia	5	47	10.6			x
Wisconsin	47	62	75.8	x		
Count (%)				8 (21)	22 (58)	5 (13)

Table 6. Comparison of state-level shortage situations with national average

	Total	Vet College	# Residuals ≤ 0	Percent	≤ 38%	38-76%	≥ 76%
Arizona	15	No	9	60		x	
Arkansas	75	No	50	66.7		x	
California	58	Yes	39	67.2		x	
Colorado	64	Yes	42	65.6		x	
Delaware	3	No	3	100			x
Florida	66	Yes	42	63.6		x	
Idaho	44	No	24	54.5		x	
Illinois	102	Yes	52	51		x	
Indiana	92	Yes	58	63		x	
Iowa	99	Yes	34	34.3	x		
Kansas	105	Yes	59	56.2		x	
Kentucky	120	No	88	73.3		x	
Louisiana	64	Yes	43	67.2		x	
Maine	16	No	5	31.2	x		
Maryland	23	Yes	10	43.5		x	
Michigan	83	Yes	57	68.7		x	
Minnesota	87	Yes	43	49.4		x	
Missouri	114	Yes	57	50		x	
Montana	56	No	26	46.4		x	
Nebraska	93	No	50	53.8		x	
New Hamp.	10	No	3	30	x		
New Mexico	33	No	13	39.4		x	
New York	62	Yes	22	35.5	x		
N. Carolina	100	Yes	76	76			x
N. Dakota	53	No	28	52.8		x	
Ohio	88	Yes	36	40.9		x	
Oklahoma	77	Yes	44	57.1		x	
Oregon	36	Yes	15	41.7		x	
Pennsylvania	67	Yes	29	43.3		x	
Rhode Island	5	No	5	100			x
S. Carolina	46	No	38	82.6			x
S. Dakota	66	No	29	43.9		x	
Texas	254	Yes	171	67.3		x	
Utah	29	No	19	65.5		x	
Vermont	14	No	4	28.6	x		
Virginia	98	Yes	84	85.7			x
W. Virginia	55	No	49	89.1			x
Wisconsin	72	Yes	20	27.8	x		
Count (%)					6 (16)	26 (68)	6 (16)

Table 7. Comparison of VMLRP omitted state shortage situations with national average

	Total	Vet College	# Residuals ≤ 0	Percent that are ≤ 0
Alabama	67	Yes	56	83.6
Connecticut	8	No	2	25
Georgia	159	Yes	125	78.6
Massachusetts	14	Yes	11	78.6
Mississippi	82	Yes	54	65.9
Nevada	17	No	12	70.6
New Jersey	21	No	20	95.2
Tennessee	95	Yes	69	72.6
Washington	39	Yes	22	56.4
Wyoming	23	No	14	60.9