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Demand for public vs. private livestock services in South India: a double hurdle analysis*

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Abstract: The demand for public and private livestock services was measured by counts of utilisation, in southern peninsular State of India, Tamil Nadu for which the districts of the State were categorized as 'Livestock Developed' (LD) and 'Livestock Under Developed' (LUD) based on initial base line. A double process approach, that envisaged to distinguish the contact process (to access to specific provider or not?) from utilisation (given that the first answer was YES, how much was consumed? That is, whether the contact was by chance or by choice) was used to analyse the factors influencing the demand for public and private livestock services. The hurdle models for animal health care and bovine breeding services were estimated by employing a Probit model and a truncated-at-zero Poisson model. The analysis pointed out that the likelihood of availing services of public system would become low as the distance of the centre from home increased, leading the farmers to choose private animal health care services. The farmer whose dependency on livestock for livelihood is more had lesser probability of contacting public service provider which indirectly indicates the level of their faith on public system. The demand for public animal health care services was less in LD districts, while their demand was more in LUD districts. Contrastingly, the farmers in LD districts preferred AI at public centres, while their counterparts in LUD districts preferred private AI.

Keywords: Livestock services; demand; hurdle model; animal health care; AI, Tamil Nadu.

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Introduction

Livestock services could be either a public good or a private good. A `public good' was said to be non-excludable and non-subtractable (Beynon *et al.*, 1998). Veterinary services displayed varying degrees of public and private good characteristics. Services such as disease surveillance, research without patent upholding and extension targeting a mass were considered a public good and therefore were best provided by public sector, while production and distribution of vaccines and drugs, treatment of individual animals and associated diagnostic support were considered private goods and theoretically were best supplied by the private good (Holden *et al.*, 1996). However, Ahuja *et al.* (2000) stated that a pure public good provided benefits that were non-excludable and non-rival, while the benefits provided by a pure private good were fully excludable and rival. Among the livestock services, clinical diagnosis (or prescription) and breeding were examples of private goods, whereas services such as disease surveillance, quarantine and food hygiene/inspection were public goods. That is, most animal health (clinical treatment, non-compulsory vaccination, sale of veterinary pharmaceutical services) and all animal breeding services (selection and multiplication of improved breeding stock, semen production and insemination) were private goods, and thus they could be efficiently delivered by private providers. The benefits from these services could be exclusively appropriated by the livestock farmers, while other farmers could not benefit from the services at the same time. Similarly, Umali *et al.* (1994) pointed out that purely private and purely public goods occupied opposite ends of the economic spectrum, whereas some animal health services lied between these limits, while a few produced externalities or spill-over effects. These occurred as Pigou (1946) explained, when an individual, rendered (or consumed) some services for which payment was received (or made), coincidentally the other people were also rendered services from which payment could not be exacted.

According to Leonard (1990), animal health services in broader terms included preventing and curing diseases. Preventive services included immunization of animals, eradication or control of carriers or vectors, such as ticks and flies, other disease control measures, such as veterinary surveillance, quarantine, slaughter of infected animals and control of import and export of live animals and inspection and control of animal products to prevent transmission of diseases to humans. However, Umali *et al.* (1994) applied the principles of 'rivalry' and 'excludability' to identify the most appropriate sources of delivery of veterinary services. Also, they emphatically stated that it was necessary to classify each service on the basis of its public and private character, while taking into account any externalities, moral hazard problems, or free rider problems that might accompany the production or consumption of the service to determine the appropriate channel for delivery. Based on these characteristics, they grouped livestock services into two, viz., health and production. Clinical intervention, preventive veterinary services and provision of veterinary inputs formed the health services, while animal breeding, livestock research and extension were production services. Their classification further proceeded such that the clinical diagnosis and treatment, production and distribution of vaccines and

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other veterinary supplies as to be pure private goods and services such as veterinary surveillance, research and extension, on the other hand, to be public goods. Underlying these principles, FAO (1998) suggested the following responsibilities to public and private sectors for delivery of animal health services:

Public sector

Ensuring the health of the national herd including disease surveillance, compliance monitoring, quarantine, quality control of remedies and vaccines, planning for emergencies and reporting to international bodies and neighbouring countries; food safety supervision, import and export inspection and certification according to international standards; regulation, monitoring and support of other partners in animal health care system; accreditation of personnel; creation of an enabling environment for the private sector; and general formulation of livestock development policy.

Private sector

Clinical diagnosis and treatment; production and distribution of remedies and vaccines; artificial insemination (AI); management of herd health and production programmes; marketing livestock and products; and similar services.

Shared responsibility

Disease diagnosis and reporting; compulsory testing; accreditation; tick and fly control; food hygiene and inspection; continuing education and training; diagnostic support; animal welfare; notifiable disease control; disease emergency response; zoonosis control; research and advice and extension.

Even though responsibilities for rendering these livestock services can well be assigned between public and private providers, in India, recognising the importance of livestock to the rural poor and their inability to avail the fully paid livestock services, the Governments in centre and the States have been extending these services at a huge subsidy with their vast veterinary institutional network built-up in the past five decades through many livestock sector promotion schemes to augment livestock production and productivity. In addition, there are co-operatives, NGOs and private entrepreneurs endeavouring these livestock services to a lesser extent. The key focus all through the past planning periods had been on improving the delivery of veterinary services by strengthening the capabilities and coverage of State Animal Husbandry Departments. Thus, the number of State run veterinary institutions grew from about 2000 in 1951 to over 52000 in 2003. However, all these investments aimed mostly at curative services or livestock development schemes including crossbreeding. The share of professionals responsible for disease investigation and control was only 3.5 per cent, supplemented by limited disease prevention role of the animal health service in the field (Ahuja *et al.,* 2000).

Although public sector is believed to be the appropriate means of delivering livestock services, the government generally could not perform, with the efficiency with which it should have done, in practice. Some even now argue that it could be better to privatise these 'public services' (Leonard, 1993). The advocacy for privatization has, however, been tempered by the recognition that in many situations, livestock services require some form of public management and intervention. The availability and quality of these livestock services are therefore unlikely to improve, unless public sector performance is strengthened (Holden *et al.,* 1996). Serious doubts have also been expressed about the desirability and sustainability of public veterinary service provision in India. Even the steering group constituted by the Government of India observed that free veterinary and artificial insemination services have resulted in an infrastructure that is vast and expensive, which the State governments are finding extremely difficult to sustain (GOI, 1996). As Ahuja *et al.* (2000) noted the vicious cycle of limited cost recovery, contributing to budgetary constraints that, in turn, limit the availability and quality of public provision of livestock services, together undercut the tremendous potential of the Indian livestock sector. Hence the veterinary services sector in India consumed 60-80 per cent of the budget allocated to livestock support services, Prabaharan (2000) advocated that the mandate of the Government of India with regard to livestock services should be modified so that the current clinical veterinary and artificial breeding services were moved to private hands and government departments devote their energy to disease prevention and control. According to him, privatisation of veterinary services would also facilitate withdrawal of subsidies, which could then be utilised to develop the infrastructure for further promotion of the livestock sector in India. Policy initiatives aimed at classifying the livestock services (or imposing cost recovery for certain services), which could alleviate these financial difficulties, however, are often deferred by the policy makers on the assumption that the farmers would not be willing to pay for these services. In the light of above scenario, the demand for public and private livestock services was measured by counts of utilisation, in southern peninsular State of India, Tamil Nadu. A double process approach, which envisaged to distinguish the contact process (to access to specific provider or not?) from utilisation (given that the first answer was YES, how much was consumed? That is, whether the contact was by chance or by choice). Although this double process approach had been found to be used extensively to analyse human health care

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Table 1. Demand for animal health care services: estimates of double hurdle model - first stage (Probit estimation)

Explanatory variables	Public services			Private services		
	Coefficient	SE	'Z' value	Coefficient	SE	'Z' value
Age of head of the family	-0.0127 (-0.0009)	0.0130 (0.0011)	-0.98 (-0.83)	-0.0383* (-0.0060)	0.0172 (0.0037)	-2.22 (-1.61)
Mean household education	-0.0352 (-0.0262)	0.2596 (0.0243)	-1.36 (-1.08)	-0.2240 (-0.0352)	0.5297 (0.0850)	0.42 (0.41)
Milk price (Rs./lt.)	0.1112* (0.0083)	0.0477 (0.0049)	2.33 (1.70)	0.5302 (0.0832)	0.5126 (0.0755)	1.03 (1.10)
Quantity of milk sold (litre/day)	-0.0211 (-0.0016)	0.0328 (0.0025)	-0.64 (-0.63)	-0.0681 (-0.0107)	0.0569 (0.0102)	-1.20 (-1.04)
Average visit cost (Rs.)	-0.0733** (-0.0055)	0.0083 (0.0025)	-8.85 (-2.22)	0.0657** (0.0103)	0.0148 (0.0041)	4.43 (2.51)
Acute medical cases	0.9396** (0.0912)	0.2737 (0.0476)	3.43 (1.91)	-3.1245** (-0.7101)	0.8700 (0.1782)	-3.59 (-3.99)
Acute surgical cases	0.5408 (0.0608)	0.4311 (0.0623)	1.25 (0.98)	-1.8476** (-0.5677)	0.5048 (0.1597)	-3.66 (-3.55)
Chronic surgical cases	0.1800 (0.0155)	0.4217 (0.0415)	0.43 (0.37)	-4.4441** (-0.9404)	0.8306 (0.0433)	-5.35 (-21.73)
Obstetrical cases	-1.8386** (-0.0614)	0.5895 (0.0336)	-3.12 (-1.82)	3.0907** (0.1911)	0.6044 (0.0957)	5.11 (2.00)
Gynaecological cases	1.5107** (0.2815)	0.4892 (0.1520)	3.09 (1.85)	-4.4949** (-0.9686)	0.8906 (0.0316)	-5.05 (-30.70)
Distance from nearest public veterinary centre (travel time in minutes)	-0.0657** (-0.0049)	0.0111 (0.0026)	-5.91 (-1.86)	0.0896** (0.0141)	0.0194 (0.0065)	4.61 (2.15)
Value of animal affected (in Rs.'000)	0.0203 (0.0015)	0.0311 (0.0023)	0.65 (0.64)	0.4125** (0.0647)	0.1462 (0.0259)	2.82 (2.50)
Livelihood share of livestock	-1.5997* (-0.1189)	0.7352 (0.0811)	-2.18 (-1.47)	-1.1038 (-0.1732)	1.1135 (0.2176)	-0.99 (-0.80)
Annual household income (Rs.'000)	-0.0061** (-0.0005)	0.0024 (0.0003)	-2.59 (-1.68)	-0.0019 (-0.0003)	0.0035 (0.0006)	-0.53 (0.53)
Veterinary livestock units owned	0.0815 (0.0061)	0.0898 (0.0076)	0.91 (0.80)	-0.0130 (-0.0021)	0.1379 (0.0212)	-0.09 (-0.10)
Possession of crossbred cow/graded buffalo (dummy)	0.0520 (0.0289)	0.3297 (0.0222)	1.58 (1.30)	1.7714 (0.4873)	0.7833 (0.2391)	2.26 (2.04)
Waiting time (minutes)	0.0036 (0.0003)	0.0055 (0.0004)	0.65 (0.67)	0.0013 (0.0002)	0.0110 (0.0017)	0.12 (0.12)
Quality of services	0.5894** (0.0438)	0.1093 (0.0227)	5.39 (1.93)	1.7108** (0.2685)	0.2941 (0.1287)	5.82 (2.09)
District versatility	-0.6962** (-0.0501)	0.2416 (0.0327)	-2.88 (-1.53)	0.3833 (0.0618)	0.4120 (0.0656)	0.93 (0.94)
Constant	2.7091*	1.0644	2.55	-20.9360**	6.1984	-3.38
Number of observations	741	….	….	741	….	….
Wald χ^2 (19)	127.17	….	….	76.25	….	….
Prob > χ^2	0.0000	….	….	0.0000	….	….
Pseudo R^2	0.8574	….	….	0.9585	….	….
Log pseudo likelihood	-134.0695	….	….	-68.6399	….	….

Marginal effects are given in parentheses under coefficients with their respective standard errors (SE) and 'Z' values.
**Significant (P≤ 0.05) ** Highly significant (P≤ 0.01)*

demand (Fabbri & Monfardini, 2002; Noronha & Andrade, 2002), this approach was adopted to analyse the factors influencing demand for animal health care and bovine breeding services in this pioneering study.

Materials and methods

Sampling design

Following Selvakumar *et al.* (2002), the districts of Tamil Nadu state was classified under two categories, viz., 'livestock-developed' (LD) and 'livestock-underdeveloped' (LUD), based on initial baseline developed using the value of livestock output, total rural population and common property resources available for livestock husbandry. A multistage sampling procedure was adopted to select the respondents of the study. In the first stage, as stated above, four districts, two each from LD (Coimbatore and Villupuram districts) and LUD (Thanjavur and Sivagangai districts) areas were selected randomly. In the second stage, 16 blocks, four from each of the four selected districts, were chosen at random and in the third stage, two public veterinary centres from each chosen block were selected using simple random

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Table 2. Demand for animal health care services: estimates of double hurdle model - second stage (Zero truncated Poisson regression)

	Public services			Private services		
Explanatory variables	**Coefficient**	**SE**	**'Z' value**	**Coefficient**	**SE**	**'Z' value**
Age of head of the family	-0.0004 (0.0005)	0.0049 (0.0058)	0.08 (0.08)	0.0043 (0.0024)	0.0080 (0.0045)	0.53 (0.53)
Mean household education	-0.0983 (-0.1176)	0.1072 (0.128)	-0.92 (-0.92)	0.0090 (0.0051)	0.1612 (0.0911)	0.06 (0.06)
Milk price (Rs./lt.)	-0.0213 (-0.0255)	0.0245 (0.0293)	-0.87 (-0.87)	-0.0320 (-0.0181)	0.1120 (0.0632)	-0.29 (-0.29)
Quantity of milk sold (litre/day)	0.0011 (0.0013)	0.0121 (0.015)	0.09 (0.09)	0.0181 (0.0102)	0.0130 (0.0074)	1.40 (1.38)
Average visit cost (Rs.)	-0.0042 (-0.0050)	0.0054 (0.0065)	-0.77 (-0.77)	-0.0033* (-0.0018)	0.0016 (0.0009)	-1.99 (-1.98)
Acute medical cases	1.0482** (1.5817)	0.2236 (0.3892)	4.69 (4.06)	2.4047** (1.9613)	0.7335 (0.7979)	3.28 (2.46)
Acute surgical cases	1.1008** (2.1707)	0.2406 (0.6783)	4.57 (3.20)	2.6501** (6.3625)	0.7465 (4.3357)	3.55 (1.47)
Chronic surgical cases	1.1178** (2.2758)	0.2504 (0.7487)	4.46 (3.04)	2.7237** (7.5659)	0.7853 (5.6512)	3.47 (1.34)
Obstetrical cases	1.4812** (4.0350)	0.5311 (2.7050)	2.79 (1.49)	1.8531* (1.6694)	0.7411 (0.9500)	2.50 (1.76)
Gynaecological cases	1.2004** (2.1002)	0.2231 (0.5007)	5.38 (4.19)	2.4947** (6.0218)	0.8159 (4.8459)	3.06 (1.24)
Distance from nearest public veterinary centre (travel time in min)	-0.0310** (-0.0371)	0.0078 (0.0091)	-3.97 (-4.06)	0.0164* (0.0093)	0.0065 (0.0037)	2.55 (2.51)
Value of animal affected (in Rs.'000)	-0.0388* (-0.0465)	0.0155 (0.0182)	-2.50 (-2.55)	0.0967** (0.0546)	0.0224 (0.0133)	4.32 (4.10)
Livelihood share of livestock	-0.0465 (-0.0556)	0.3369 (0.4032)	-0.14 (-0.14)	0.3610 (0.2039)	0.3821 (0.2153)	0.94 (0.95)
Annual household income (Rs.'000)	-0.0003 (-0.0004)	0.0012 (0.0014)	-0.26 (-0.26)	0.0003 (0.0002)	0.0005 (0.0003)	0.69 (0.69)
Veterinary livestock units owned	-0.0097 (-0.0116)	0.0253 (0.0303)	-0.38 (-0.38)	0.0191 (0.0108)	0.0379 (0.0214)	0.51 (0.50)
Possession of crossbred cow/graded buffalo (dummy)	0.0371 (0.0439)	0.1493 (0.1745)	0.25 (0.25)	-0.1984 (-0.1199)	0.2200 (0.1424)	-0.90 (-0.84)
Waiting time (minutes)	-0.0007 (-0.0008)	0.0024 (0.0028)	-0.28 (-0.28)	0.0002 (0.0001)	0.0028 (0.0016)	0.08 (0.08)
Quality of services	0.3647** (0.4365)	0.0999 (0.1206)	3.65 (3.62)	0.3297** (0.1862)	0.1001 (0.0582)	3.29 (3.20)
District versatility	-0.0425 (-0.0504)	0.1090 (0.1286)	-0.39 (-0.39)	-0.0688 (-0.0390)	0.1530 (0.0874)	-0.45 (-0.45)
Constant	-1.0269	0.9325	-1.10	-6.3350**	1.3843	-4.58
Number of observations	382	….	….	359	….	….
Wald χ^2 (19)	262.36	….	….	228.86	….	….
Prob > χ^2	0.0000	….	….	0.0000	….	….
Pseudo R^2	0.2491	….	….	0.2978	….	….
Log pseudo likelihood	-395.4902	….	….	-269.8073	….	….

Marginal effects are given in parentheses under coefficients with their respective standard errors (SE) and 'Z' values.
** Significant ($P \leq 0.05$) ** Highly significant ($P \leq 0.01$)*

sampling technique. In the fourth stage, 10 farmers were randomly selected amongst those seeking services in each chosen public veterinary centre on the day of interview, thus constituting a total sample size of 320 for the study. The access to and uptake of animal health care and breeding services in the year preceding to the interview was obtained along with socio-economic details of farmers were gathered using pilot tested interview schedule.

Econometric model

The econometric models concerned with discrete counts of veterinary visits and inseminations were found to be appropriate to analyse the factors influencing demand for animal health care and bovine breeding services. The Poisson hurdle model is more appropriate than Ordinary Least Square (OLS) models as it takes into account the discrete nature of the dependent variable and also that there may be two underlying processes that lead to either zeros or positive outcomes (Heineck, 2004). The idea underlying the hurdle formulations is that a binomial

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probability model governs the binary outcome of whether a count variate has a zero or a positive realization. If the realization is positive, the "hurdle is crossed", and the conditional distribution of the positives is governed by a truncated-at zero count data model (Mullahy, 1986). This would also enable to assess whether the service of a specific provider was obtained either by chance or choice.

Following Heineck (2004), the log likelihood function of the process would be

$$\ln L = \ln\left\{\prod_{i\in\Omega_0}(e^{-e^{x_i\beta_1}})\prod_{i\in\Omega_1}(1-e^{-e^{x_i\beta_1}})\prod_{i\in\Omega_1}\frac{e^{y_i x_i\beta_2}}{(e^{e^{x_i\beta_2}}-1)y_i!}\right\}$$

$$=\ln\left\{\sum_{i\in\Omega_0}-e^{x_i\beta_1}+\sum_{i\in\Omega_1}\ln(1-e^{-e^{x_i\beta_1}})\right\}+\left\{\sum_{i\in\Omega_1}y_i x_i\beta_2-\sum_{i\in\Omega_1}\ln(e^{e^{x_i\beta_2}}-1)-\sum_{i\in\Omega_1}\ln(y_i!)\right\}$$

$$=\ln\{L_1(\beta_1)\}+\ln\{L_2(\beta_2)\}$$

Where $\Omega_0=\{i\mid y_i=0\},\Omega_1=\{i\mid y_i\neq 0\}$ and

$$\Omega_0\cup\Omega_1=\{1,2,....,N\}.$$

That is, the log likelihood is the sum of the log likelihood from the binomial probability model, $\ln L_1(\beta_1)$, and the log likelihood of the truncated-at-zero count model, $\ln L_2(\beta_2)$.

Therefore without losing information, the hurdle-model can be maximized by maximizing the two components separately. Here, the hurdle models for animal health care and bovine breeding services were estimated by employing a Probit model and a truncated-at-zero Poisson model. To ease interpretation (Long, 1997), marginal effects were calculated following the Probit and the truncated count data models.

Results and discussion

Demand for livestock services

Determinants of demand for animal health care services: The econometric models of demand for animal health care services used here are those concerned with discrete counts of visits to either public veterinary centres or private livestock service providers. A double process approach, which envisaged to distinguish the contact process (to access to specific provider or not?) from utilisation (given that the first answer was YES, how much was consumed? That is, whether the contact was by chance or by choice). Although this double process approach had been found to be used extensively to analyse human health care demand (Fabbri & Monfardini, 2002; Noronha & Andrade, 2002), this approach was adopted to analyse the factors influencing demand for animal health care and bovine breeding services in this pioneering study. The demand for public and private animal health care services was measured by counts of utilisation, i.e. number of public and private visits consumed by the farmers in the sample.

The results of the maximum likelihood estimation of the two parts of the hurdle model (probit at the first stage and zero truncated poisson at the second stage) are presented in Tables 1 and 2. It appeared that the first stage model (probit) exhibited a better fit than the second stage model (zero truncated poisson).

Notably, the probit stage indicated that the age of the head of the family had a significant negative probability for choosing private services. That means, as age advances the probability for availing animal health care services from private livestock service provider declines. However, higher milk price corresponded to higher chances of contacting public veterinary centres with the probit coefficient being 0.1112. Likewise, as visit cost increased, the coefficient for choosing public veterinary centres decreased significantly (-0.0733), while that of private service increased (0.0657). It becomes imperative to recall that the visit cost in public veterinary centres was mostly due to the labour cost involved for bringing the animals to the centre. Again, it was due to the distance from centre and hence, the results could be justified. As indicated by marginal effects of probit coefficients that the farmers are more likely to choose public veterinary centre for treating acute medical (0.0912) and gynaecological (0.2815) cases compared to the significant negative prospects for private services. Further, initial contact likelihoods for all types of diseases/disorders, except obstetrical cases were significantly negative for private services. The significant negative coefficient of obstetrical cases for public services indicated that the respondents did not favour the use of public veterinary centres for these cases. As expected, the likelihood for availing the services of public system would become low as the distance to the centre from home increased. On the contrary, when the distance to nearest public veterinary centre increased, the farmers are more likely to choose private animal health care services. Higher the value of animal affected corresponded to higher probability of contacting a private service provider. Similarly larger livelihood share of livestock and annual household income were found to reduce the probability of contacting public service provider. Better quality of service was found to increase the demand for both public and private services, especially for private provider even at a higher rate. Importantly, the significant district versatility variable indicated the less probable contact of farmers in LD districts with public delivery system for availing animal health care services. The results of the study are in accordance with the findings of Tambi *et al.* (1999) obtained from the high potential agricultural areas of Kenya.

In the second stage, where positive counts alone were considered in the zero truncated poisson

Table 3. Demand for bovine breeding services: estimates of double hurdle model - first stage (Probit estimation)

Explanatory variables	Public services			Private services		
	Coefficient	SE	'Z' value	Coefficient	SE	'Z' value
Milk price (Rs. per litre)	0.0736 (0.0283)	0.0728 (0.0280)	1.01 (1.01)	0.6986** (0.0658)	0.1154 (0.0147)	6.06 (4.47)
Quantity of milk sold (litre/day)	-0.0583** (-0.0224)	0.0140 (0.0054)	-4.15 (-4.15)	0.1522** (0.0143)	0.0250 (0.0029)	6.09 (4.90)
Average insemination cost (Rs.)	-0.0799** (-0.0307)	0.0121 (0.0046)	-6.60 (-6.69)	0.1007** (0.0095)	0.0122 (0.0020)	8.24 (4.87)
Success of insemination	-0.1848 (-0.0706)	0.1165 (0.0444)	-1.59 (-1.59)	0.5377** (0.0484)	0.1926 (0.0167)	2.79 (2.90)
Species of animal	0.1288 (0.0500)	0.1656 (0.0648)	0.78 (0.77)	0.5030 (0.0351)	0.2901 (0.0167)	1.73 (2.11)
Distance from nearest public veterinary centre (travel time in minutes)	0.0023 (0.0009)	0.0040 (0.0015)	0.59 (0.59)	0.0184** (0.0017)	0.0059 (0.0005)	3.13 (3.28)
Mean household education	-0.0036 (-0.0014)	0.1320 (0.0507)	-0.03 (-0.03)	-0.2102 (-0.0198)	0.2101 (0.0188)	-1.00 (-1.05)
Veterinary livestock units owned	-0.0207 (-0.0080)	0.0356 (0.0137)	-0.58 (-0.58)	-0.1705** (-0.0161)	0.0570 (0.0053)	-2.99 (-3.04)
No. of crossbred cows owned	0.1649** (0.0633)	0.0620 (0.0239)	2.66 (2.65)	-0.0146 (-0.0014)	0.1029 (0.0098)	-0.14 (-0.14)
No. of graded buffaloes owned	-0.0864 (-0.0332)	0.0805 (0.0309)	-1.07 (-1.08)	-0.5844** (-0.0551)	0.1429 (0.0174)	-4.09 (-3.16)
Value of animal inseminated (in Rs.'000)	0.0000 (0.0000)	0.0000 (0.0000)	0.75 (0.75)	0.0000 (0.0000)	0.0000 (0.0000)	1.05 (1.08)
Annual household income (Rs.'000)	0.0002 (0.0001)	0.0008 (0.000)	0.31 (0.31)	-0.0008 (-0.0001)	0.0013 (0.0001)	-0.67 (-0.65)
District versatility	0.2971* (0.1141)	0.1256 (0.0481)	2.37 (2.37)	-1.2935** (-0.1490)	0.2588 (0.0309)	-5.00 (-4.82)
Constant	2.4351**	0.8649	2.82	-10.4140**	1.2409	-8.39
Number of observations	632	….	….	632	….	….
Wald χ^2 (13)	118.62	….	….	148.22	….	….
Prob > χ^2	0.0000	….	….	0.0000	….	….
Pseudo R^2	0.4013	….	….	0.2495	….	….
Log pseudo likelihood	-274.5529	….	….	-319.2912	….	….

Marginal effects are given in parentheses under coefficients with their respective standard errors (SE) and 'Z' values.
** Significant (P≤ 0.05) ** Highly significant (P≤ 0.01)*

regression, the probabilities of many regressors had been changed. This could be due to the reason that the farmers would initially choose some sort of treatment for their animals, irrespective of inherent factors with the delivery system. However, for frequent visits to be made, farmers considered many factors including the ones that are relevant to animal diseases.

The regressor, average visit cost turned to be negatively significant (p≤0.05) for private services, which showed that the demand would be narrowed down as the average visit cost of private services increased. That is, initially the cost was not considered as an inhibiting factor for a single visit, but when it became multiple visits, the cost started affecting negatively the demand for private animal health care services. Surprisingly, the marginal effects for choosing private services were more for different types of cases, such as acute medical (1.9613), acute surgical (6.3625), chronic surgical (7.5659), obstetrical (1.6694) and gynaecological (6.0218) cases as compared to chronic medical cases, which could be due to the satisfaction the farmers attained in their previous experience. The distance exhibited a significant and negative probability for choosing public services. That is, as the distance to the nearest public veterinary centre increased, the likelihood for choosing private livestock services was more compared to the negative effect exerted on public delivery system. In the same way, as the value of animal affected increased, the demand for private services was significantly (p≤0.01) more vis-à-vis negative attitude exhibited towards public delivery system. More importantly, when the quality of services improved, the farmers tended to prefer public delivery system than private services for obvious reasons. Therefore, efforts to improve these quality attributes in public delivery system would help to promote confidence among farmers.

Determinants of demand for bovine breeding services: The demand for public and private bovine breeding services was measured by counts of insemination services availed by the farmers. The results of the maximum likelihood estimation of the two parts of the hurdle model (probit at the first stage and zero truncated poisson at the second stage) are presented

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Table 4. Demand for bovine breeding services: estimates of double hurdle model - second stage (Zero truncated Poisson regression)

Explanatory variables	Public services			Private services		
	Coefficient	SE	'Z' value	Coefficient	SE	'Z' value
Milk price (Rs.per litre)	-0.0553 (-0.0074)	0.0871 (0.0117)	-0.64 (-0.63)	0.6737** (0.0133)	0.1971 (0.0033)	3.42 (3.97)
Quantity of milk sold (litre/day)	0.0162 (0.0022)	0.0174 (0.0023)	0.93 (0.93)	0.0377** (0.0007)	0.0130 (0.0002)	2.91 (3.06)
Average insemination cost (Rs.)	-0.1250** (-0.0167)	0.0102 (0.0034)	-12.24 (-4.95)	-0.0109* (-0.0002)	0.0043 (0.0001)	-2.52 (-2.38)
Success of insemination	2.0148** (0.2836)	0.4273 (0.0425)	4.72 (6.67)	16.3137** (0.6261)	0.2682 (0.0913)	60.82 (6.86)
Species of animal	-0.5929 (-0.1021)	0.3295 (0.0800)	-1.80 (-1.28)	0.5122 (0.0083)	0.4638 (0.0062)	1.10 (1.34)
Distance from nearest public veterinary centre (travel time in minutes)	-0.0001 (-0.0000)	0.0032 (0.0004)	-0.04 (-0.04)	0.0072 (0.0001)	0.0073 (0.0001)	0.99 (0.99)
Mean household education	-0.3324 (-0.0444)	0.1808 (0.0243)	-1.84 (-1.83)	-0.2299 (-0.0045)	0.2021 (0.0041)	-1.14 (-1.11)
Veterinary livestock units owned	-0.0732* (-0.0098)	0.0376 (0.0053)	-1.95 (-1.85)	0.0566 (0.0011)	0.0725 (0.0014)	0.78 (0.79)
No. of crossbred cows owned	0.1189 (0.0159)	0.0778 (0.0106)	1.53 (1.50)	0.2884** (0.0057)	0.0995 (0.0019)	2.90 (2.93)
No. of graded buffaloes owned	0.4681** (0.0625)	0.1491 (0.0225)	3.14 (2.78)	-0.2987 (-0.0059)	0.3476 (0.0069)	-0.86 (-0.85)
Value of animal inseminated (in Rs.'000)	0.0001* (0.0000)	0.0000 (0.0000)	2.16 (2.26)	0.0002** (0.0000)	0.0000 (0.0000)	5.68 (6.78)
Annual household income (Rs.'000)	-0.0009 (-0.0001)	0.0008 (0.000)	-1.18 (-1.18)	0.0002 (0.0000)	0.0002 (0.0000)	1.04 (1.00)
District versatility	0.2607 (0.0338)	0.2031 (0.0272)	1.28 (1.24)	-0.0121 (-0.0002)	0.2327 (0.0045)	-0.05 (-0.05)
Constant	1.2809	1.1419	1.12	-12.4607**	1.5040	-8.29
Number of observations	379	....	....	253	....	....
Wald χ^2 (13)	311.85	....	....	126.45	....	....
Prob > χ^2	0.0000	....	....	0.0000	....	....
Pseudo R^2	0.5031	....	....	0.3202	....	....
Log pseudo likelihood	-146.7268	....	....	-147.0984	....	....

Marginal effects are given in parentheses under coefficients with their respective standard errors (SE) and 'Z' values.
** Significant (P≤ 0.05)** Highly significant (P≤ 0.01)*

in Tables 3 & 4. As seen in the models for animal health care services, the first stage of these models were also found to be fitted well compared to the second stage (zero truncated poisson).

The probit model in the first stage indicated that milk price had a significant (p≤0.01) effect on deciding the private insemination services. This means that as the milk price increased, the demand for private artificial inseminations also increased. Likewise, the quantity of daily milk sales also played a significant role in choosing the source of insemination. Specifically, an increase in the quantum of daily milk sales would significantly reduce the likelihood of availing insemination at public veterinary centres (-0.0583), thus boosting the chance of availing private insemination (0.1522). Although average cost of insemination tended to boost the chance for private insemination, it significantly reduced the chance of public services. The reason could be that the farmers ought to think that the semen straws used in private were to be of higher quality, and so they were ready to accept even higher cost. However for the negative probit coefficient towards public delivery system, the obvious reason was the labour charges incurred for taking the animals to the centre. Success of insemination [measured in terms of a proxy; pregnant (1) and non-pregnant (0)] was found to have a higher likelihood towards privately performed breeding services. As found in animal health care services, distance to the public veterinary centre had significantly improved the demand for private bovine breeding services (0.0184), while veterinary livestock units owned had significantly reduced the chance of preferring private services. Similarly, number of crossbred cows owned had been found significantly improving the chance of availing public services. That is, the farmers tended to prefer public delivery system over private, as the number of crossbred cows was more in the herd. Likewise, as the number of graded buffaloes to the herd increased, it significantly (p≤0.01) lessened the chance of availing private insemination services. In general, the buffaloes were mostly inseminated at public veterinary centres, as they could not be restrained in other places for AI. It is imperative

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to note that the demand for AI at public veterinary centre was found to be more among the farmers in LD districts, while the farmers in LUD districts tended to prefer private AI.

The second stage, zero truncated poisson regression model, indicated that the milk price had a significant and positive influence on the use of private AI. As milk price increased, the marginal probability (0.0133) of using private insemination services also increased. Quantity of milk sold also exerted a similar effect on availing private insemination services. However, the average cost of insemination had a significant negative effect towards public services (-0.0167) than towards private insemination (-0.0002). The results did not agree with the findings of Ahuja *et al.* (2000), who found that the price was not an important determinant of demand for bovine breeding in Gujarat, Rajasthan and Kerala. On the contrary, the regressor, success of insemination had a significantly higher probability towards private services than public insemination services. Differing from probit results, as the number of crossbred cows owned increased with the farmers, they tended to favour private artificial insemination. The results showed that the frequency of visits would be more, if more number of crossbreds were owned. The discussion with farmers also revealed that those who owned more number of crossbred cows established a good proximity with private service provider and proceeded for multiple visits. However, the reverse was true in case of more number of graded buffaloes owned. This could be due to the fact that the buffaloes could not be restrained easily outside, where no drives (trevis) were available. The analysis also indicated that the VLUs had a significant and negative effect on the use of public insemination services. This could be due to the fact that when the VLU owned increased; the farmers could not bring their bovines for public centres, as they had to manage other animals also.

Although value of animals inseminated was found to be significant for both public and private insemination services, the probability for choosing private insemination was more and increased with the values of animals inseminated. Notably, the district versatility factor did not have any significant effect on frequency of visits made both for public and private insemination services.

Conclusion

The analysis indicated that the likelihood of availing services of public system would become low as the distance of the centre from home increased, leading the farmers to choose private animal health care services. The farmer whose dependency on livestock for livelihood is more had lesser probability of contacting public service provider which indirectly indicates the level of their faith on public system. However, better quality of service was found to increase the demand for both public and private services, especially for private provider even at a higher rate. Importantly, the significant district versatility variable indicated the less probable contact of farmers in LD districts for availing public animal health care services. Although average cost of insemination tended to boost the chance for private AI, it significantly reduced the chance of public services. Success of insemination [measured in terms of a proxy; pregnant (1) and non-pregnant (0)] was found to have a higher likelihood towards privately performed breeding services. It is imperative to note that the demand for AI at public veterinary centre was found to be more among the farmers in LD districts, while the farmers in LUD districts tended to prefer private AI.

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