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Cost-benefit analysis of vaccination against goat pox

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ABSTRACT

The present study has quantified the economic impact of control of goat pox disease in India using a vaccine developed against the disease at ICAR-IVRI, applying an economic surplus model. The findings of the study have revealed significant benefits of Goat pox control programme using the vaccine. The potential change in total surplus, as a result of Goat pox control programme was ₹ 2.42 crore/annum. The change in total economic surplus and research and delivery cost were projected from 1999 (year of the start of the project) to 2030 after adjusting for the above adoption pattern. Using a long run discount rate of 7.50%, the benefits were compared to research and delivery cost and the NPV, IRR and BCR were calculated. The NPV, IRR and BCR of Goat pox control programme were ₹ 9.25 billion, 38% and 19: 1, respectively. Sensitivity analysis revealed that the benefits are most sensitive to assumptions regarding lower degree of immunity offered by the vaccine and higher discount rate.

Keywords: Economic surplus, Small ruminants, Vaccine goat pox

Small ruminants, in India, are mostly associated with the rural poor. Over 65% of population in India lives in rural areas, and are mostly dependent on agriculture for their livelihood. However, about 10–12% of the rural families are landless and 80% of the land holders are marginal and small farmers, owning less than 2 ha land (GoI 2013). Managerial advantages like low input requirement, less initial capital investment, early sexual maturity, higher prolificacy and ease in marketing, makes small ruminant rearing a remunerative enterprise for the resource poor farmers (Kumar 2010). Small ruminants also act as cash buffer, reduces the risk of crop failure in mixed farming and provide tremendous potential for improving the food, employment and livelihood security of rural people (Ramesh *et al.* 2012, Singh *et al.* 2013). The role of small ruminants in meat supply is growing in India as meat of these species are still the most preferred (Shivakumara *et al.* 2017).

India ranks 2nd in goat population and 3rd in sheep population in the world. The country has 43 registered sheep breeds and 34 registered goat breeds (NBAGR 2018). Goat rearing is one of the important source of livelihood particularly for landless labourers and marginal farmers across the country (Mohan *et al.* 2012). In plains of India, goat is the major supplier of meat. In India, the per capita availability is far below the requirement (Devi *et al.* 2014).

Goats are largely kept by the small landholders because of low initial investment requirement and operational costs. They are assets that can easily be liquidized for cash in times of need, since they are meat animals with a convenient size for slaughter (Hossain *et al.* 2004). Diseases in particular pox adversely affect the productivity of the small ruminants in the country. Pox is endemic in India and several outbreaks have been reported regularly from almost all the states. Pox disease is responsible for high rate of mortality (50%) and infection (80–100%), leading to heavy economic losses to small ruminant farming community. It takes about 6 years for a flock to recover from a pox outbreak.

A Vero cell-attenuated goat pox virus vaccine using Uttarkashi isolate was developed by ICAR-Indian Veterinary Research Institute, Izatnagar (ICAR-IVRI), amenable for large scale production and application as per international norms. The vaccine has been found potent and safe when tested in animals under laboratory trials and field trials (over 1 lakh doses tested). Production of small quantity (1 ml) of virus may yield 10,000 doses of vaccine. Therefore, scalability of the vaccine and downstream processing is very simple and easy. The vaccine is being marketed since 2016 and the technology has been transferred to four different vaccine producing sectors. The vaccine produces long lasting immunity with the protection offered up to 4 years. Therefore, use of a single dose of vaccine in goat will be sufficient for immunization during the complete productive life of the animal. The control of this disease is vital for small ruminant productivity and disease control programme, if initiated, may lead to eradication of the disease in the country leading to improved productivity, which in turn, is important for livelihood security of the poor farmers.

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The present study attempts to quantify the potential impact of the vaccine in India using an economic surplus model.

MATERIALS AND METHODS

An economic surplus model (Alston *et al.* 1995) was used to measure the potential benefits of goat pox control as well as the potential benefits of and returns to research aimed at alleviating the disease. A static model of closed economy was used in the analysis. Assuming a closed economy implies that the adoption of a cost-reducing or yield enhancing technology increases the supply of a commodity such as meat. The increase in supply of goat meat as a result of control programme in the domestic market will reduce both the cost of the commodity to consumers and the price to produce INR The simple case of linear supply and demand curves with parallel shifts was chosen.

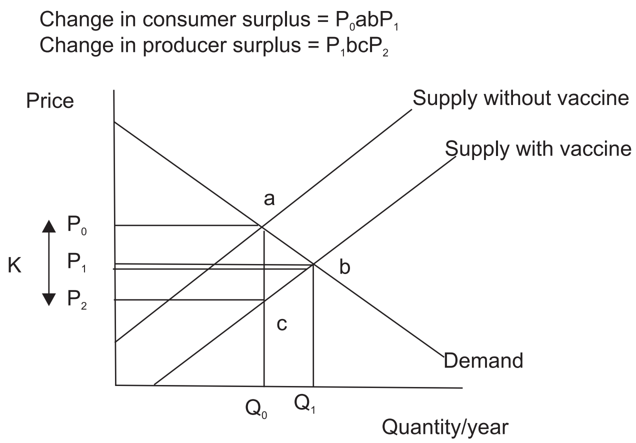

Fig. 1. Measuring change in total surplus

In Fig. 1, gross annual research benefits are measured by the area between P_0abcP_2 beneath the demand curve. This area represents the total increase in economic welfare (change in total surplus) and comprises both the changes in producer (P_0abP_1) and consumer surplus (P_1bcP_2) resulting from the shift in supply. Consumers are better off because they consume more at a lower price. Although, producers are receiving a lower price for their meat, they are able to sell more, so their benefits increase. The algebraic derivations of these surpluses are shown in Table 1. It is assumed that the vaccine will be easily accessible at a relatively low cost to the producer and the treatment required in case of incidence of goat pox will be reduced.

Measuring supply and demand elasticities: Demand and supply elasticities were both assumed as 1. The authors could not come across estimate of supply elasticity for goat meat through literature review in the Indian context. In literature available on economic surplus, earlier authors have suggested using unitary value of elasticities wherever such estimates are not available (Jones *et al.* 2006). Montes *et al.* (2008) had also used a supply elasticity of 1.0 for their assessment of impact of internal parasite control programme

Table 1. Calculations of change in total surplus due to PPR vaccine

Parameter	Formula
Elasticity of supply	$\varepsilon = [(\delta Q_s/Q_s) / (\delta P_s/P_s)]$
Elasticity of demand	$\eta = [(\delta Q_d/Q_d) / (\delta P_d/P_d)]$
Gross proportionate productivity gain/head (%)	$E(Y) = (Q_1 - Q_0)/Q_0$
Gross cost change/tonne (%)	$C = E(Y)/\varepsilon$
Input cost change/head (%)	$E(c)$
Input cost change/tonne (%)	$i = E(c)/(1+E(Y))$
Net proportionate reduction in cost/tonne output (%)	$k = C - i$ $k' = k \times A^*$
Price (₹/tonne)	P
Quantity (tonnes)	Q_0
Relative reduction in price	$Z = k \times \varepsilon/(\varepsilon + \eta)$
Change in total surplus (₹)	$K \times P \times Q_0\ (1 + (0.5 \times Z \times \eta))$
Change in consumer surplus (₹)	$Z \times P \times Q_0\ (1 + (0.5 \times Z \times \eta))$
Change in producer surplus (₹)	$(k - Z) \times P \times Q_0\ (1 + (0.5 \times Z \times \eta))$

*A is adoption rate.

in Philippines. Estimates of demand elasticities for livestock food products are available in the Indian context (Kumar *et al.* 2009). However, although own price elasticity was calculated for milk, combined elasticity was computed for meat, egg and fish (-0.821). As such in this study, demand elasticity for goat meat was also considered as 1.

Measuring gross proportionate productivity gain per head (*E*(*Y*)): To measure gross proportionate productivity gain per head (goat), it was assumed that cent per cent vaccination of small ruminant population will remove the incidence of the disease. If disease induced productivity loss (both due to morbidity and mortality) is mitigated, then the avoided loss can be imputed as gain in productivity due to the technology (vaccine). To have an estimate of this avoided productivity loss, it is first required to have an estimate of number of cases and deaths due to goat pox. Literature on prevalence of goat pox in the Indian context is scant. The study thus relied on a primary survey to ascertain the morbidity and mortality rates of goat pox. Concentration of goats is mainly in the states of West Bengal, Rajasthan, Uttar Pradesh, Maharashtra, Bihar and Madhya Pradesh. A survey was conducted in three states, viz. Uttar Pradesh, Rajasthan and Haryana. Stratified multistage sampling technique was used for selecting the herds (ultimate sampling units). The state-wise number of goats surveyed are presented in Table 2. Annexure 1 presents the state and district-wise number of goats surveyed.

Table 2. State-wise number of goats covered in the survey

State	No. of goats
Uttar Pradesh	2,607
Haryana	1,751
Rajasthan	1,667

Identification of the disease is the most crucial issue in any survey on livestock disease incidence. For identifying the incidence of goat pox, the method of indirect visual surveillance as given in FAO Animal Health Manual (Roder and Obi 1997) and participatory disease surveillance as reported by earlier authors (Hussain *et al.* 2008, Jost *et al.* 2010, Kihu *et al.* 2015) were adapted. This mostly consisted of relying on farmers' recall to gain details of diseases that affected their herds. Focused group discussions were held in each selected village to understand how farmers identify different diseases that affect their animals and then rank these diseases in order of their importance. Then personal interviews were held with each selected farmer to collect detailed information on the disease, supported by an extensive checklist for disease identification based on clinical symptoms and photographs. The reference period for collecting the data was June 2015 to December 2015. Table 3 elicits the morbidity and mortality rates as observed in the sample survey carried out in this study. Imputing these rates on the goat population of the country (19th Livestock Census 2012), the number of cases and deaths were worked out as 38, 38, 913 and 5, 13, 657, respectively. Assuming a live body weight loss of 20% for infected goats and average yield 11.01 kg for each goat (BAHS 2014), the gross productivity gain (in terms of live body weight) was worked out as 9.38% per head.

Table 3. Morbidity and mortality rates

State	Total goats	Morbidity	Mortality	Morbidity rate (%)	Mortality (%)
Haryana	1,751	132	0	7.54	0.00
UP	2,607	32	16	1.23	0.62
Rajasthan	1,667	7	7	0.42	0.42
Total	6,025	171	23	2.84	0.38

Measuring input cost change per head ($E(c)$): The input cost change was accounted for by adding the cost of vaccine and vaccination to the cost of rearing a goat/sheep. Production cost of vaccine per dose as obtained from manufacturers was INR 1.00. Cost of vaccination (INR 4.50/vaccination dose) was arrived at based upon expert opinion. This per unit cost of vaccine and vaccination (INR 5.50) was then imputed upon the population of goat in the country. Cost of rearing a goat per annum as given in various published works vary, ranging from INR 226 (Kumar *et al.* 2010) to INR 750 (Singh *et al.* 2013), depending upon the study area. For this study to find the proportionate change in per head cost, cost per annum for rearing a goat was assumed as INR 500. The input cost change as a result of vaccination was then obtained as a proportion of this cost of rearing of small ruminant.

Measuring net proportionate reduction in cost (k): The research-induced supply-shift parameter, k, is the single most important parameter influencing total economic surplus results from unit cost reductions (Alene *et al.* 2009). k was estimated as per the formula given in Table 1. k' was estimated by multiplying k with A, the adoption rate of the vaccine. k' was finally used in the economic surplus model.

Table 4. Sources and values of economic surplus input data

Parameter	Goat	Source of information
Elasticity of supply (ε)	1	Assumed (Montes *et al.* 2008)
Elasticity of demand (η)	−1	Assumed (Montes *et al.* 2008)
Gross proportionate productivity gain/head (%) [(E(Y)]	9.38	Computed
Gross cost change/tonne (%) (C)	9.38	Formula
Input cost change/head (%) [E(c)]	1.00	Computed
Input cost change/tonne (%) (i)	1.37	Formula
Net proportionate reduction in cost/tonne output (%) (k)	8.01	Formula
Price (₹/kg) (P)	340	Field survey

Table 4 presents the sources and values of parameters to be used in the economic surplus model. Gross annual research benefits, measured by the change in total surplus, represent the maximum potential benefits to society from a new technology. To estimate the likely net benefits accruing to current research, however, some uncertainties will be considered: the uncertainty surrounding if and when the research may be successful, the uncertainty in the proportion of farmers who will adopt the vaccine and the rate at which they adopt. The economic surplus model accounts for such uncertainties by the use of probabilities. It will thus be necessary to estimate the most probable research and

Table 5. Summary of assumptions for baseline analysis of potential returns to Goat pox vaccine research

Research period (Starting from 1999–2007)	:	8 years
Research costs	:	Total ₹ 2, 17, 27, 754 for 8 years (1999–2007) deflated at 2016 prices
Adoption period	:	Vaccine marketed since 2016
Adoption rate	:	3% at present at All-India level (40 Lakh doses sold at All-India level in 2016)
Ceiling adoption rate	:	Not covered under national control programme of DAHDF. By 2030, adoption is assumed to be restricted to 50%. In case brought under national control programme, adoption rate is assumed to be 80% by 2030.
Discount rate	:	7.5%
Cost of vaccine and vaccination*	:	₹ 5.5/dose

*Production cost of vaccine per dose as obtained from manufacturers is ₹ 1/dose. Cost of vaccination based upon expert opinion was assumed as ₹ 4.5/animal).

adoption lags, the probability of research success, and the probable ceiling level of adoption. Table 5 summarizes the assumptions for baseline analysis of returns to goat pox vaccination.

Using the change in total economic surpluses as benefits and the research and delivery cost as costs of the control programme, following economic criteria were calculated to ascertain the economic feasibility of the vaccination process.

Net Present Value (NPV)

$$NPV=\sum_{t=1}^{n} B_n/(1+i)^n - \sum_{t=1}^{n} C_n/(1+i)^n$$

Benefit Cost Ratio (BCR)

$$BCR=\frac{\sum_{t=1}^{n} B_n/(1+i)^n}{\sum_{t=1}^{n} C_n/(1+i)^n}$$

Internal Rate of Return (IRR)

IRR is the discount rate which makes NPV equal to zero. This is the maximum interest rate which a programme intervention (in this case disease control through vaccination) can pay for the use of capital resource in it.

Thus, when $\sum_{t=1}^{n} \frac{(B_n - C_n)}{(1+r)^n} = 0$ the value of r becomes the IRR.

where B_n, Year-wise benefits; C_n, Year-wise costs; n, Number of years (t=1 to n); i, Discount rate.

The criteria on the basis of which a project is considered is to be economically feasible is that the IRR should be more than the market rate of interest.

RESULTS AND DISCUSSION

The potential change in total surplus, as a result of Goat pox control programme is INR 2.42 billion per annum. Yield increase, as a result of vaccination, mainly occurs by avoidance of incidence of the disease and deaths caused due to it. Increase in yield in turn results in reduction in cost per kg of output. The estimated net proportionate reduction in cost per tonne of output, as result of vaccination, was estimated at 8.01%. The higher yield as a result of control programme, increases the supply of goat meat. Both consumers and producers may benefit from this change as the prices reduce for the consumers and the yield gain reduces cost for the producers and they can compensate for lower price by selling offering quantity in the market. In this case of goat pox control by vaccination, as unitary elasticities were assumed both for demand and supply, benefits to producers and consumers are same. Kristjanson *et al.* (1999) had however reported higher potential benefits to producers than those to consumers as result of trypanosomiasis control in African animals in case of meat production.

Impact of vaccination against Goat pox: The change in economic surplus and the research and delivery cost were projected to 2030. The vaccine is being marketed since 2016. As per the number of doses sold, the present level of vaccination is 3%. Overall, as opined by experts, the ceiling level of 50% vaccination will be reached by 2025. The vaccination coverage by 2030 will be lower in comparison to diseases like FMD, CSF and PPR, which have been brought under national control strategies of Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers' Welfare, Government of India. The change in total economic surplus and research and delivery cost were projected from 1999 (year of the start of the project) to 2030 after adjusting for the above adoption pattern. Using a long run discount rate of 7.50%, the benefits were compared to research and delivery cost and the NPV, IRR and BCR were calculated. The NPV, IRR and BCR of Goat pox control programme were INR 9.25 billion, 38% and 19:1, respectively. Thus, from the point of view of these economic criteria, investment in control of goat pox by vaccination is economically feasible.

Literature on application of economic surplus model in impact assessment pertaining to animal health is scant. Montes *et al.* (2008) had reported a BCR of 10.4: 1 while assessing the impact of control programme of internal parasites in goats in Philippines. In the Indian context, Bardhan *et al.* (2017) had applied the economic surplus model to estimate the economic feasibility of control of *peste-des-petits ruminants* (PPR) through vaccination. The authors reported a BCR of 123: 1 and an IRR of 119%. PPR is highly endemic in the country and the prevalence is significantly higher than goat pox. For instance, in the above-mentioned study by Bardhan *et al.* (2017), the authors had observed morbidity and mortality rates of 11.51% and 4.36% in goats and 5.35% and 2.77% in sheep, respectively. Because of the higher incidence of PPR in small ruminants, the benefits expected to be derived from PPR control programme - in terms of potential yield increase - are expected to be much higher than in case of goat pox.

Sensitivity analysis: There can be variations in many of the assumptions while calculating the returns to Goat control programme, especially when the benefits and costs are projected in distant future. In this context, sensitivity analysis was carried out to ascertain the effect of changes in several of the baseline assumptions. The results of these analyses are presented in Table 6. In the first scenario (conservative), it is assumed that the rate at which vaccination increases per annum is lower by 5% as compared to the baseline assumption. Further, in this scenario, it is also assumed that ceiling vaccination level will remain at 30%. Given this scenario, NPV decreased by INR 3.00 billion. IRR, under these assumptions decreased to 36%. In an optimistic scenario, it was assumed that the rate of increase in vaccination per annum was 5% more and the adoption level will reach 70% vaccination target. In this case, the NPV increased by INR 1.57 billion, while IRR increased to 39%. The discount rate chosen for the analysis was 7.5%. In a different scenario, a higher discount rate (10%) was adopted to ascertain the effect of

Table 6. Sensitivity of estimated vaccine impact to assumptions

Assumption	NPV (₹ in crores)	IRR (%)	BCR
Conservative estimates regarding adoption			
i. Adoption rate declines by 5% per annum as compared to baseline assumption	625.54 (–300.06)	36.00	18.74
ii. Ceiling adoption level is 30%			
Optimistic estimates regarding adoption			
i. Adoption rate increases by 5% per annum as compared to baseline assumption	1082.97 (+157.37)	39.00	19.13
ii. Ceiling adoption level of 70%			
Higher discount rate (10%)	485.88 (–439.72)	35.00	18.71
Vaccine affording 80% immunity	729.26 (–196.34)	36.00	15.20
Higher demand elasticity (η=2)	923.11 (–2.49)	38.00	18.98
Cost per vaccination increases by 50%	900.58 (–25.02)	38.00	12.79

*Figures in parentheses indicate changes in NPV from the baseline values.

higher discount rate on the benefits. It is assumed that high discount rate discourage investments with long term benefits (Kristjanson *et al.* 1999). At this higher discount rate, NPV declined by INR 4.40 billion. IRR, under this assumption of higher discount rate, reduced to 35%. In the pessimistic scenario, assuming that the vaccine would provide immunity to 80% of animals, the benefits of the PPR control programme decreased by INR 1.96 billion. Under this lower immunity assumption, IRR and BCR declined to 36% and 15: 1, respectively. Under the assumption that the cost of vaccination increases by 50%, NPV declined by INR 0.25 billion, while IRR and BCR declined to 38% and 13: 1, respectively. Under the assumption of higher demand elasticity (s=2), to account for possibility of increased price sensitivity, the NPV decreased by a meager INR 20 million.

The present study has attempted to quantify the economic impact of control of goat pox disease in India using a vaccine developed against the disease at ICAR-IVRI, applying an economic surplus model. The findings of the study have revealed significant benefits of Goat pox control programme using the vaccine. Sensitivity analysis revealed that the benefits are most sensitive to assumptions regarding lower degree of immunity offered by the vaccine and higher discount rate. The changes in results of the model, based on baseline assumption, was negligible for changes in assumption in regard to adoption rates and higher demand elasticity. Control of diseases involves optimization of resource allocation decisions at national scale because the inputs it uses are scarce and have alternative uses. In this regard, it is expected that the findings of the study would provide valuable inputs towards formulating various livestock health intervention efforts.

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