# **Appendix**

Hessian Matrix =

To ensure a maximum, , , and

if , i.e., vaccinations reduce losses at a decreasing rate.

if

where , i.e., introductions increase losses at increasing rate and , i.e., the marginal value of vaccinations increases with increase in introductions.

to ensure a maximum.

Table A1: The Effect of Vaccinations on Livestock Disease Death (when *Vaccinations* is a dichotomous variable) – Marginal Effects from Zero-Inflated Poisson Regression

|  |  |  |  |
| --- | --- | --- | --- |
|  | Cattle Disease Death | Goat Disease Death | Sheep Disease Death |
| *Vaccinations (Yes/No)a* | -0.358  (1.60) | -6.59\*\*  (3.04) | -6.45\*\*  (2.89) |
| *Cattle* | 0.947\*\*\*  (0.122) | 0.010  (0.091) | 0.472\*\*\*  (0.117) |
| *Sheep* | 0.015  (0.094) | 0.230\*\*\*  (0.070) | 0.711\*\*\*  (0.108) |
| *Goats* | -0.233\*\*  (0.098) | 0.867\*\*\*  (0.092) | 0.069  (0.099) |
| *Transhumance Distance* | 0.106  (0.069) | 0.044  (0.056) | -0.159\*\*  (0.068) |
| *Grazing Time* | 0.042  (0.097) | 0.160\*\*  (0.074) | 0.006  (0.096) |
| *Watering Time* | 0.029  (0.098) | -0.073  (0.073) | -0.296\*\*\*  (0.093) |
| *Sub-Village Disease Death* | 0.041  (0.035) | 0.087\*\*\*  (0.032) | 0.108\*\*\*  (0.035) |
| Vuong Test (P-Value) | 4.96  (0.000) | 5.23  (0.000) | 5.30  (0.000) |
| aPredicted values from a first-stage logit regression of *Vaccinations (Yes/No)*.  \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated via delta method. | | | |

Table A2: Relationship between Vaccinations and Livestock Disease Death – Marginal Effects from Zero-Inflated Poisson Regression without Using IV for Vaccinations

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *Cattle Disease Death* | *Goat Disease Death* | *Sheep Disease Death* | *Cattle Disease Death* | *Goat Disease Death* | *Sheep Disease Death* |
| *Vaccinations (Count)* | -0.79\*\*\*  (0.293) | -4.34\*\*\*  (0.595) | 1.01\*  (0.59) | - | - | - |
| *Vaccinations (Yes/No)* | - | - | - | -0.813\*\*  (0.351) | -5.05\*\*\*  (0.711) | 0.93  (0.666) |
| *Cattle* | 0.940\*\*\*  (0.112) | 0.084  (0.315) | 0.345\*\*\*  (0.108) | 0.928\*\*\*  (0.111) | 0.055  (0.314) | 0.372\*\*\*  (0.108) |
| *Sheep* | 0.025  (0.087) | 0.209\*\*\*  (0.067) | 0.627\*\*\*  (0.100) | 0.021  (0.089) | 0.208\*\*\*  (0.066) | 0.64\*\*\*  (0.101) |
| *Goats* | -0.218\*\*  (0.096) | 0.830\*\*\*  (0.086) | 0.038  (0.094) | -0.215\*\*  (0.096) | 0.847\*\*\*  (0.087) | 0.027  (0.096) |
| *Transhumance Distance* | 0.101  (0.068) | 0.010  (0.054) | -0.164\*\*  (0.067) | 0.110  (0.068) | 0.021  (0.054) | -0.176\*\*\*  (0.067) |
| *Grazing Time* | 0.037  (0.089) | 0.192\*\*\*  (0.071) | 0.074  (0.091) | 0.027  (0.093) | 0.185\*\*\*  (0.070) | 0.085  (0.092) |
| *Watering Time* | 0.010  (0.096) | -0.046  (0.071) | -0.265\*\*\*  (0.091) | 0.025  (0.095) | -0.029  (0.071) | -0.275\*\*\*  (0.091) |
| *Sub-Village Disease Death* | 0.033  (0.035) | 0.084\*\*\*  (0.031) | 0.125\*\*\*  (0.032) | 0.033  (0.034) | 0.083\*\*\*  (0.031) | 0.123\*\*\*  (0.034) |
| Vuong Test (P-Value) | 4.80  (0.000) | 4.56  (0.000) | 5.24  (0.000) | 4.83  (0.000) | 4.59  (0.000) | 5.14  (0.000) |
| \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated using the delta method. | | | | | | |

Table A3: Relationship between Anthrax and CBPP Vaccine and Livestock Disease Death – Marginal Effects from Zero-Inflated Poisson Regression

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *Cattle Disease Death* | *Goat Disease Death* | *Sheep Disease Death* | *Cattle Disease Death* | *Goat Disease Death* | *Sheep Disease Death* |
| *Anthrax Vaccine* | 0.911  (0.776) | -5.63\*\*\*  (1.51) | -4.17\*\*\*  (1.53) | - | - | - |
| *CBPP Vaccine* | - | - | - | -1.08\*\*  (0.517) | -0.519  (0.515) | -0.659  (0.898) |
| *Cattle* | 0.913\*\*\*  (0.111) | -0.084  (0.084) | 0.385\*\*\*  (0.108) | 0.923\*\*\*  (0.112) | -0.022  (0.085) | 0.414\*\*\*  (0.109) |
| *Sheep* | 0.006  (0.087) | 0.191\*\*\*  (0.066) | 0.648\*\*\*  (0.100) | 0.043  (0.088) | 0.217\*\*\*  (0.066) | 0.653\*\*\*  (0.101) |
| *Goats* | -0.226\*\*  (0.096) | 0.797\*\*\*  (0.084) | 0.020  (0.096) | -0.237\*\*  (0.096) | 0.783\*\*\*  (0.084) | 0.015  (0.096) |
| *Transhumance Distance* | 0.117\*  (0.069) | 0.025  (0.054) | -0.186  (0.671) | 0.111  (0.070) | 0.009  (0.054) | -0.196\*\*\*  (0.066) |
| *Grazing Time* | 0.034  (0.092) | 0.213\*\*\*  (0.070) | 0.066  (0.091) | 0.038  (0.093) | 0.211\*\*\*  (0.070) | 0.071  (0.091) |
| *Watering Time* | 0.031  (0.095) | -0.030  (0.071) | -0.265\*\*\*  (0.091) | 0.017  (0.095) | -0.036  (0.070) | -0.267\*\*\*  (0.091) |
| *Sub-Village Disease Death* | 0.036  (0.033) | 0.088\*\*\*  (0.030) | 0.114\*\*\*  (0.034) | 0.033  (0.037) | 0.081\*\*\*  (0.030) | 0.116\*\*\*  (0.033) |
| \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated using the delta method. | | | | | | |

Table A4: The Effect of Vaccinations on Livestock Abortions – Marginal Effects from Zero-Inflated Poisson Regression

|  |  |  |  |
| --- | --- | --- | --- |
|  | Cattle Abortions | Goat Abortions | Sheep Abortions |
| Vaccinationsa | 0.835\*\*  (0.41) | 1.65\*\*  (0.758) | 0.413  (0.808) |
| Cattle | 0.234  (0.185) | 0.081  (0.123) | 0.089  (0.149) |
| Sheep | -0.091  (0.143) | -0.008  (0.093) | 0.952\*\*\*  (0.142) |
| Goats | 0.425\*\*  (0.177) | 0.423\*\*\*  (0.118) | -0.249\*  (0.129) |
| Transhumance Distance | 0.204\*  (0.113) | -0.002  (0.076) | -0.171\*  (0.088) |
| Grazing Time | -0.010  (0.159) | 0.170\*  (0.103) | 0.177  (0.126) |
| Watering Time | 0.269\*  (0.162) | 0.315\*\*\*  (0.106) | 0.240\*  (0.122) |
| Sub-Village Abortions | 0.173\*  (0.089) | 0.108\*  (0.056) | 0.133\*\*\*  (0.036) |
| Vuong Test (P-Value) | 2.91  (0.001) | 3.95  (0.000) | 3.96  (0.000) |
| aPredicted values from a first-stage regression of *Vaccinations*.  \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated via delta method. | | | |

Table A5: Relationship between Herd Introductions and Livestock Disease Death – Marginal Effects from Negative Binomial Regression without Using IV for Introductions

|  |  |  |  |
| --- | --- | --- | --- |
|  | *Cattle Disease Death* | *Sheep Disease Death* | *Goat Disease Death* |
| *Cattle Introductions* | -0.002  (0.002) | - | - |
| *Sheep Introductions* | - | -0.023  (0.019) | - |
| *Goat Introductions* | - | - | -0.167  (0.115) |
| *Cattle* | 0.735\*\*\*  (0.156) | 0.001  (0.001) | 0.008  (0.010) |
| *Sheep* | 0.399\*\*  (0.199) | 0.275\*  (0.143) | 0.740\*\*\*  (0.141) |
| *Goats* | 0.378  (0.256) | 0.508\*\*\*  (0.153) | 0.038  (0.094) |
| *Transhumance Distance* | 0.007  (0.009) | 0.003  (0.008) | 0.002  (0.007) |
| *Watering Time* | -0.162  (0.183) | 0.108  (0.140) | 0.067  (0.091) |
| *Sub-Village Disease Death* | 0.116  (0.651) | -0.338  (0.569) | 0.331  (0.577) |
| Likelihood Ratio Test Statistic (P-Value) | 40.6  (0.000) | 3297.5  (0.000) | 823.4  (0.000) |
| \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated using the delta method. | | | |

Table A6: Relationship between Herd Introductions and Livestock Abortions – Marginal Effects from Negative Binomial Regression without Using IV for Introductions

|  |  |  |  |
| --- | --- | --- | --- |
|  | *Cattle Abortions* | *Sheep Abortions* | *Goat Abortions* |
| *Cattle Introductions* | -0.032\*\*\*  (0.006) | - | - |
| *Sheep Introductions* | - | 0.038  (0.127) | - |
| *Goat Introductions* | - | - | -0.004  (0.115) |
| *Cattle* | 0.671  (1.01) | 0.009  (0.009) | -0.008  (0.010) |
| *Sheep* | 0.041  (0.027) | 0.143  (0.160) | 0.008  (0.012) |
| *Goats* | 0.015  (0.032) | 0.616\*\*\*  (0.180) | 0.018  (0.094) |
| *Transhumance Distance* | -0.004\*\*  (0.001) | -0.004  (0.008) | -0.002\*  (0.0007) |
| *Watering Time* | 0.068\*\*  (0.028) | 0.179  (0.152) | 0.040\*\*\*  (0.012) |
| *Sub-Village Abortions* | 0.091\*\*\*  (0.016) | 0.192\*\*\*  (0.049) | 0.099\*\*\*  (0.031) |
| Likelihood Ratio Test Statistic (P-Value) | 561.7  (0.000) | 298.5  (0.000) | 784.1  (0.000) |
| \*\*\*, \*\*, \* indicate significance at 1, 5 and 10% levels, respectively.  Standard errors for marginal effects are estimated via delta method. | | | |