Factors Affecting Sheep Theft in the Free State Province of South Africa

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Abstract: Livestock theft has a big impact on the livestock industry of South Africa and is threatening the sustainability of the industry. In order to generate information that can be used to inform sheep farmers on how to effectively mitigate stock theft on their farms, the objective of this study was to investigate whether the factors affecting the occurrence of livestock theft are significantly different from the factors affecting the level of livestock theft experienced in the Free State Province of South Africa. The study was based on data captured in 292 structured questionnaires completed during telephonic interviews with livestock farmers in the Free State Province. The Craggs model specification was used to statistically test whether or not the same factors affect the occurrence of stock theft and the level of stock theft experienced by the respondents. The results revealed that factors affecting the occurrence of stock theft are significantly different from the factors affecting the level of livestock theft. Technologies used by farmers proved to be significantly related to the occurrence of livestock theft, while loss controlling actions taken by farmers proved to have significant relationships to the level of livestock theft experienced. Technologies used include stock theft collars and alarms. Loss controlling actions include night patrols, counting animals and access control. The results proved that the stock theft problem faced by farmers can be divided into occurrence and the level of occurrence aspects. Thus, investing in controlling actions may decrease the level of stock theft, but not necessarily stop stock theft. Other challenges faced by farmers that threaten the sustainability of their farming enterprises should be approached in a similar manner to generate information that can be used to more effectively overcome the challenge at hand.

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1. Introduction and Background

Livestock theft is nothing new to South African farmers and is considered by some to be as old as farming itself [1,2]. Recorded cases of livestock theft in South Africa can be traced back to 1806 [3]. In some African cultures, cattle raiding (livestock theft) formed a major part of warfare. It was even considered legitimate to enter neighbouring chiefdoms and raid their cattle during times of peace. These raiders who returned with large numbers of cattle were seen as heroes, while petty thieves were despised [4]. Livestock theft is not a problem that is unique to South Africa or even Africa. Various countries also experience livestock theft and have done research to try and identify causes and solutions to this problem. African countries include

Lesotho [5], Kenya [6–8] Eritrea [9] and Nigeria [10], while other countries include the USA [11] and Australia [12]. From reviewed literature, it seems that livestock theft has become more violent and organized in recent years, e.g., with guns are used in perpetrating these thefts. One of the main causes of livestock theft is poverty among unemployed and drought-stricken crop farmers [5,7,13].

Livestock theft statistics show that all nine South African provinces are victims of stock theft [14]. The annual economic impact of livestock theft on the South African red meat industry (sheep, cattle and goats) for the year 2011/12 was estimated at 300 million South African Rand (ZAR) [15]. This amount is far less than the estimate of Clack [2] who calculated the 2011/12 annual losses at approximately ZAR 487 million. The total cost of losses to the red meat sector further increased to approximately ZAR 514 million in 2013/14 [16].

It should be noted that farmers not only have to deal with controlling livestock theft [2] but also other problems such as predators [17,18] and extreme weather conditions (draught, animal diseases, etc.) [19]. As the cost of controlling these increasing problems, more pressure is placed on the farmer's profit margin. In some cases, livestock farmers have already left the livestock industry because of stock theft, resulting in a shortage of supply and increased prices, threatening sustainability [1].

1.1. Problem Statement

Despite the significant losses associated with livestock theft in South Africa, the topic has received very little attention from researchers. The authors of this study could not find any research of factors affecting the occurrence of livestock theft under South African conditions. Thus, no scientific evidence is available to advise farmers on how to control livestock theft. The aim of this study was to explore the factors that have an effect on sheep theft in the Free State Province. The factors were analysed to determine whether factors affecting the occurrence of livestock theft are the same as factors affecting the level of livestock theft experienced. As such, a better understanding of the problem faced by the producers could contribute more effective response strategies to mitigate livestock theft in South Africa.

1.2. Study Area

The Free State Province of South Africa, which is the focus of this study, is situated centrally within South African borders (Figure 1). The Free State Province is divided into five district municipalities: Fezile Dabi, Lejweleputswa, Mangaung, Thabo Mofutsanyane and Xhariep. The province does not only share its border with six other provinces, but also with Lesotho. Lesotho, also known as the Mountain Kingdom, is completely surrounded by South Africa [20]. The border shared between the Free State Province and Lesotho is 450 km long and is guarded by 100 troops of the South African National Defence Force (SANDF) [21]. The Free State Province has a population of 2,745,590 [22] with roughly 54,000 people employed in the agricultural sector of the province [23]. According to the Department of Agriculture, Forestry and Fisheries (DAFF) there are 6065 commercial livestock farming units in the Free State Province [24]. The province has a total size of 12,943,700 ha, of which 90.9% is used for farming [24]. Grazing land, which is mainly suitable for livestock farming, makes up 58.1% of commercial farmland and 66% of emerging farmland [24]. The Free State Province has the third largest number of sheep as well as cattle, estimated at approximately 4.8 million sheep and 2.3 million cattle respectively [25].

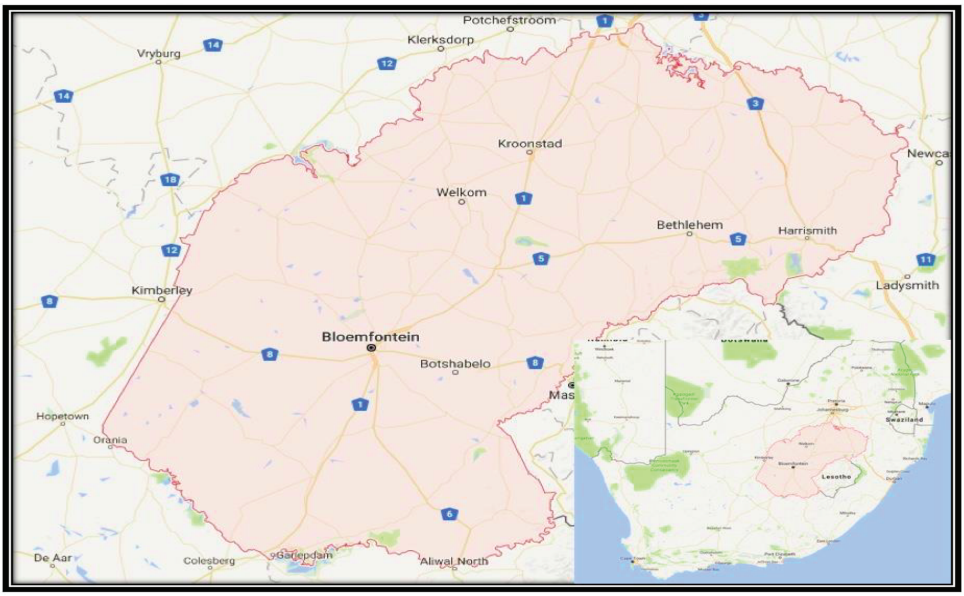

Figure 1. Geographical location of the Free State Province [26].

1.3. Data

A structured questionnaire was developed to obtain relevant information regarding livestock theft in the Free State Province. The questionnaire was designed to be administered during telephonic interviews. The questionnaire was designed based on the principals suggested by [27] and on a questionnaire used by van Niekerk [17]. The questionnaire included questions on farmers' years of farming experience, age, farm size, farm location and farm topography, losses due to livestock theft and practices used to control livestock theft. Questions of the practices used to control livestock theft included methods used, actions taken, how often these practices are performed and the annual cost of these practices.

Stratified random sampling was applied to select the respondents. Stratified random sampling is where the population is divided into subpopulations and random samples are then chosen from each subpopulation [28,29]. Livestock farmers within the Free State Province were divided into different subpopulations within the province according to their farm's demographic and topographic location. This method of sampling was chosen so that comparison and correlation between the different subpopulations can be done. By following this method, it also ensured that only livestock farmers were interviewed. The interviews took place between May and August 2014. Most of the farmers were contacted during the late afternoon and early evening. In total, 292 farmers completed the questionnaires and were included in further analyses.

2. Experimental Section

The main objective of this study was to identify factors affecting livestock theft in the Free State Province. Van Niekerk [17] found that the factors affecting the occurrence of predation and the factors affecting the level of predation are not the same. Based on this, it was hypothesised that the factors affecting the occurrence of livestock theft and factors affecting the level of livestock theft are not the same. In this study, the model used to investigate factors affecting livestock theft cover two aspects: whether or not livestock theft occurred and if livestock theft did occur, what quantity (level or the number of animals) of livestock were stolen. Similar to van Niekerk [17], the Craggs model was used to scientifically test whether the factors that affect the occurrence of livestock theft are the same as the factors that affect the level of livestock theft.

The Craggs model allows for one set of parameters to determine the probability of livestock theft occurring and another set of parameters to determine the number of livestock stolen (level of livestock theft) [30,31]. Due to the fact that it is hypothesised that the factors affecting the occurrence of livestock theft and factors affecting the quantity of livestock theft are not the same, the Craggs model would be an appropriate model for the study.

The Probit model was used to model whether or not livestock theft occurred (yes/no) and the Truncated model was used to measure the level (how much) of livestock theft experienced. According to Katchova and Miranda [32] the Probit (1) and Truncated (2) models are represented as follows:

Probit:

$$P(\alpha_i = 0) = \Phi(-\frac{\beta'_\alpha X_i}{\sigma}) \tag{1}$$

where P = is the probability, α_i = quantity of livestock theft, Φ (.) = standard normal probability density function, β'_α = a vector of coefficients, X_i = variable or an $S \times 1$ vector of personal and farm characteristics for farmer i and σ = variance.

Truncated:

$$f(\alpha_i|\alpha_i > 0) = \frac{f(\alpha_i)}{P(\alpha_i > 0)} = \frac{\frac{1}{\sigma}\Phi(\frac{\alpha_i - \beta'_\alpha X_i}{\sigma})}{\Phi(\frac{\beta'_\alpha X_i}{\sigma})} \tag{2}$$

where: $f(.)$ = the probability density function, P = the probability, α_i = the density (quantity) for the positive values, $\Phi(.)$ = standard normal probability density function, β'_α = a vector of coefficients, X_i = a variable or a $S \times 1$ vector of personal and farm characteristics for farmer i and σ = variance.

It is important to note that the Tobit model returns when the occurrence of livestock theft estimated in the Probit model (1) and the level of livestock theft experienced modelled in the Truncated model (2) have the same factors X_i and the same parameter vector β'_α [32]. Lin and Schmidt [30] prescribe the Lagrange multiplier to test the restrictions of the Tobit model. Greene, Woodruff and Tueller [33] suggests that the restrictions could be tested by calculating the following log-likelihood test statistic (3) after the Truncated model, the Tobit model and Probit model have been calculated.

$$\lambda = -2\left[\ln L_{Tobit} - \left(\ln L_{Probit} + \ln L_{Truncated\ regression}\right)\right] \tag{3}$$

where: λ = likelihood ratio statistic, L_{Tobit} = likelihood for the Tobit model, L_{Probit} = likelihood for the Probit model and $L_{Truncated\ regression}$ = likelihood for the Truncated model.

If the Cragg model has a significant *p*-value (probability), the factors affecting livestock theft differ significantly from the factors affecting the quantity of livestock theft. If, however, an insignificant *p*-value is found, the factors affecting the occurrence and quantity of livestock theft are the same and the Tobit model should be efficient for the analysis. The Cragg test was conducted in NLOGIT 4.0 statistical software (*NLOGIT*, 4.0; Econometric Software, Inc.: New York, NY, USA, 2006).

Hypothesised Factors

In an investigation of the available literature on livestock theft and the control of livestock theft, different factors were identified that affected the occurrence of livestock theft. Two main types of factors can be identified, namely internal and external factors. These main types of factors can further be divided into sub-groups. External factors include factors that the farmer has little or no control over. Identified external factors can be divided into demographic factors and topographic factors. Demographic factors include factors such as the age of farmers and topographic factors include farm size and distance from town. Internal factors are the factors that a farmer can control and include management practices for stock theft prevention and detection; physical barriers for stock theft prevention and detection; technological systems for stock theft prevention and detection; animals used for stock theft prevention and detection; and livestock insurance in South Africa. All factors considered in this study were placed in one of the sub groups.

Note that the hypothesised factors were tested for multicollinearity. None of the factors proved to have a variance inflation factor above the cut-off value of 10, therefore no multicollinearity was found to be present.

3. Results and Discussion

The factors affecting livestock theft were investigated by means of a Probit, Tobit and Truncated regression model specification. The external and internal factors were analysed separately and are discussed as such.

3.1. External Factors Affecting Livestock Theft

Results for the external factors hypothesised to affect the occurrence and level of livestock theft in the Free State Province consist of Tobit (level), Probit (occurrence) and Truncated (level) results which are shown in Table 1. The Craggs test was used to determine whether the variables affecting the occurrence of livestock theft are significantly different from the factors affecting the level of livestock theft experienced. If the factors prove to affect both the occurrence and level of stock theft experienced, the Tobit model would have been the model of choice. However, if the factors affecting the occurrence of stock theft prove to be different form the factors affecting the level, the Probit and Truncated model specifications have to be used to separately model the probability of occurrence and the level of occurrence.

Table 1. Regression results of the Tobit, Probit and Truncated specifications when analysing external factors affecting livestock theft.

Variable	Tobit	Probit	Truncated
Dependent variable	**Number of Sheep Stolen**	**Dummy = 1 if Experienced Theft, Otherwise 0**	**Number of Sheep Stolen**
Constant	−173.4253 **** (56.3445)	−3.2335 **** (0.8090)	85.2656 (269.6226)
Reporting of livestock theft			
Report within 0 and 1.99 h	108.4810 **** (18.5546)	1.7436 **** (0.2446)	−17.8845 (88.3507)
Report within 2.00 and 4.99 h	135.0665 **** (24.3078)	1.7156 **** (0.3389)	104.1057 (101.9826)
Report within 5.00 and 12.99 h	113.0441 **** (34.5546)	2.1386 **** (0.5952)	−66.6959 (135.7859)
Report within 13.00 and 24.00 h	110.4856 **** (38.5791)	0.9739 ** (0.5293)	226.0078 ** (131.2323)

Table 1. *Cont.*

	Tobit	Probit	Truncated
Management of farm workers			
Average relationship with herdsman	38.8593	0.2611	54.8602
	(32.9979)	(0.5011)	(122.4384)
Good relationship with herdsman	41.2272	0.5193	27.1038
	(28.7994)	(0.4468)	(113.2347)
Very good relationship with herdsman	16.5898	0.2078	−36.9059
	(28.8577)	(0.4435)	(115.4441)
Take ID copy	32.0676	0.0026	119.3469
	(32.3090)	(0.5289)	(100.5505)
Check employees' history	−17.0609	−0.0676	−123.6627**
	(21.3817)	(0.3485)	(63.6703)
Pay workers on weekly basis	−29.3835	−0.3287	−35.0568
	(50.0152)	(0.7251)	(218.5194)
	Tobit	**Probit**	**Truncated**
Management of farm workers			
Pay workers on monthly basis	36.9110	0.9789 *	51.6999
	(44.9871)	(0.6690)	(221.97320
Workers go to town every weekend	3.5809	0.0426	−10.5054
	(27.6891)	(0.4206)	(102.6302)
Workers go to town every second weekend	−37.9533	−0.3076	−264.2264 **
	(31.1944)	(0.4720)	(143.3688)
Workers go to town once a month	−30.4430	−0.3608	−99.3744
	(25.7465)	(0.3913)	(96.5304)
Workers receive visitors	24.9691	0.1464	91.0263
	(24.4536)	(90.3518)	(97.9315)
Visitors walk through farm	−0.3027	0.1936	−45.3874
	(14.0565)	(90.2237)	(47.7825)
Number of employees	−0.3118	−0.0126)	0.8742
	(1.0411)	(90.0157)	(3.7305)
Demographic factors			
Years farming	0.2528	0.0028	1.0222
	(0.4992)	(0.0077)	(1.7542)
Age	−0.1515	0.0017	−1.0781
	(0.5561)	(0.0083)	(2.1080)
Fulltime farmer	−15.7624	0.0501	−105.1946*
	(19.3036)	(0.2932)	(67.2876)
Topographic factors			
Plains	15.4593	0.8169 ****	−176.8991 ***
	(19.2827)	(0.2909)	(72.4865)
Mountains	16.1734	0.0192	73.6144
	(16.3314)	(0.2667)	(56.3414)
	Tobit	**Probit**	**Truncated**
Topographic factors			
Planted pastures	−8.6230	−0.2158	25.0973
	(12.4697)	(0.1932)	(45.4221)
Distance from town	1.3980	0.0392 **	−4.2555
	(1.4501)	(0.0211)	(4.7594)
Distance to informal settlement	−1.1857	−0.0279	2.4076
	(1.4783)	(0.0217)	(4.7692)

Table 1. *Cont.*

Size of farm	0.0070 ***	0.0052	0.0195 ***
	(0.0031)	(0.0049)	(0.0097)
Large town	−7.8256	−0.2227	29.8487
	(17.4066)	(0.2533)	(63.8693)
Border	45.3178 **	1.4644 ****	27.4206
	(24.9301)	(0.5467)	(80.6962)
Stock theft hotspot	9.1803	0.1651	28.8618
	(20.0244)	(0.3010)	(73.5946)
	Tobit	Probit	Truncated
Goodness of Fit			
No. of observations	292	292	292
Sigma	84.0267 ****	—	113.0711 ****
	(4.8356)	—	(12.0814)
Log likelihood	−1034.1803	−199.6506	−830.5208
% Correct prediction	—	77.055%	—
McFadden R^{2a}	—	0.2933	—
Model chi-square [b]	—	117.0961	—
Significance level [c]	—	(0.0000)	—
Likelihood-ratio test for Tobit vs. Truncated regression[d]	—	—	125.1138[d]
	—	—	(0.0000)[c]

****, **, * denote 1%, 5% and 15% significance level respectively. Standard errors are in parentheses. [a] McFadden R^2 is given by 1 − the ratio unrestricted:restricted log likelihood function values. [b] The chi-square test evaluates the null hypothesis that all coefficients (not including the constant) are jointly zero. [c] Numbers in parentheses are associated with chi-square probabilities. [d] The likelihood ratio test is given by $\lambda = 2(\ln L_{Probit} + \ln L_{Truncated\ regression} - \ln L_{Tobit})$.

The aim of these regressions was not to predict the probability of livestock theft but rather identify the internal and external factors associated with a lower probability of livestock theft. Thus, a significance level of 15% was considered acceptable for indicating a statistically significant relationship. In order to ease discussion and identify trends, external factors were divided into suitable categories: reporting of livestock theft, management of farm workers, demographic factors and topographic factors.

The Graggs test indicated whether the factors affecting the occurrence of livestock theft are significantly different from the factors affecting the level of livestock. Results from the Graggs test (Table 1) indicate that the log-likelihood test ratio of 125.11 is highly significant ($p < 0.01$). Therefore, the Tobit specifications are rejected in favour of the more general Graggs model specification. Thus, external factors affecting the occurrence of livestock theft are significantly different from the factors affecting the level of livestock theft in the Free State Province.

The Probit regression (Table 1) identified eight external factors that have a significant relationship with the occurrence of livestock theft in the Free State Province. The reporting of livestock theft shows that all of the reporting options offered to farmers proved to be significant: "report within 0 and 1.99 hours" ($p < 0.01$), "report within 2.00 and 4.99 hours" ($p < 0.01$), "report within 5.00 and 12.99 hours" ($p < 0.01$), "report within 13.00 and 24.00 hours" ($p < 0.10$). Strangely, all of these factors proved to be positively related to the occurrence of livestock theft. Thus, it does not matter how long it took to report the theft, the probability of the occurrence of livestock theft increases. Under the management of the farm worker factors, "paying workers on a monthly basis" ($p < 0.15$) showed a positive relationship to the occurrence of livestock theft. This implies that where farm workers were paid once a month, there was a higher probability for the occurrence of livestock theft. Results for the topographic factors showed that "plains" ($p < 0.01$), "distance from town" ($p < 0.10$) and "border" ($p < 0.01$) all related with the occurrence of livestock theft in a positive direction. Thus, farms with more plains (flatter land) are more likely to experience livestock theft. This contradicts the findings of Barclay and Donnermeyer [12] who found that higher stock theft rates are experienced in hilly terrain. It should also be taken into account that large parts of the Free State Province are relatively flat. Farms further away from towns have a higher probability for the occurrence of livestock theft; this agrees with the findings of Barclay and Donnermeyer [12] but contradict the findings of Bunei et al. [8]. One could argue that isolated farms create the opportunity for theft without being seen by the farmer. Lastly, farms close to the Lesotho border are more likely to experience livestock theft.

The external factors that have a significant relationship with the level of livestock theft experienced in the Free State Province are shown by the Truncated results in Table 1. Contrary to the result from the Probit model, only the "reporting theft within 13.00 and 24.00 hours" ($p < 0.10$) variable proved to be significant in the reporting of livestock theft category. Thus, farmers who experienced a higher level of stock theft tended to report a crime 13.00–24.00 h after it was committed. Management of farm workers had two significant factors: "checking employees' history ($p < 0.10$) and "workers go to town every second weekend" ($p < 0.10$). Both of these factors had a negative sign for their coefficient. The results thus suggest that checking employees' history and taking workers to town every second weekend are associated with lower levels of livestock theft. One reason why checking employees' history was associated with lower levels of livestock theft could be that no farmer would hire a known criminal. In cases where workers are taken to town every second weekend it could ensure that they are able to buy enough food in town so that they do not need to steal livestock for food, if that were the case. It could also be a sign that farm workers are involved in organised crime and could be serving as informants to criminals when not taken to town, however this result should not be generalized for all farmworkers.

Demographic factors indicated that "fulltime farmers" ($p < 0.15$) experience a lower level of stock theft. This could be due to the fact that fulltime farmers usually have more time to check up on the livestock and can detect any strange activity on the farm during the day. Topographic factors that proved to be significant with the level of stock theft experienced was "plains" ($p < 0.05$) and "size of the farm"($p < 0.05$). When interpreting the direction of signs, plains had a negative sign, meaning farms which have more plains (flatter) experience a lower level of livestock theft. It could be that a thief will not easily be able to hide a large number of animals in a flat area but it could easily be done in mountainous terrain. The size of the farm had a positive relationship, which means that farmers who have larger farms have experienced higher levels of livestock theft. This is simply because a farmer will struggle to focus on the whole farm simultaneously. Paddocks far from the farm house might also not be in the line of sight to detect any strange activity immediately.

3.2. Internal Factors That Affect Livestock Theft

The internal factors hypothesised to affect the occurrence and level of livestock theft in the Free State Province were analysed and the results are shown in Table 2. In order to ease discussion and help identify trends, external factors were also divided into groups: management practices, physical barriers, technology used, animals used and actions taken against stock theft.

Table 2. Regression results for the Tobit, Probit and Truncated specifications when analysing internal factors influencing livestock theft.

Variable	Tobit	Probit	Truncated
Dependent Variable	**Number of Sheep Stolen**	**Dummy = 1 if Experienced Theft, Otherwise 0**	**Number of Sheep Stolen**
Constant	−65.1119 **** (25.0723)	−0.6914 ** (0.3668)	−210.2690 ** (111.7880)
Management practices			
Guards	34.5417 ** (17.8570)	0.4824 * (0.2983)	25.6400 (54.5760)
Strategic Guard	−15.3475 (32.9571)	0.2301 (0.5915)	−200.0290 (161.2492)
Theft informant	167.7423 **** (39.2791)	1.0776 (0.7645)	340.2137 **** (86.7694)
Strategic Theft informant	29.0855 (24.5194)	0.3976 (0.4269)	129.3073 ** (75.0451)
Physical barriers			
Corral at night	42.6286 **** (12.9723)	0.9725 **** (0.2045)	−34.0825 (48.4926)
Strategic Corralling	26.4890 * (17.4323)	0.1120 (0.2827)	168.5605 **** (64.3844)
Lock gates	32.8182 (54.71061)	0.6940 (0.8656)	−210.6150 (378.8318)
Electric fencing	−0.6457 (30.5192)	−0.2567 (0.4543)	140.8787 (107.4632)
Strategic Electric fences	−73.6186 (58.3410)	−1.1324 (0.7962)	−37.4893 (331.9862)

Table 2. *Cont.*

Variable	Tobit	Probit	Truncated
Technology used			
Stock theft collars	55.6696 ****	0.9733 ****	128.1724 ***
	(20.1175)	(0.3713)	(63.1425)
Lights in corral	−59.0573	−1.2619 *	172.9464
	(58.8714)	(0.8661)	(271.1620)
Alarm in corral	24.4059	1.2170 ***	−134.6190
	(30.1628)	(0.5705)	(120.4728)
Camera	80.7218 ****	0.1899	236.6964 ****
	(23.0408)	(0.3820)	(66.2950)
Strategic Stock theft collars	50.8349 **	1.2312 ***	1.1539
	(30.4859)	(0.6117)	(86.6459)
Strategic Camera	37.8077	0.6102	−45.2779
	(35.2207)	(0.6110)	(109.6997)
Animals used			
Ostrich	35.9263	0.4373	156.4953
	(44.8285)	(0.6499)	(134.5210)
Donkey	−4.3010	0.0990	−136.4890
	(27.6415)	(0.4161)	(121.2614)
Wildebeest	−41.6752	0.1438	−69.1198
	(83.2292)	(1.1605)	(236.7963)
Animals used			
Dogs	8.1136	0.0788	50.9674
	(22.5095)	(0.3612)	(89.4025)
Strategic Dogs	−15.2595	0.3690	−123.5780
	(30.0255)	(0.5280)	(111.2376)
Actions taken against stock theft			
Active patrols	32.9270 ***	0.1381	156.1180 ****
	(13.5464)	(0.2002)	(57.9760)
Access control	−1.4453	0.2898	−108.1990 *
	(15.3461)	(0.2303)	(67.5339)
Strategic Patrols	14.2459	0.2953	5.5086
	(18.1697)	(0.2869)	(64.7334)
Strategic access control	29.9737 **	0.0083	103.5554 **
	(17.7402)	(0.2829)	(54.7067)
Count daily	−18.1366	−0.3721 *	−35.1218
	(15.0682)	(0.2302)	(53.3414)
Count more than once per day	−34.7825	−0.6842	−40.3194
	(42.0292)	(0.5651)	(215.4136)
Count once per week	−0.7589	0.0944	−78.5614
	(15.0015)	(0.2269)	(57.0154)
Count more than once per week	24.0160	0.5281 ***	−9.9554
	(17.2187)	(0.2691)	(57.2689)
Count monthly	23.7764	0.5931	−34.7871
	(30.1053)	(0.5154)	(108.8222)
Farmers union patrols	13.1396	0.1899	14.5626
	(17.6982)	(0.2662)	(66.8547)
Neighbourhood watch patrols	-8.0858	0.2093	-116.6720*

Table 2. *Cont.*

Variable	Tobit	Probit	Truncated
	(17.5835)	(0.2781)	(71.2700)
Private company patrols	20.5376	0.1392	48.3712
	(19.6144)	(0.2961)	(68.7394)
No Patrols	14.4166	0.1087	12.5930
	(22.0436)	(0.3254)	(85.0541)
Goodness of Fit			
No. of observations	292	292	292
Sigma	81.1383****	—	106.2761****
	(4.6923)	—	(12.4284)
Log likelihood	-1046.2581	-163.0667	-815.9966
% Correct predictions	—	69.63%	—
McFadden R^{2a}	—	0.1855	—
Model chi-square [b]	—	74.2947	—
Significance level [c]	—	(0.0000)	—
Likelihood-ratio test for Tobit vs. Truncated regression[d]	—	—	134.3896[d]
			(0.0000)[c]

****, **, * denote 1%, 5% and 15% significance level respectively. Standard errors are in parentheses. [a] McFadden R^2 is given by one minus the ratio of the unrestricted, to restricted log likelihood function values. [b] The chi-square test evaluates the null hypothesis that all coefficients (not including the constant) are jointly zero. [c] Numbers in parentheses are associated with chi-square probabilities. [d] The likelihood ratio test is given by $\lambda = 2\ (\ln L_{Probit} + \ln L_{Truncated\ regression} - \ln L_{Tobit})$.

Similar to the findings for the external factors (Table 1), results from the internal factors (Table 2) indicate that the log-likelihood test ratio of 134.39 is highly significant ($p < 0.01$). Therefore, the Tobit specifications are relaxed in favour of the more general Graggs model. Thus, internal factors affecting the occurrence of livestock theft are significantly different from the factors affecting the level of livestock theft. If the Tobit model were to be used, it would fail to identify the correct factors affecting livestock theft.

Eight of the internal factors have a significant relationship with the occurrence (Probit) of livestock theft in the Free State Province. The use of livestock "guards" ($p < 0.15$) proved to be the only significant management variable positively related to the occurrence of stock theft. Thus, farmers who have a higher probability of experiencing livestock theft are making use of guards. Thus, farmers who experienced livestock theft on a regular basis have started to use guards in an attempt to control livestock theft. The only significant physical barrier variable affecting the occurrence of livestock theft is "corralling at night" ($p < 0.01$). The positive sign of the coefficient would imply that farmers who have a higher probability of experiencing livestock theft are corralling at night. This could be similar to the use of guards where the sheep are corralled in an attempt to control livestock theft. Three of the technology factors proved to be positively related to the occurrence of livestock theft and only one negatively. "stock theft collars" $p < 0.01$), "alarms in corral" ($p < 0.05$) and "strategic stock theft collars" ($p < 0.05$) were positively related, while "light in corral" ($p < 0.15$) was negatively related to the occurrence of livestock theft. The results suggest that farmers who are more likely to experience livestock theft used stock theft collars. It does not matter whether the stock theft collars are used actively or strategically. Farmers who are more likely to experience livestock theft placed alarms in their corrals and farmers who have light in their corrals are less likely to experience livestock theft. It seems that farmers are using stock theft collars and alarms because of regular losses to stock theft and that where lights are placed in corrals, it has led to lower occurrence rates of livestock theft.

None of the animals used to control livestock theft proved to have a significant relationship with the occurrence of livestock theft. Although it was hypothesised that many of the actions taken by farmers could influence the occurrence of livestock theft, only two proved to be significant. "counting animals on a daily basis" ($p < 0.15$) was negatively related to the occurrence of livestock theft and "counting animals more than once a week" ($p < 0.05$) had a positive relationship to the occurrence of livestock theft. Thus, farmers who count their animals on a daily basis are less likely to experience livestock theft and farmers who count two to three times a week are more likely to experience livestock theft. The results suggest that farmers who count on a regular basis have a lower probability for the occurrence of livestock theft.

Results from the Truncated regression show (Table 2) that nine of the internal factors have a significant relationship with the level of livestock theft experienced by farmers in the Free State Province. Management practices that have a significant relationship with the level of stock theft experienced by farmers are "theft informant" ($p < 0.01$) and "strategic theft informant" ($p < 0.10$). Taking into account the positive sign of the coefficient, farmers who are more likely to experience a higher level of livestock theft make use of a stock theft informant (both actively and strategically). "strategic collars" ($p < 0.01$) is the only physical barrier significantly related to the level of livestock theft experienced. The positive sign shows those farmers who have a probability of experiencing a higher level of livestock theft corral their animals during strategic times of the year. Two of the technologies used to control livestock theft were significant. Both "stock theft collars" ($p < 0.05$) and "cameras" ($p < 0.01$) proved to have a positive relationship to the level of livestock theft experienced. Thus, farmers who are more likely to experience a higher level of livestock theft use stock theft collars and farmers who have a higher probability of experiencing a higher level of livestock theft use cameras in and around their corrals.

As in the case of the occurrence of livestock theft (Probit), none of the animals used to control livestock theft proved to have a significant effect on the level of livestock theft experienced. Results show that the actions taken against stock theft contain four significant factors. "Active patrols" ($p < 0.01$) and "strategic access control" ($p < 0.10$) had a positive coefficient, implying that farmers who experience a higher level of livestock theft patrols throughout the year and farmers who are more likely to experience higher levels of stock theft control access to their farms during known troublesome times. "access control" ($p < 0.15$) and "neighbourhood watch patrols" ($p < 0.10$) have had negative relationships with the level of livestock theft experienced. This implies that farmers who have access control to their farms and farmers who take part in neighbourhood watches experience lower levels of livestock theft.

From a management point of view, it seems that farmers who count more often have a lower probability of experiencing livestock theft than those who count less often. This could be due to the fact that a farmer who counts his animals more often will become aware of theft at an earlier stage and thieves will have less time to get rid of the animals and/or evidence in their possession. Stock theft collars proved to be significantly related to the occurrence as well as the level of livestock theft with positive coefficients in both cases. Thus, farmers who have higher probability for the occurrence as well as the level of livestock theft, use stock theft collars. This could be an indication of how desperate the farmers who lose large numbers of livestock on a regular basis are to find a control method that works.

The signs and coefficients of the regression analyses shown in Tables 1 and 2 suggest that farmers should count their animals on a daily basis to become aware of thefts as soon as possible.

4. Conclusions

Investigation of the external factors proved that eight external factors were associated with the occurrence of livestock theft and six external factors showed a significant relationship to the level of livestock theft experienced. Results show that farmers who report their incidents of crime in any of the offered time slots increase their probability of experiencing livestock theft. However, farmers who have a higher probability of experiencing stock theft and a higher level of stock theft report their cases 13.00–24.00 h after the animals are stolen. The results thus suggest that farmers who took longer to report their cases were more likely to experience stock theft and farmers who experienced stock theft at higher level on a regular basis took longer to report. It could be that those farmers who lost large numbers of animals on a regular basis are fed up with the thefts and probably feel that it would not help to report the cases as early as possible. Interesting to note is that plains proved to be significantly related to a higher occurrence rate of livestock theft and negatively related to the level of livestock theft experienced. The results suggest that it is easier to steal one or two sheep in a flat environment; however, it is hard to conceal a large number of sheep at a time. Thus, thefts occur on a regular basis in small quantities on flatter land, whereas more mountainous areas create the opportunity to steal a larger number of animals on a less frequent basis. Strangely, it seems that farms bordering Lesotho experience stock theft on a more regular basis, but not necessarily on a larger scale than the rest of the Free State Province.

When focussing on the internal factors, eight internal factors had a significant relationship to the occurrence of livestock theft, while nine internal factors were associated with the level of livestock theft experienced. Moreover, these results showed that factors (external and internal) affecting the occurrence of livestock theft and factors affecting the level of livestock theft are different. Thus, the results from this study relate to the results that van Niekerk [17] and Badenhorst [18] reported for predation management.

Acknowledgments: The authors would like to acknowledge the Red Meat Research and Development Trust (RMRDT) who provided the funding for the collection of the data.

Author Contributions: W.A. Lombard and Antonie Geyer conceived and designed the experiments; W.A. Lombard and Walter van Niekerk performed the experiments; W.A. Lombard and Henry Jordaan analysed the data; Henry Jordaan contributed reagents/materials/analysis tools; W.A. Lombard, Walter van Niekerk and Henry Jordaan wrote the paper. All authors have read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Parliamentary Monetary Group (PMG). An overview of stock theft in South Africa. Meeting report from 25 May 2010. PMG. Available online: http://www.pmg.org.za (accessed on 10 October 2013).
2. Clack, W.J. The extent of stock theft in South Africa. *Acta Criminol.: South. Afr. J. Criminol.* **2013**, *26*, 77–91.
3. Alberti, L. *Account of the Xhosa(1811)*; Fehr, W., Ed.; Balkema: Cape Town, South Africa, 1968.
4. Peires, J. Unsocial bandits: The stock thieves of Qumbu and their enemies. Democracy popular precedents practice culture. 13–15 July 1994, University of Witwatersrand, History workshop, 1994. Available online: http://wiredspace.wits.ac.za/handle/10539/8020 (accessed on 11 October 2013).
5. Khoabane, S.; Black, P. On the economic effects of livestock theft in Lesotho: An asset-based approach. *J. Dev. Agric. Econ.* **2012**, *4*, 142–146.
6. Anderson, D. Stock theft and moral economy in colonial Kenya. *Africa: J. Int. Afr. Inst.* **1986**, *56*, 399–416. [CrossRef]
7. Cheserek, G.J.; Omondi, P.; Odenyo, V.A.O. Nature and Causes of Cattle Rustling among some Pastoral Communities in Kenya. *J. Emerg. Trends Manag. Sci.* **2012**, *3*, 173–179.
8. Bunei, E.K.; Rono, J.K.; Chessa, S.R. Factors influencing farm crime in Kenya: Opinions and experiences of farmers. *Int. J. Rural Criminol.* **2013**, *2*, 75–100.

9. Mohammed, M.A.; Ortmann, G.F. Factors influencing adoption of livestock insurance by commercial dairy farmers in three Zobatat of Eritrea. *Agrekon* **2005**, *44*, 172–186. [CrossRef]
10. Olowa, W.O. The Effects of Livestock Pilferage on Household Poverty in Developing Countries: Theoretical Evidence from Nigeria. *Bangladesh e-J. Sociol.* **2010**, *7*, 42–46.
11. Anderson, K.M.; McCall, M. *Farm Crime in Australia*; Australian Institute of Criminology: Canberra, Australia, 2005.
12. Barclay, E.; Donnermeyer, J.F. Crime in regional Australia. In Proceedings of the 4th National Outlook Symposium on Crime in Australia, New Crimes or New Responses Convened by the Australian Institute of Criminology, Canberra, 21–22 June 2001; Australian Institute of Criminology: Canberra, Australia, 2001.
13. Dzimba, J.; Matooane, M. The impact of stock theft on human security. In *Strategies for Combating Stock Theft in Lesotho*; Kariri, J.N., Mistry, D., Eds.; Institute for Security Studies: Pretoria, South Africa, 2005.
14. National Stock Theft Prevention Forum (NSTPF; Pretoria, South Africa). South African livestock theft numbers 2010/11–2013/14. Unpublished data. 2014.
15. Red Meat Producers Organization (RPO). Business Plan and Budget for Production Development: 2012–2014, 2012. Red Meats South Africa. Available online: http://www.redmeatsa.co.za/wp-content/uploads/2014/09/RPO-Budget-and-Business-Plan-28Levy-Period-2012-201429-Production-Development9.pdf (accessed on 23 February 2015).
16. Red Meat Producers Organization (RPO). Diere van R750 Miljoen jaarliks gesteel. *Landbou Weekblad*, 26 September 2014.
17. Van Niekerk, H.N. The Cost of Predation on Small Livestock in South Africa by Medium-Sized Predators. Master's Thesis, University of the Free State, Bloemfontein, South Africa, November 2010.
18. Badenhorst, C.G. The Economic Cost of Large Stock Predation in The North West province of South Africa. Master's Thesis, University of the Free State, Bloemfontein, South Africa, July 2014.
19. Bureau for Food and Agricultural Policy (BFAP). Baseline Agricultural Outlook 2014–2023. BFAP. Available online: http://www.bfap.co.za/images/documents/baseline/bfap_baseline_2014.pdf (accessed on 20 February 2015).
20. Lesotho. The official website of Lesotho, 2015. Available online: www.gov.ls (accessed on 6 January 2015).
21. Steinberg, J. *The Lesotho/Free State Border*; Institute for Security Studies: Pretoria, South Africa, 2005; ISS Paper 113.
22. Statistics South Africa. Census 2011 Municipal factsheet, 2011. Statistics South Africa. Available online: http://www.statssa.gov.za/census/census_2011/census_products/Census_2011_Municipal_fact_sheet.pdf (accessed on 22 December 2016).
23. Statistics South Africa. Gross domestic product. Statistical release, 2014. Statistics South Africa. Available online: http://www.statssa.gov.za/publications/P0441/P04413rdQuarter2014.pdf (accessed on 22 December 2016).

24. Department of Agriculture, Forestry and Fisheries (DAFF) South Africa. Abstract of Agricultural Statistics 2013, 2013. DAFF. Available online: http://www.nda.agric.za/docs/statsinfo/Abstact2013.pdf (accessed on 22 December 2016).
25. Department of Agriculture, Forestry and Fisheries (DAFF; Pretoria, South Africa). Livestock statistics per magisterial districts in the Free State. Unpublished data. 2014.
26. Google Maps. Map for the Free State Province, 2015. Available online: https://www.google.co.za/maps/place/Free+State/@-28.6629083,24.8220063,7z/data=!3m1!4b1!4m5!3m4!1s0x1e8fc56133d61419:0xedf58a554da20a47!8m2!3d-28.4541105!4d26.7967849 (accessed on 15 December 2015).
27. Moberly, R.L. The cost of fox predation to agriculture in Britain. Ph.D. Thesis, Environment Department, University of York, York, UK, March 2002.
28. Cochran, W.G. *Sampling Techniques*, 3rd ed.; John Wiley & Sons: New York, NY, USA, 1977.
29. Fienberg, S.E. Notes on Stratified Sampling for Statistics 36–303: Sampling, Surveys, and Society. In Presented at the Department of Statistics, Carnegie Mellon University, Pittsburgh, PA, USA, 12 March 2003; Available online: http://www.stat.cmu.edu/~fienberg/Stat36-303-03/Handouts/StratificationNotes-03.pdf (accessed on 22 December 2016).
30. Lin, T.; Schmidt, P. A test of the Tobit specification against an alternative suggested by Cragg. *Rev. Econ. Stat.* **1984**, *66*, 174–177. [CrossRef]
31. Cragg, J.G. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* **1971**, *39*, 829–844. [CrossRef]
32. Katchova, A.L.; Miranda, M.J. *Two-Step Econometric Estimation of Farm Characteristics Affecting Marketing Contract Decisions*; American Agricultural Economics Association: Milwaukee, WI, USA, 2004.
33. Greene, J.S.; Woodruff, R.A.; Tueller, T.T. Livestock-guarding dogs for predator control: Costs, benefits, and practicality. *Wildl. Soc. Bull.* **1984**, *12*, 44–50.