A study on risk factors for bovine tuberculosis in the disease-free regions of Italy

Supplementary materials

The supplementary material reports the simplified R syntax used to estimate the binomial Generalized Linear Mixed Model (GLMM) with a complementary log-log (cloglog) link function, the full fixed-effect estimates, the random-effect variance components, the model-fit statistics, and the multicollinearity diagnostics for the fixed-effect structure. Multicollinearity was assessed using variance inflation factors (VIF). No evidence of problematic multicollinearity was detected.

In addition, Supplementary Figure S1 presents the correlation matrix of the fixed-effect estimates.

Text S1. Simplified R syntax of the final mixed-effects model

```
glmer(outbreak ~ fixed effects + (1 | province),
      family = binomial(link = "cloglog"),
      control = glmerControl(
        optimizer = "bobyqa",
        optCtrl = list(maxfun = 2e5)))
```

Table S1. Full fixed-effect estimates.

Variable	Variable description	Range	Estimate	SE	z	p-value
Intercept			-12.8161	0.8555	-14.981	< 0.001
Year	Year of breakdown occurrence	2022				
		2023	1.0521	0.3817	2.757	0.00584
		2024	1.4358	0.3973	3.614	< 0.001
		2025	1.7517	0.3947	4.438	< 0.001
bTB history	A bTB breakdown occurred in the same herd in the previous 5 years	FALSE				
		TRUE	1.0236	0.4008	2.554	0.01065
bTB check	The herd had a bTB checks in the previous year	NO				
		YES	0.0179	0.2391	0.075	0.94027
Herd status	Herd status in the previous year	bTB Free				
		Other	1.9243	0.2925	6.579	< 0.001
ProdType	Herd production type	Dairy				
		Beef-Fattening	-0.2382	0.4099	-0.581	0.56123

		Beef-Breeding	0.4843	0.2951	1.641	0.10078
		Mixed	-0.4341	0.4528	-0.959	0.33777
ManType	Management of the herd	Housed				
		Outdoor	0.0591	0.2784	0.212	0.83201
		Transhumant	1.0218	0.4358	2.345	0.01905
		Not specified	-0.126	0.2752	-0.458	0.64713
HerdSize	Herd size on 31 December of the previous year	1-10				
		11-100	2.7013	0.399	6.77	< 0.001
		>100	3.2045	0.4657	6.882	< 0.001
N_Purchased	Number of purchased bovine heads in the previous year	0-67410	0.1795	0.0657	2.731	0.0063
N_Sold	Number of sold bovine heads in the previous year	0-65988	-0.0279	0.0679	-0.411	0.68074
cat_slaugh	Percentage of bovine heads slaughtered in the previous year	High (≥25%)				
		Low (<25%)	-0.5061	0.3096	-1.635	0.10214
cat_break	Proximity (2 km) with a bTB breakdown occurred in the previous 5 years	NO				
		YES	1.9288	0.2726	7.076	< 0.001
N_Herds_2km	No. of bovine Herds within 2km	0-164	-0.1106	0.1216	-0.91	0.36294
Y_OTF	Number of years since the province of the herd has held the OTF status	0-3	1.3523	0.508	2.662	0.00777
		4-7	0.9131	0.3893	2.346	0.01899
		>7				

Table S2. Variance components of the random effects.

Grouping factor	Term	Variance	Std. Dev.	Exp(SD)
Province	Intercept	3.34	1.83	6.23

Table S3. Model fit statistics.

Statistics	Value
AIC	1696.5
BIC	1940.5
logLik	-825.3
No. observations	299157
No. provinces	86
Optimizer	bobyqa

Table S4. Variance inflation factors (VIF) for fixed-effect predictors. VIF values greater than 10 are generally considered indicative of severe multicollinearity; values above 5 may suggest moderate collinearity requiring attention.

Variable	Variable description	VIF	VIF 95% CI	SE inflation factor	Tolerance	Tolerance 95% CI
Year	Year of breakdown occurrence	2.351	2.338–2.364	1.533	0.425	0.423–0.428
bTB history	A bTB breakdown occurred in the same herd in the previous 5 years	1.445	1.438–1.452	1.202	0.692	0.689–0.695
bTB check	The herd had a bTB checks in the previous year	1.265	1.259–1.270	1.125	0.791	0.787–0.794
Herd status	Herd status in the previous year	1.456	1.449–1.463	1.207	0.687	0.684–0.690
ProdType	Herd production type	2.374	2.361–2.388	1.541	0.421	0.419–0.424
ManType	Management of the herd	1.296	1.291–1.302	1.138	0.771	0.768–0.775
HerdSize	Herd size on 31 December of the previous year	1.322	1.316–1.328	1.15	0.756	0.753–0.760
cat_purc	Purchasing of bovine heads in the previous year	1.233	1.228–1.238	1.11	0.811	0.808–0.815
cat_sell	Selling of bovine heads in the previous year	1.401	1.395–1.408	1.184	0.714	0.710–0.717
cat_slaugh	Percentage of bovine heads slaughtered in the previous year	1.499	1.492–1.506	1.224	0.667	0.664–0.670
cat_break	Proximity (2 km) with a bTB breakdown occurred in the previous 5 years	1.513	1.505–1.520	1.23	0.661	0.658–0.664
N_Herds_2km	No. of bovine Herds within 2km	1.06	1.056–1.064	1.03	0.943	0.939–0.947
Y_OTF	Number of years since the province of the herd has held the OTF status	2.405	2.392–2.419	1.551	0.416	0.413–0.418

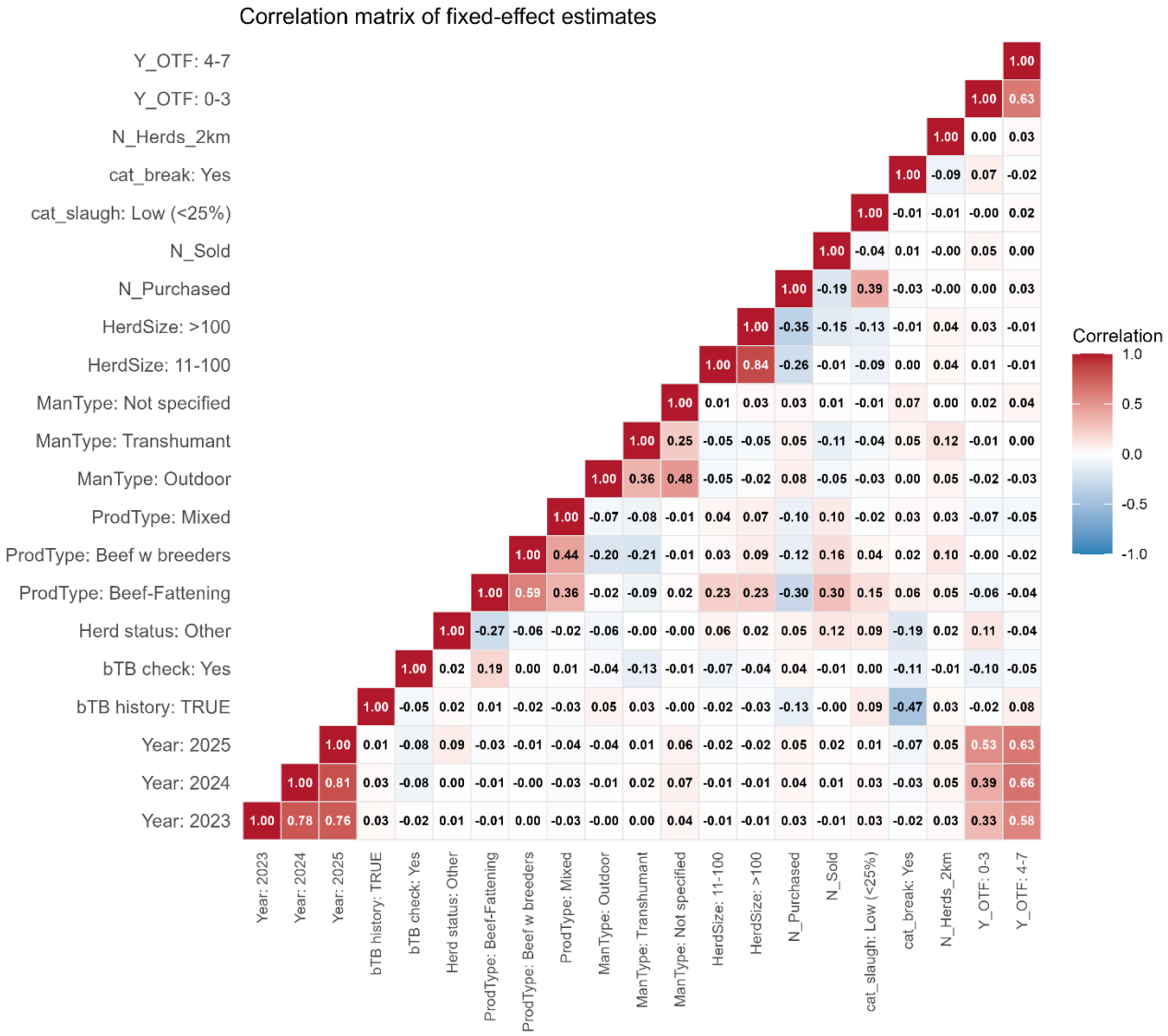


Figure S1: correlation matrix of the fixed-effect estimates