UK foot-and-mouth disease economic impacts: an integrated farm, policy, market and trade laboratory

Syntera Research Note 01 - exploratory edition
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Exploratory economic modelling; not peer reviewed and not an estimate of a current UK outbreak.

Author disclaimer

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Abstract

This paper documents a browser-based UK FMD economic laboratory that integrates three working but scale-specific models: a monthly farm linear programme (LP), a finite-horizon policy dynamic programme (DP), and a multi-market partial-equilibrium (PE) welfare model. Published median market outcomes from Feng, Patton and Davis (2017) provide fixed aggregate scenario context. The laboratory does not reproduce EXODIS, simulate premises or spatial spread, or generate a new outbreak duration. Users alter economic inputs and rerun the models. The central purpose is to expose assumptions, distributional effects and model boundaries, rather than provide a single headline loss.

Under the current research defaults, the farm LP mitigation package changes annual farm-resource surplus by -£1,070 relative to disruption without added mitigation. The policy DP produces a discounted net social saving of £1.89m over 16 quarters. In the PE model, mitigation changes annual domestic welfare by -£204.54m; the sign is conditional because restoring exports can reverse short-run domestic consumer gains from redirected supply while imposing real programme costs. These results are different accounts and must not be added.

1. Decision problem and scope

FMD creates simultaneous farm, government, market and trade consequences. Farm restrictions can alter feeding, labour, sale timing and margins. Public policy changes resource use, transfers and the timing of economic recovery. Market closure redirects product and changes prices, quantities and the distribution of gains and losses between consumers, exposed producers, other producers and taxpayers. A valid appraisal must therefore keep physical production, financial transfers, resource costs, gross revenue exposure and welfare changes separate.

The model uses published aggregate scenarios as background assumptions. It does not optimise outbreak operations or infer transmission. Model users select either the stamping-out or vaccination-to-die median reported by Feng et al. and can then change clearly identified economic inputs. Each default, unit, range and selected value is visible in the laboratory. JSON and CSV downloads preserve the exact input and output record.

Published aggregate scenario context

Measure	Stamping out median	Vaccinate-to-die median
Days to application for disease-free status	171	141
Beef price versus baseline	-7.9%	-5.7%
Sheepmeat price versus baseline	-24.5%	-18.4%
Pigmeat price versus baseline	-17.4%	-13.6%

2. Evidence and data

Feng et al. connect fixed outputs from earlier EXODIS simulations to a UK agricultural market model. Their median period to application for disease-free status is 171 days for stamping out and 141 days for vaccination to die. The study assumes an export-ban period linked to the disease period and an additional 90 days, and tests alternative import-displacement responses. Its 2017 baseline is historically situated and is not a contemporary forecast.

The PE reference uses editable 2025 UK production and trade anchors from Agriculture in the United Kingdom 2025. Pig production is 937 thousand tonnes and the standard pig price is 201.3 p/kg. Sheepmeat and beef anchors follow the same Defra chapter and the established Syntera BTV market reference. The repository UK PE file identifies candidate trade, production and

exchange-rate files, but the three trade CSV candidates are empty and the CSV production and exchange-rate fallbacks are absent. The laboratory therefore displays transparent aggregate inputs rather than implying those files have been run.

3. Farm linear programme

3.1 Structure and equations

The LP follows the repository farm resilience optimiser. Decision variables are sheep head, cattle head and monthly feed dry matter for six feed sources. It maximises annual contribution: gross output less non-feed variable costs, feed costs, disruption damage, mitigation resources and fixed mitigation cost, plus any transfers. It imposes head bounds, twelve monthly labour constraints, maximum dry-matter intake, metabolisable-energy and crude-protein requirements, concentrate limits, monthly forage supply, and annual silage, hay and concentrate supply.

For scenario s, max Z_s = sum_i[(gross_i - nonfeed_i - disruption_i,s - mitigation_i,s + transfer_i,s) x_i] - sum_i,f,m feedcost_i,f y_i,f,m - fixed_s, subject to A_s z <= b and z >= 0. The browser uses a two-phase simplex and reports constraint slack, residual and solver iterations. The LP contains 146 decision variables and more than 90 resource constraints. Continuous head values are planning equivalents, not recommendations for an individual farm.

3.2 Inputs and limitations

Farm coefficients, forage growth, feed energy/protein and monthly animal requirements are inherited from legacy_pages/506_Syntera_Farm_LP_TAD.py. These are repository prototype defaults, not official farm-accountancy averages. FMD price and disruption assumptions are layered onto that structure. The original LP supports sheep and cattle only; pigs and dairy-market effects therefore appear in the DP and PE, not as fabricated LP enterprises.

Farm LP result

Scenario	Sheep head	Cattle head	Farm contribution	Government	Net farm-resource surplus
Published baseline	481.4	55.0	£64,544	£0	£64,544
FMD market disruption	464.8	55.0	£57,690	£0	£57,690
FMD + economic mitigation	474.0	55.0	£56,620	£0	£56,620

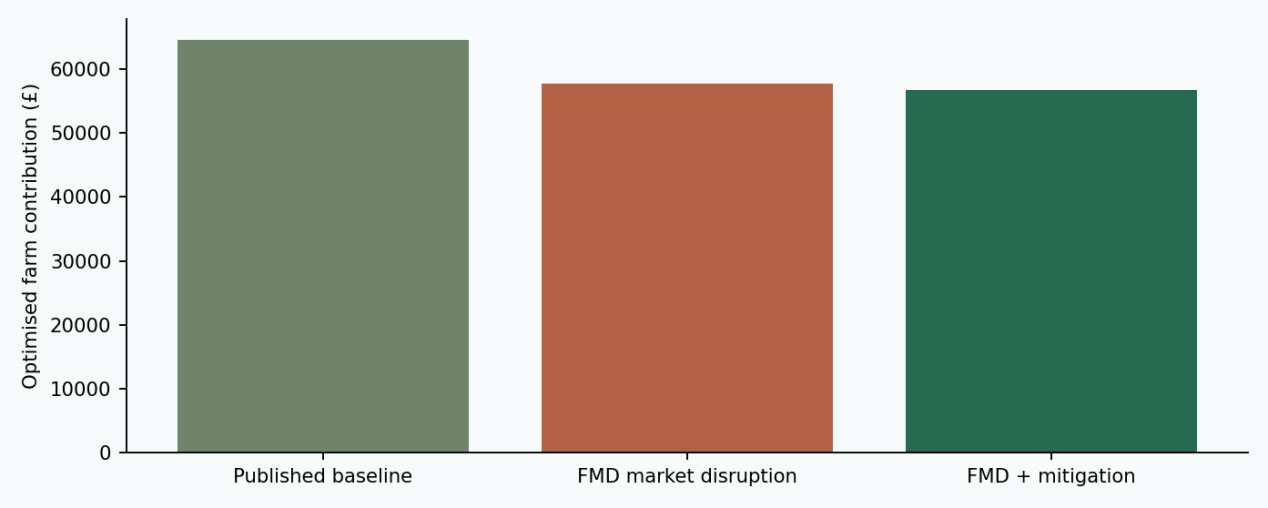

Figure 1. Optimised farm contribution under the three LP scenarios. The mitigation result is conditional on entered costs and effectiveness; it is not observed Farm Business Income.

4. Policy dynamic programme

4.1 Economic-state adaptation

The UK fmd_uk_economic_twin.py dp_bridge is a threshold table and is not a dynamic programme. The laboratory therefore uses the audited Syntera Bellman architecture from the BTV laboratory and page 521, with new FMD economic states and costs. The state comprises aggregate disruption pressure, preparedness coverage and recovered market capacity. These are economic indexes rather than simulated infection prevalence.

The recursion is V_t(s)=min_a { C_t(s,a) + beta E[V_(t+1)(s prime)] }. Four policy choices are evaluated: no added capacity, rapid-response capacity, vaccination preparedness and integrated recovery support. Farm groups choose among no added action, preparedness, continuity measures, or both based on private costs and anticipated next-period benefits. A quarterly public budget rules out unaffordable state-action combinations.

4.2 Results and interpretation

Policy DP result

Account	No added capacity	Optimised policy
Discounted social cost	£7.29m	£5.40m
Government expenditure	£0	£699,163
Private cost	£7.29m	£4.70m
Net social saving	-	£1.89m

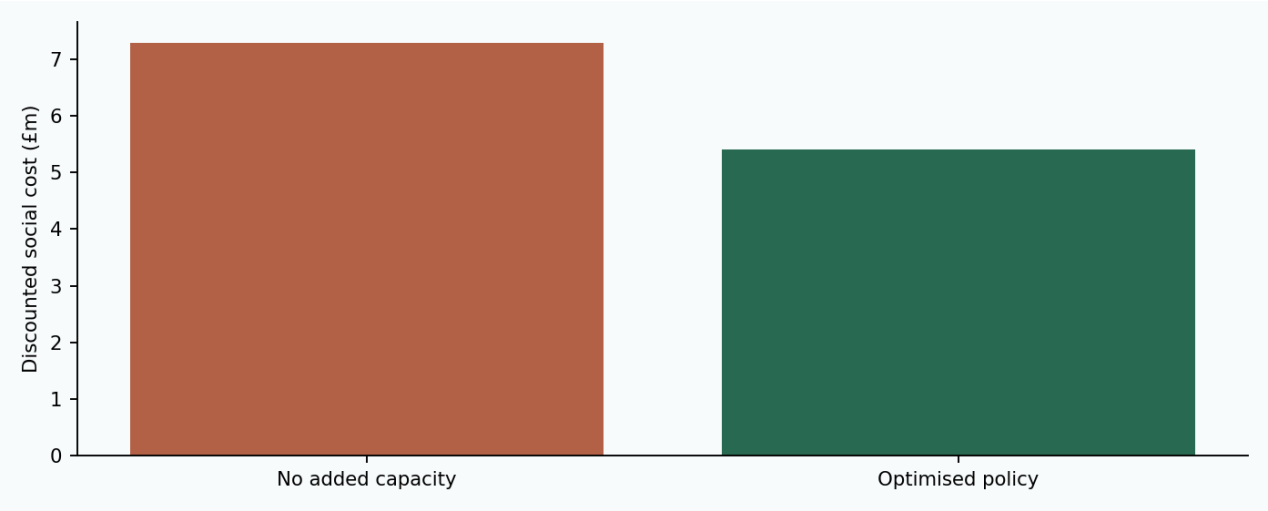

Figure 2. Discounted social costs under no added capacity and the optimised state-dependent policy. This is a conditional economic DP, not an operational outbreak prescription.

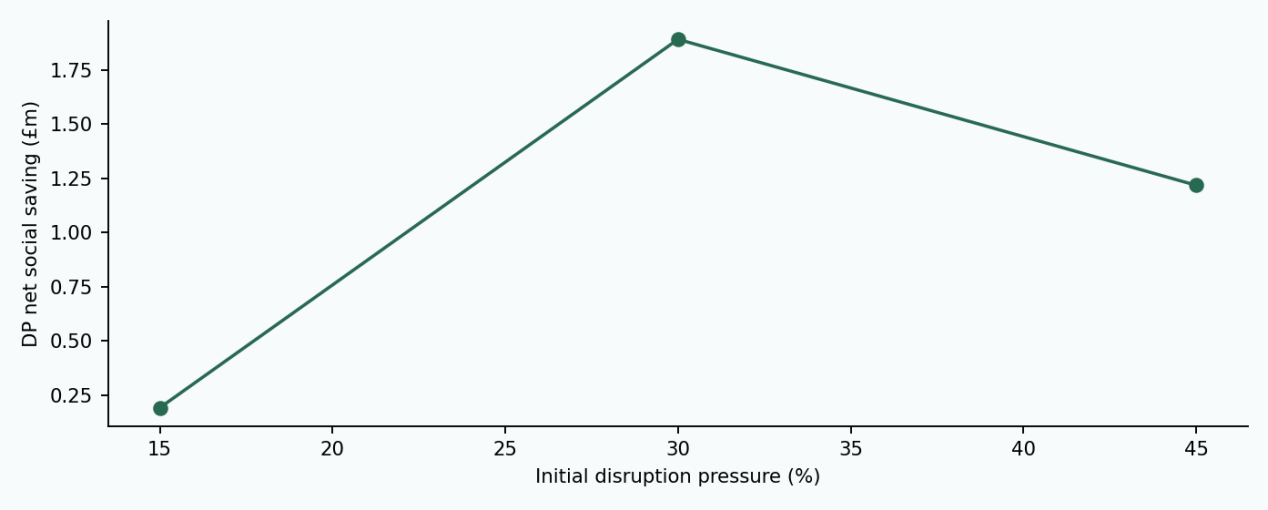

Figure 3. DP net social saving under alternative initial economic-disruption pressure. One-factor sensitivity, not a confidence interval.

The optimised path changes across reachable economic states. Consequently, the displayed policy table reports the probability of each action across the state distribution rather than one deterministic response schedule. Transition persistence, future pressure, preparedness decay, market recovery, farm response and public costs are editable research assumptions. Calibration against matched UK aggregate simulation outputs remains a research requirement.

5. Partial-equilibrium market and welfare model

5.1 Market clearing

For each of sheepmeat, beef and pigmeat, domestic supply, demand, imports and exports respond to price with constant elasticities. The equilibrium price solves Q_u(p)+Q_e(p)+M(p)-D(p)-X(p)=0, where u and e denote unexposed and economically exposed production. Bisection solves the market root. Consumer surplus and producer-surplus changes are integrated from the demand and supply curves. Mitigation resources are real costs. Subsidies and compensation are transfers: they affect producer and government accounts but cancel from domestic welfare except for administrative and real-resource costs.

An FMD export-demand shock may lower domestic prices by redirecting product. Consumers can gain while producers lose. Mitigation that restores export demand may therefore reduce the short-run domestic consumer gain even while improving producer outcomes. This is why gross exports at risk, sector output value and domestic welfare must not be treated as interchangeable losses.

PE market clearing

Market / scenario	Price	Output	Imports	Exports	Exposed share
Sheepmeat / Published baseline	£7.100	282.00	91.00	99.00	0.0%
Beef / Published baseline	£6.470	898.00	309.00	142.00	0.0%
Pigmeat / Published baseline	£2.013	937.00	766.00	342.00	0.0%
Sheepmeat / FMD market disruption	£5.547	259.81	62.85	12.67	20.0%
Beef / FMD market disruption	£5.835	872.49	264.67	15.74	12.0%
Pigmeat / FMD market disruption	£1.772	890.67	608.99	39.85	15.0%
Sheepmeat / FMD + economic mitigation	£6.139	269.04	73.16	47.52	13.1%
Beef / FMD + economic mitigation	£6.065	882.44	280.43	62.87	7.9%
Pigmeat / FMD + economic mitigation	£1.863	909.55	666.38	155.74	9.9%

PE welfare result

Scenario	Consumers/users	Exposed producers	Other producers	Government	Domestic welfare
Published baseline	£0	£0	£0	£0	£0
FMD market disruption	£1.48bn	-£237.92m	-£1.02bn	£0	£225.29m
FMD + economic mitigation	£919.90m	-£114.36m	-£779.80m	-£5.00m	£20.74m

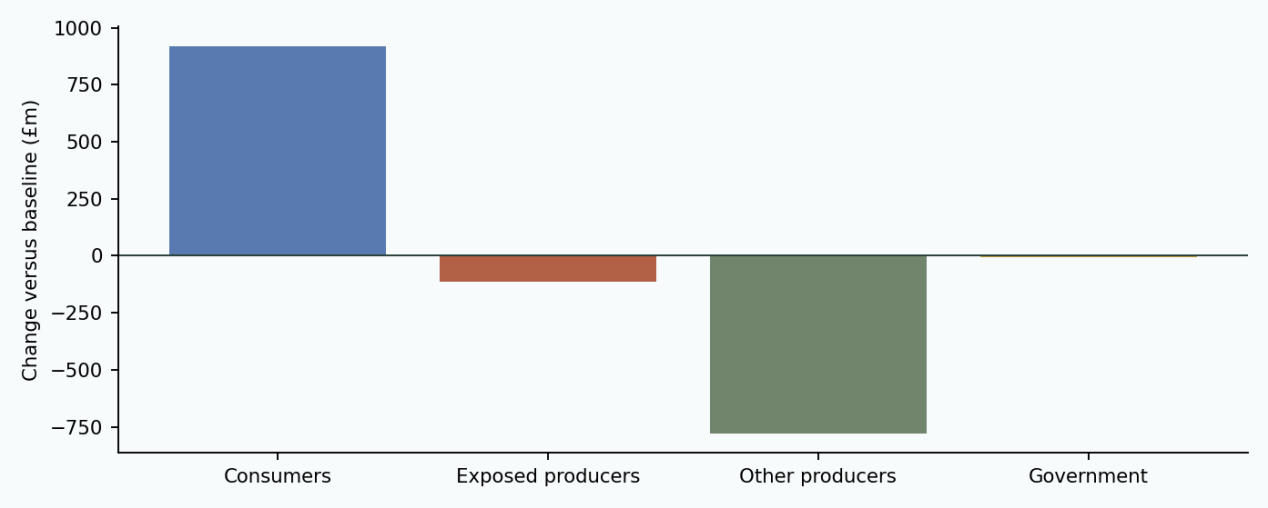

Figure 4. Distributional welfare changes in the mitigation scenario versus the model baseline. Positive consumer effects can coexist with producer and government costs.

5.2 PE limitations

Elasticities and affected shares are editable scenario parameters rather than newly estimated UK coefficients. The model is annual and does not represent product quality, regionalisation, Northern Ireland protocol effects, processing bottlenecks, storage, bilateral market reopening or separate live-animal trade. Foreign welfare is outside the domestic account. A negative net mitigation result therefore does not establish that preparedness is undesirable; it identifies which assumptions, beneficiaries and accounting boundary drive the result.

6. Trade and market-access analysis

The PE explicitly contains baseline import and export quantities and an export-demand shock. This is stronger than applying a blocked-revenue multiplier, because domestic price, consumption, imports, exports and producer welfare clear together. Nevertheless, the source trade files were unavailable, so the displayed baseline remains an editable aggregate data layer.

Product-level work should replace it with verified HMRC or Defra commodity flows, destination shares, eligibility rules and reopening dates.

Gross revenue exposure equals annual affected export value times interruption duration. It is useful as a liquidity indicator but is not welfare loss. Redirected exports affect domestic price; adding gross exposure to the PE welfare result would double count the trade channel. The dashboard and paper keep these measures separate.

7. Sensitivity analysis

Coverage sensitivity

Mitigation coverage	LP net benefit	PE net domestic welfare change
0.0%	-£2,377	-£177.03m
25.0%	-£1,689	-£187.34m
50.0%	-£1,203	-£199.29m
75.0%	-£925	-£212.91m
100.0%	-£831	-£228.20m

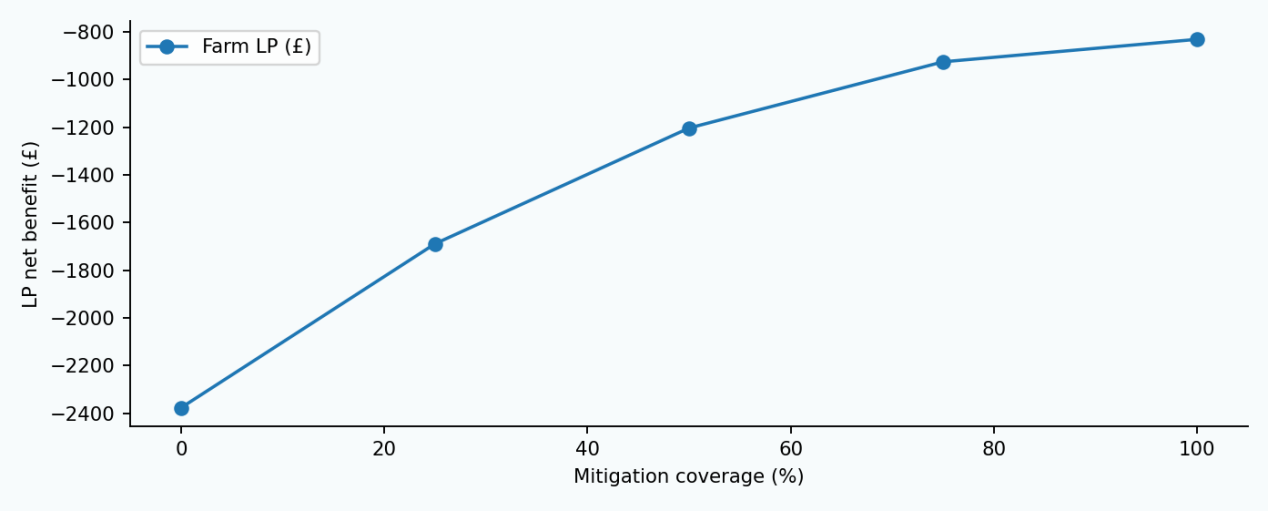

Figure 5. Farm LP net benefit across mitigation coverage. The PE series is retained in the table because it is on a different monetary scale.

DP disruption-pressure sensitivity

Initial pressure	Net social saving	Government expenditure	Optimised social cost
15.0%	£192,329	£459,701	£5.06m
30.0%	£1.89m	£699,163	£5.40m
45.0%	£1.22m	£519,758	£6.36m

Coverage is not an optimisation result or universal target. At zero coverage, other entered programme costs can remain. At high coverage, unit mitigation cost can exceed avoided loss. Likewise, higher initial disruption pressure changes the DP value of preparedness. These deterministic sweeps show structural dependence; they are not probability intervals.

8. Accounting, double counting and distribution

Gross output is price multiplied by quantity and is not net income. Farm contribution excludes fixed costs, rent, support payments and unpaid family labour. Gross blocked exports are revenue exposure, not a resource loss. Compensation is normally a transfer. Producer and consumer surplus integrate behavioural responses and cannot be added to output-value differences. Public administration and physical response resources are real costs. The model downloads preserve these accounts separately.

Barnes et al. (2023) provide a useful bottom-up taxonomy for consequential farm costs: testing and handling, movement constraints, delayed sales, additional feed and labour, business disruption and uncompensated output loss. Their study concerns bTB. Its monetary unit costs are not transferred to FMD; only the cost-identification and survey logic are relevant.

9. Source-to-result audit and reproducibility

Model-to-source audit

Displayed model	Repository source	Integrated function	Important boundary
Farm LP	legacy_pages/506_Syntera_Farm_LP_TAD.py	Monthly simplex LP: enterprise head and feed allocation	Sheep and cattle only; prototype farm defaults
Policy DP	Page 521 / BTV audited DP architecture; app/fmd_uk_economic_twin.py reviewed	Bellman solution over aggregate economic states	New FMD economic transition assumptions; no disease-spread simulation
Market PE	model/uk_fmd_pe_engine.py lineage plus Syntera PE engine	Price clearing and welfare integration	Editable aggregate baseline; repository trade CSV candidates are empty
Published scenario	Feng, Patton and Davis (2017), Tables 2-4	Scenario selector and price/output-loss anchors	Historical model results; not a 2026 forecast

Every model run occurs in the browser. Changing an input invalidates the previous result until the user reruns the relevant model. The JSON download contains engine version, timestamp, scenario classification, all inputs and complete nested outputs. The CSV download flattens the same audit record. This publication archives the engine, inputs, model results and paper tables.

10. Limitations and research agenda

The main empirical gaps are a verified product-level trade baseline, current farm budgets for representative dairy, beef, sheep and pig systems, matched public-response cost lines, and calibrated UK market elasticities. The DP needs elicited or empirically estimated transition probabilities linking preparedness and economic recovery. The PE needs bilateral trade and foreign-welfare extensions. The LP needs pig and dairy enterprise modules before claiming whole-sector farm coverage. Uncertainty should ultimately be represented by parameter distributions and correlated scenarios rather than one-factor sweeps.

The next publishable version should freeze a dated data release, document reconciliation across UK and GB geographical scopes, distinguish price years and currencies, validate each solver independently, and compare model outputs with published studies without forcing numerical agreement. Peer review should focus particularly on market-welfare boundaries, transfer treatment and transition calibration.

11. Conclusions

A strong FMD economic assessment cannot be reduced to one historic headline cost. The laboratory shows how the answer changes across farm constraints, policy timing, market behaviour, trade adjustment and the chosen welfare boundary. Its value lies in transparent conditional reasoning: users can see each assumption, rerun the calculation, inspect constraints and distribution, and retain a reproducible record. The current results support research and preparedness discussion; they do not forecast a UK outbreak or provide operational disease-control advice.

References

Feng, S., Patton, M. and Davis, J. (2017). Market Impact of Foot-and-Mouth Disease Control Strategies: A UK Case Study. Frontiers in Veterinary Science 4:129. doi:10.3389/fvets.2017.00129.

Barnes, A.P., Moxey, A., Brocklehurst, S., Barratt, A.S., McKendrick, I., Innocent, G. and Vosough Ahmadi, B. (2023). The consequential costs of bovine tuberculosis breakdowns in England and Wales. Preventive Veterinary Medicine 211:105808.

National Audit Office (2002). The 2001 Outbreak of Foot and Mouth Disease.

National Audit Office (2025). Resilience to animal diseases.

Defra (2026). Agriculture in the United Kingdom 2025, Chapter 8: Livestock.

Syntera repository files: legacy_pages/506_Syntera_Farm_LP_TAD.py; app/fmd_uk_economic_twin.py; model/uk_fmd_pe_engine.py; config/uk_fmd_params.json.