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Why Veterinary Antimicrobial Stewardship Works in Some Clinical Settings but Fails in Others: A Realist Review of Prescribing Behavior, Diagnostic Access, Client Expectations, Practice Systems, Economic Pressures, and Policy Context, 2017–2026

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ABSTRACT

Veterinary antimicrobial stewardship is implemented across clinical environments that differ substantially in diagnostic capacity, prescribing routines, client or farmer relationships, organizational resources, economic constraints, guideline infrastructure, and regulatory expectations. Consequently, interventions with similar stewardship objectives may produce different prescribing responses across settings. This realist review examined how contexts interact with mechanisms to influence veterinary antimicrobial prescribing and stewardship outcomes. Searches conducted on 22 August 2026 generated 109 result instances; 46 duplicates were removed, leaving 63 unique records for screening. Thirteen records were excluded during initial screening and 12 after detailed eligibility assessment, yielding 38 included evidence units. Evidence was appraised for relevance, richness, and rigor and coded through context–mechanism–outcome reasoning, with attention to confirming, disconfirming, and context-dependent findings. The synthesis indicates that stewardship is unlikely to function as a simple consequence of guideline exposure or clinician knowledge. Diagnostic actionability, clinical uncertainty, prescribing habits, client or farmer negotiation, team organization, time, affordability, availability of feasible alternatives, and regulatory accountability can modify whether stewardship resources become usable in practice. Intervention evidence also indicates that improvements in selected prescribing behaviors, adherence measures, or intentions do not necessarily imply uniform reductions in antimicrobial use or improvements in clinical, welfare, resistance, or public-health outcomes. A refined program theory is therefore developed in which stewardship depends on context-sensitive activation of capability, opportunity, confidence, legitimacy, and practical feasibility. The resulting configurations are explanatory propositions rather than validated causal rules and require prospective testing across species, diseases, practice systems, and policy environments.

Keywords: Veterinary antimicrobial stewardship, Realist review, Prescribing behaviour, Diagnostic access, Implementation context, Antimicrobial use

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Introduction

Veterinary antimicrobial stewardship is increasingly supported by guidelines, surveillance, education, and prescribing oversight, yet access to stewardship guidance and reported prescribing appropriateness vary

substantially between countries and clinical settings [1]. Large practice-network data likewise show that antimicrobial dispensing differs by species, disease presentation, and region, indicating that stewardship performance cannot be inferred from a single prescribing indicator [2]. Production-animal systems introduce additional constraints: disease-specific antimicrobial demand may remain concentrated where preventive or therapeutic alternatives are limited, while local policy implementation can alter the environment in which prescribers act [3, 4]. This review therefore examines not simply whether stewardship interventions work, but how diagnostic, behavioural, relational, organizational, economic, and regulatory contexts influence the mechanisms through which they may change veterinary prescribing.

Why effectiveness varies across veterinary settings

Variation is expected when the same stewardship resource encounters different opportunities for use. Guideline awareness may be high yet practical integration weak [1]; production systems with persistent disease burdens may face constraints that do not arise in companion-animal consultations [3]. Policy environments can also differ in professional expectations, accountability, communication time, and implementation support [4]. The relevant question is therefore not whether a guideline, educational intervention, diagnostic test, or restriction is intrinsically effective. The proposed realist interpretation is that each resource can activate different reasoning and behaviour depending on clinical risk, available alternatives, economic feasibility, workflow, professional norms, and relationships with animal owners or producers. Similar interventions may consequently generate different outcomes without those differences being inherently contradictory.

Review questions

The review addressed four linked questions. First, which clinical, diagnostic, behavioural, relational, organizational, economic, and regulatory contexts recur in veterinary antimicrobial-prescribing evidence? Second, what mechanism reasoning plausibly explains how these contexts alter responses to stewardship resources? Third, which prescribing, adherence, intention, or antimicrobial-use patterns occur when particular context–mechanism combinations are present, and what rival explanations constrain those interpretations? Fourth, under what conditions might apparently successful or unsuccessful stewardship interventions be transferable across companion-animal, livestock, hospital, ambulatory, and production settings? These questions were used to develop and refine context–mechanism–outcome configurations rather than to calculate a pooled intervention effect or construct a universal hierarchy of determinants.

Materials and Methods

A realist-review design was used because the review sought explanations for variable stewardship responses rather than a single average intervention effect. Realist synthesis examines how programs generate outcomes through mechanisms activated under particular contextual conditions [5]. Searches were undertaken on 22 August 2026 for veterinary antimicrobial prescribing, stewardship, diagnostic access, behavioural determinants, client or farmer influences, practice systems, economics, regulation, and relevant realist-review methodology. Eligible evidence comprised peer-reviewed journal articles published from 2017 through 2026 with verifiable DOI information, appropriate journal eligibility, and direct relevance to a predefined review domain or methodological requirement. Selection, extraction, relevance and rigor appraisal, context–mechanism–outcome coding, rival-explanation assessment, and program-theory refinement were conducted using the verified review ledger.

Realist-review approach

Contexts were treated as conditions that could alter whether a stewardship resource became meaningful or feasible, while mechanisms were treated as changes in reasoning or response rather than as interchangeable measured variables. This distinction follows realist-informed approaches that require mechanisms to be interpreted in relation to the resources and circumstances through which they operate [6, 7]. Outcomes included prescribing decisions, antimicrobial selection, adherence indicators, antimicrobial-use patterns, and behavioural intentions where reported. Clinical recovery, animal welfare, antimicrobial resistance, and public-health benefit were not inferred from prescribing outcomes unless directly measured. Configurations were refined by comparing supporting evidence with null, contradictory, or context-dependent findings and by retaining plausible rival explanations where the available evidence could not discriminate between them.

Initial program theory

The initial program theory proposed that stewardship works when resources alter decisions in a context that permits clinicians and practice systems to act on them. Diagnostic access was expected to reduce uncertainty only when testing was timely, affordable, and actionable. Guidelines were expected to influence behaviour when locally relevant and accessible within workflow. Education was expected to matter when knowledge represented a genuine constraint rather than when opportunity or feasibility was limiting. Client or farmer relationships, economic constraints, team organization, and regulation were expected to modify perceived legitimacy and practical options. These propositions were treated as provisional explanatory hypotheses, consistent with iterative realist theory refinement [5], rather than as established causal pathways or universally applicable intervention rules.

Information sources

The evidence search combined web-indexed bibliographic retrieval with article verification through PubMed, publisher and journal platforms, institutional repositories, and bibliographic-index records. This strategy was used to identify veterinary empirical evidence and methodological sources relevant to program-theory development and testing. The search did not constitute a conventional exported search from multiple subscription bibliographic databases, and this limits claims of exhaustive retrieval. Search records were maintained at the result-instance and unique-record levels so that duplicate removal and eligibility decisions could be reconciled. DOI identity, publication year, peer-review status, journal eligibility, subject relevance, species or system context, and ability to support a specific review claim or context–mechanism–outcome proposition were checked before final inclusion.

Search strategy

Searching was iterative because realist reviews require both substantive evidence and material capable of developing or testing program theory. Realist-search practice commonly extends beyond a single exhaustive query and instead pursues theoretically informative evidence as configurations develop [8]. Different search routes may retrieve different forms of program-theory material, which supports methodological complementarity rather than treating one retrieval route as inherently sufficient [9]. Search refinement therefore moved among companion-animal prescribing, livestock antimicrobial use, diagnostic access, client and farmer decision contexts, organizational conditions, economic pressures, regulation, intervention studies, and realist-review methodology. Evidence contribution was assessed in relation to relevance, richness, and rigor rather than through a single undifferentiated quality score [10].

Study selection

The search generated 109 result instances. After removal of 46 duplicate article, DOI, or version instances, 63 unique candidate records remained. All 63 underwent initial screening; 13 were excluded because they were outside the date window, were non-peer-reviewed or otherwise ineligible publication types, or could not support a defined review claim. Fifty reports proceeded to detailed eligibility assessment. None was classified as not retrieved. Twelve were then excluded because journal eligibility could not be verified, the record proved ineligible after source verification, exact claim or configuration fit was insufficient, or the report overlapped another source without a distinct realist contribution. Thirty-eight evidence units remained for synthesis.

The selection process required several different adjudication states that would be obscured by a simple included/excluded dichotomy; these distinctions are retained below because they determine how evidential confidence and transferability are interpreted. **Table 1** presents record classes and evidential roles in a context-sensitive realist stewardship review.

Table 1. Record classes and evidential roles in a context-sensitive realist stewardship review

Record class	Contribution to realist synthesis	Veterinary context filter	Disposition	Independence or verification check
Direct veterinary evidence	Tests substantive configuration	**Setting:** Species, disease, practice type **Basis:** Defined veterinary setting and outcome	Include	**Constraint:** Context may restrict transfer **Recheck:** Recheck against rival settings

Realist-method foundation	Supports review reasoning	**Setting:** Not species-specific **Basis:** Explicit realist methodological contribution	Include	**Constraint:** Cannot support veterinary effect claims **Recheck:** Use for methods only
Topic-adjacent record	Background relevance only	**Setting:** Veterinary link incomplete **Basis:** No exact planned claim supported	Exclude	**Constraint:** Apparent relevance may overstate fit **Recheck:** Reconsider only if theory gap emerges
Journal eligibility unresolved	Evidential fit potentially adequate	**Setting:** Any setting **Basis:** Required status not verifiable	Exclude	**Constraint:** Quality cannot be substituted for eligibility **Recheck:** Reassess only with verifiable status
Duplicate or overlapping report	No independent evidence unit	**Setting:** Same study or DOI **Basis:** Repeated article/version or non-distinct report	Remove or exclude	**Constraint:** Multiple publications can mimic replication **Recheck:** Retain distinct contribution only

Data extraction

For each included source, extraction captured setting, country or region, species or population, level of analysis, study design, intervention or exposure, focal constructs, data source, analytical method, reported findings, contradictory or null findings, feasibility considerations, limitations, and transferability boundaries. Realist-specific extraction additionally recorded context, mechanism reasoning, observed outcome pattern, rival explanation, evidential strength, and the part of the evolving program theory to which the evidence contributed. Mechanisms were not inferred merely because a statistical association was reported; they required an explanatory account connecting resources or constraints to participant reasoning or behaviour, consistent with realist operationalization [6]. Missing design or sample information was retained as unreported rather than reconstructed.

Relevance and rigor appraisal

Appraisal was contribution-specific. Survey syntheses were useful for identifying recurring veterinarian knowledge, attitude, and practice domains but were interpreted cautiously because heterogeneity and self-report limit causal inference [11]. Institutional stewardship evaluations offered stronger evidence that selected prescribing endpoints can change, while remaining vulnerable to setting and temporal confounding [12]. Performance-indicator research helped distinguish guideline existence from measurable adherence behaviours [13]. Qualitative investigation was given substantial relevance when it explained how drug, dose, or duration decisions were negotiated under uncertainty, even though such evidence cannot estimate mechanism prevalence [14]. Accordingly, no universal numerical quality score was generated; evidential confidence reflected methodological fit to the particular claim being tested.

Context–mechanism–outcome coding

Coding separated contextual conditions from the reasoning they might activate and from the outcomes subsequently observed. Diagnostic availability, client affordability, workflow, regulation, or guideline access were coded as contexts when they altered the decision environment. Confidence in withholding treatment, risk aversion, perceived professional legitimacy, anticipated client conflict, or reliance on familiar prescribing routines were treated as candidate mechanism reasoning when supported by the source. Prescribing, antimicrobial selection, adherence, intention, or use constituted outcomes according to the original study. Rich qualitative evidence on prescribing complexity was particularly useful for avoiding the assumption that contextual variables themselves were mechanisms [14]. Every proposed configuration also retained a rival explanation, such as clinical severity, case mix, secular change, or self-report bias.

Evidence synthesis and program-theory refinement

Evidence was synthesized by comparing recurring configurations across companion-animal and production settings and then actively seeking evidence that complicated or contradicted preliminary explanations. A proposed mechanism was strengthened when different designs or settings supported compatible reasoning, but its transferability was narrowed when findings depended on disease, practice system, country, or outcome definition. Relevance and rigor were therefore evaluated in relation to the contribution each source made to a configuration rather than through uniform weighting [10]. Program-theory refinement preserved partial responses: an

intervention could improve one adherence measure while leaving another unchanged, or alter intention without establishing actual prescribing change. The synthesis consequently prioritized conditional explanations and explicit boundaries over a single ranking of stewardship determinants.

Results and Discussion

Recent empirical evidence confirmed substantial heterogeneity in the environments in which stewardship decisions occur. Illinois companion-animal veterinarians reported multiple influences on antimicrobial prescribing, supporting a multidimensional rather than single-driver account of decision making [15]. Washington State evidence similarly demonstrated variation in reported stewardship and prescribing practices across small- and mixed-animal medicine [16]. Mixed-method evidence from Singapore added relational and implementation dimensions, indicating that clinically appropriate prescribing is embedded within consultation and practice context [17]. Japanese clinic-level analysis further showed associations between practice characteristics and the use of antimicrobials important to human medicine [18]. These studies collectively support context-sensitive interpretation, but their observational and self-reported components do not establish that any individual determinant causes prescribing behaviour.

Evidence-base characteristics

The included evidence combined veterinary surveys, qualitative and mixed-method studies, routine prescribing analyses, intervention evaluations, systematic or interpretive syntheses, and realist-methodological sources. Survey-based veterinary evidence was especially useful for mapping recurring behavioural and contextual determinants [11], whereas institutional intervention studies permitted more direct assessment of selected prescribing changes [12]. Measurement-focused work clarified how guideline adherence could be decomposed into observable behaviours [13], and qualitative evidence supplied richer explanations of uncertainty and decision processes [14]. Recent studies extended these domains across North American, Asian, European, companion-animal, and production settings [15]. However, variation in design, outcome definition, species, disease, practice structure, and national policy prevented treatment of the evidence base as a homogeneous intervention literature.

Diagnostic access as context

Diagnostic access mattered less as a binary presence or absence than as a chain linking availability to actionability. Illinois companion-animal evidence identified diagnostic and clinical considerations among factors surrounding antimicrobial decisions [15]. Japanese clinic-level evidence likewise showed that prescribing choices varied with practice characteristics [18]. The proposed realist interpretation is that testing can reduce empirical prescribing only when a relevant result is timely, affordable, and sufficiently credible to alter treatment. Delay, cost, uncertain interpretation, or severe illness may prevent an available test from activating diagnostic confidence. Conversely, rapid access does not establish that withholding or narrowing treatment is safe in every case.

The diagnostic states below separate access from actionability without assigning an unsupported score. **Table 2** presents where diagnostic access falls relative to the antimicrobial prescribing window.

Table 2. Where diagnostic access falls relative to the antimicrobial prescribing window

Decision-window question	Inaccessible	Delayed	Actionable	Discordant
Meaning for prescribing uncertainty	Uncertainty remains	Result misses decision window	Result changes confidence	Uncertainty persists
Disease or access constraint	Cost; geography; laboratory access	Acute disease; turnaround	Disease; test validity	Severity; prior treatment
Test evidence available	No usable pathway	Late result	Timely result	Test–clinical conflict
Antimicrobial option opened or closed	Empirical treatment may persist	Treatment precedes result	Withhold, narrow, or redirect may become feasible	Continue or redirect
Clinical exception	Severity may justify treatment	Delay is not misuse	Safety is case-specific	Result is not absolute
Re-entry point	Review alternatives	Reassess later	Monitor response	Reassess diagnosis
Basis	Proposed	Proposed	Proposed	Proposed

Veterinarian knowledge and beliefs

Knowledge was relevant but insufficient to explain stewardship behaviour. A systematic review of veterinary surveys found recurring variation in knowledge, attitudes, and practices, alongside heterogeneity in how these constructs were measured [11]. Qualitative work on antimicrobial selection indicated that veterinarians integrate prior experience, perceived risk, diagnostic uncertainty, and practical considerations when choosing drug, dose, and duration [14]. The synthesis therefore treats knowledge as one component of professional capability rather than a universal mechanism. Beliefs about disease severity, therapeutic risk, client acceptance, and alternatives may determine whether knowledge becomes action. Educational deficits and implementation deficits should consequently remain analytically distinct.

Prescribing habits and clinical uncertainty

Behavioural evidence supported a conditional account of prescribing habits. A qualitative COM-B analysis in Bangladesh linked antimicrobial decisions to interacting capability, opportunity, and motivation rather than knowledge alone [19]. A livestock meta-ethnography identified recurring but context-dependent professional, social, and structural influences [20]. Focus-group evidence from livestock veterinarians showed that beliefs and practical feasibility can coexist as determinants of antibiotic use [21]. Companion-animal evidence from Hong Kong added a contrasting environment in which prescribing reflected professional judgment and contextual constraints [22]. Habits are therefore interpreted as learned responses reinforced by uncertainty and local norms, not fixed clinician traits. Genuine clinical indication remains a rival explanation for apparently conservative or broad empirical treatment.

Client expectations

Client and farmer expectations entered the program theory through negotiation, trust, perceived demand, affordability, and feasibility of recommended care. Singapore mixed-method evidence showed that antimicrobial decisions are embedded in consultation and practice context rather than isolated technical choices [17]. The proposed mechanism is relational: clinicians may anticipate acceptance, conflict, adherence, or financial difficulty when recommending diagnostics, delayed treatment, narrower therapy, or non-antimicrobial management. This does not establish that clients cause inappropriate prescribing or that veterinarians accurately perceive preferences. The same prescription could reflect clinical necessity, explicit demand, anticipated demand, concern about follow-up, or attempts to maintain a workable therapeutic relationship.

Practice organization

Practice organization can determine whether stewardship resources become routine action. Singapore mixed-method evidence indicates that prescribing occurs within a wider implementation environment rather than solely at the individual-clinician level [17]. The proposed organizational mechanism is distributed capability: information gathering, diagnostics, communication, dispensing, follow-up, and reinforcement of local norms may be shared across a veterinary team. Where roles, records, escalation routes, and feedback are coherent, stewardship may be easier to enact; where fragmented, knowledgeable prescribers may still face friction or inconsistent signals. Organizational structure should therefore be interpreted as a context modifying opportunity and accountability, not as evidence that larger or better-resourced practices are intrinsically better stewards.

Consultation time

Time constraints matter when prudent prescribing requires explanation, diagnostic discussion, negotiation, or follow-up. Nigerian livestock evidence identified resource limitations and client expectations as barriers to antimicrobial-resistance management [23]. Singapore research on shared decision-making showed that antibiotic choices are negotiated within veterinarian–client interactions [24]. United States support-staff data indicated that stewardship-related work extends beyond the prescriber, although involvement does not prove an effect on antimicrobial use [25]. Qualitative companion-animal research also identified practice-system barriers and potential solutions [26]. Time is therefore proposed as an enabling or constraining context: additional minutes matter only when they permit explanation, deliberation, coordination, or diagnostic planning capable of altering the feasible decision.

Economic pressures

Economic pressures differ between pet care and production medicine, but both can narrow stewardship options. In companion-animal practice, diagnostic affordability and owner capacity may affect whether uncertainty can be resolved before treatment [17]. In livestock systems, costs can include diagnostics, prevention, housing changes, alternatives, production losses, and consequences of delayed control. The realist implication is not that financial incentives necessarily promote antimicrobial prescribing. Rather, cost structures can determine which resources are actionable and which risks clinicians or producers will accept. Economic context therefore interacts with diagnostic access, disease burden, client or farmer preferences, and regulation, and should not be reduced to a single presumed commercial motive.

Guideline availability

Guidelines appeared most plausible as stewardship resources when they reduced uncertainty and decision friction in the prescribing setting. Multinational evidence showed variation in awareness and use of companion-animal guidelines and strong interest in integration with patient-management systems [1]. Institutional evaluation demonstrated that guidance can alter selected prescribing endpoints, although changes remain setting-specific [12]. Performance-indicator work further showed that adherence must be translated into observable behaviours rather than inferred from guideline existence [13]. The proposed distinction is therefore between guideline presence and guideline usability. Local relevance, accessibility, workflow integration, credible recommendations, and feasible alternatives may determine whether guidance activates professional confidence and normative alignment or remains informational background.

Regulation and policy

Regulation can alter prescribing incentives and accountability, but effects depend on the surrounding system. Danish pig-veterinarian research identified legislation alongside financial constraints, limited alternatives, housing conditions, and diagnostic needs, while reporting perceived unintended changes in antimicrobial-class use [27]. United Kingdom bovine respiratory disease evidence showed that clinical assessment, experience, resistance concerns, and veterinarian–farmer relationships coexist within treatment decisions [28]. A Dutch stepped-wedge program supporting adherence to a *Streptococcus suis* guideline reduced farm-level antimicrobial use while some process indicators remained unchanged [29]. Australian dairy evidence further demonstrates that antimicrobial practice is embedded in production and veterinary-management context [30]. Regulation is therefore one component of a wider stewardship system rather than an independently sufficient mechanism.

Table 3 presents stewardship mechanisms, enabling infrastructure, and displacement risks across regulatory instruments.

Table 3. Stewardship mechanisms, enabling infrastructure, and displacement risks across regulatory instruments

Regulatory instrument	Mechanism used	Infrastructure and context	Prescribing response	Displacement or confounding risk	Evaluation design
Limited control	Low accountability	**Conditions:** Local norms **Evidence:** Voluntary practice	Practice-led response	Regulation is not sole stewardship route	**Review:** Review governance **Basis:** Proposed
Guidance	Norm setting	**Conditions:** Usability; alternatives **Evidence:** Recommendation uptake	Selective adherence	Guidance does not prove change	**Review:** Review barriers **Basis:** Proposed
Benchmarking	Feedback	**Conditions:** Data infrastructure **Evidence:** Prescribing comparison	Norm-oriented response	Secular trends may confound	**Review:** Track longitudinally **Basis:** Proposed
Restriction	Constrains choices	**Conditions:** Disease burden; substitutes **Evidence:** Class controls	Use may fall or redistribute	Substitution possible	**Review:** Track class and total use **Basis:** Proposed
Policy plus alternatives	Aligns accountability and opportunity	**Conditions:** Diagnostics; prevention; management **Evidence:** Multiple supports	Coordinated response plausible	Component effects uncertain	**Review:** Test mechanisms **Basis:** Proposed

Context–mechanism–outcome configurations

Eight refined configurations emerged as proposed explanatory patterns: diagnostic actionability, locally usable guidance, uncertainty and habitual risk management, client or farmer negotiation, team capability, economic feasibility, regulatory accountability, and intervention–barrier fit. These configurations are not mutually exclusive. One consultation may activate several simultaneously, and the same context can support different reasoning depending on disease severity, experience, alternatives, or perceived consequences. Outcomes were interpreted at the level actually measured—prescribing, drug-class choice, adherence, antimicrobial use, or intention—rather than translated into unmeasured clinical or public-health benefit. Rival explanations, particularly case mix, secular change, self-report, and intervention co-components, remain part of each configuration rather than residual methodological detail.

Refined program theory

The refined program theory proposes that veterinary antimicrobial stewardship influences prescribing when stewardship resources become credible, feasible, and actionable within the clinician's decision environment. Diagnostic access may activate confidence; usable guidance may activate normative clarity; team organization may increase opportunity; communication may support negotiated acceptance; feasible alternatives may reduce perceived therapeutic risk; and regulation may strengthen accountability. Conversely, delayed diagnostics, severe uncertainty, client or production constraints, fragmented workflow, or poorly matched policy can prevent the intended mechanism from activating or redirect behaviour toward another antimicrobial choice. These relationships remain proposed and context-dependent. Prescribing outcomes can also feed back through audit, experience, client expectations, and policy responses, altering the context for later decisions.

The resulting program theory is visualized below to preserve competing configurations, boundaries, and feedback.

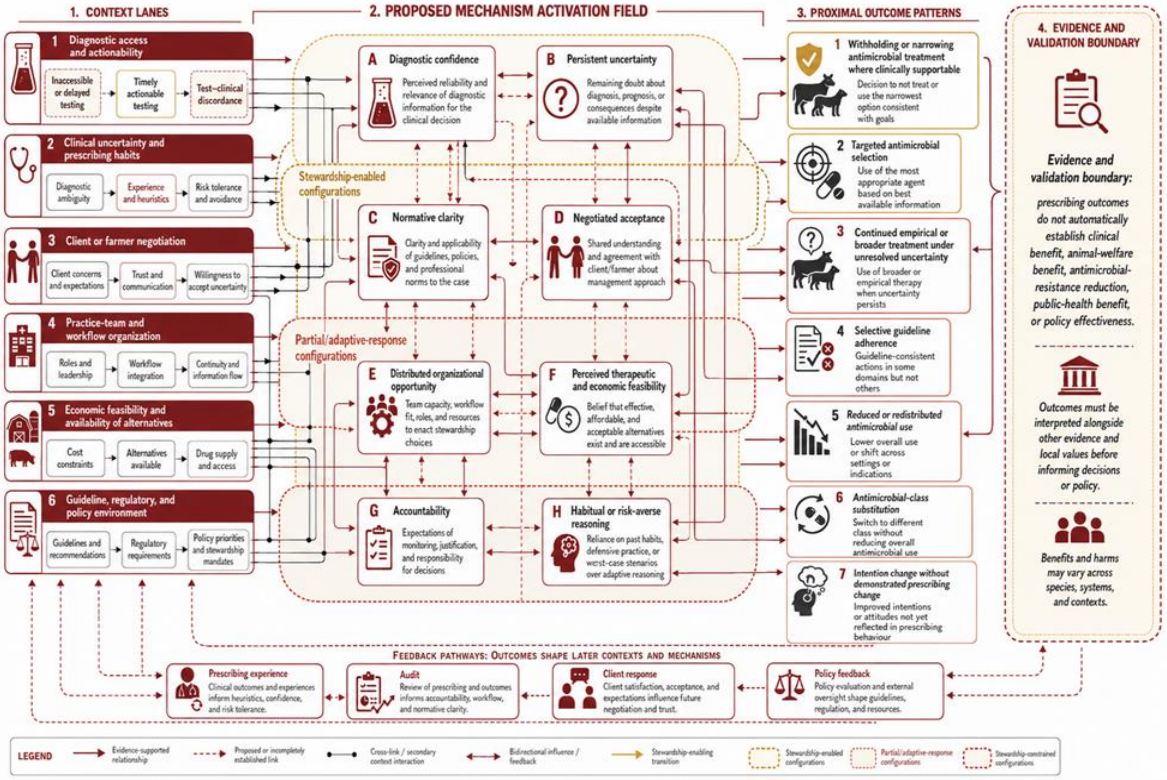

Figure 1. Conditional Activation and Failure Pathways in Veterinary Antimicrobial Stewardship

Discussion

The synthesis explains inconsistency in veterinary stewardship evidence without assuming that one intervention is universally effective or ineffective. Similar resources can produce different responses because they encounter different combinations of disease risk, diagnostic capacity, professional reasoning, client or farmer relationships, organizational support, economic feasibility, and policy constraints. The review also separates outcome levels. A change in awareness, intention, adherence, antimicrobial class, or total use does not automatically demonstrate

improved animal health, welfare, resistance patterns, or public-health outcomes. The refined program theory therefore shifts attention from intervention labels to mechanism activation under specified contexts. Its value is explanatory and hypothesis-generating: it identifies configurations for comparative evaluation but does not establish a validated causal architecture or justify implementation without local clinical and system assessment.

Why similar stewardship interventions produce different outcomes

Evidence from distinct intervention and social contexts illustrates why similar stewardship strategies can diverge. Research on the social significance of animals suggests that care expectations may vary with how animals are valued within particular relationships and systems [31]. Continuing-education evidence from Quebec indicates that educational effects are bounded by determinants beyond information provision [32]. Veterinary-team research identifies technicians as a potential stewardship resource without establishing an independent prescribing effect [33]. A 2026 educational study increased veterinarians' stated intention to avoid antimicrobials for canine acute diarrhoea, but intention—not prescribing—was measured [34]. Across intervention studies, outcome differences therefore require interpretation at the level actually observed rather than conceptual pooling [29, 32, 34].

Implications for intervention design

The findings support a proposed design principle: diagnose the dominant contextual constraint before selecting a stewardship resource. Education is unlikely to resolve a problem driven primarily by diagnostic unavailability, unaffordable alternatives, workflow fragmentation, or regulatory incentives. Restrictive policy may likewise produce limited or unintended adaptation when clinicians lack credible alternatives or timely information. Multicomponent programs may be appropriate where several mechanisms must be activated together, but their complexity makes component attribution difficult [29]. Intervention design should therefore specify the intended context, resource, mechanism reasoning, proximal outcome, rival explanation, and safety boundary in advance. This architecture is not implementation-ready guidance; it is a testable way to align stewardship strategies with the barriers they are intended to change.

Transferability across veterinary settings

Transferability should be judged by similarity of context–mechanism relationships rather than intervention labels. Livestock synthesis shows that prescribing mechanisms recur across settings but change meaning under different production, professional, and social conditions [20]. Danish pig evidence highlights regulatory and infrastructural constraints that may not apply to companion-animal clinics [27]. Bovine respiratory disease decisions likewise depend on disease-specific clinical and farmer contexts [28]. The Dutch *Streptococcus suis* program supports a context-matched intervention but does not establish that the same package will perform similarly elsewhere [29]. Social valuation of animals adds another contextual layer [31]. Replication should therefore test whether the hypothesized mechanism is activated locally instead of assuming that an intervention can simply be transported.

Limitations

Several limitations constrain the synthesis. Earlier Dutch qualitative evidence remains useful for identifying client, uncertainty, and professional mechanisms, but these may have shifted with newer stewardship infrastructure [35]. United Kingdom mixed-method research triangulates clinical and reported decision processes, yet observational and self-reported evidence cannot establish a causal hierarchy among drivers [36]. COM-B evidence from Irish dairy practice supports behavioural interpretation while underscoring that livestock mechanisms cannot be transferred uncritically to companion-animal care [37]. Swiss intervention evidence shows disease-specific prescribing change under stewardship, but external validity remains bounded by clinical condition, country, and implementation setting [38]. The web-indexed search strategy was also less exhaustive than a conventional multi-database export, so eligible evidence may have been missed.

Conclusion

Veterinary antimicrobial stewardship appears to depend on whether evidence, guidance, diagnostics, relationships, organizational capacity, economic feasibility, and policy conditions make prudent prescribing actionable in a particular setting. The proposed realist program theory explains variation through conditional mechanism activation rather than a universal intervention hierarchy. It distinguishes prescribing outcomes from

clinical, welfare, resistance, and public-health effects and preserves important species and system boundaries. Prospective comparative studies are needed to test, refine, or reject the proposed configurations before they are used as generalized intervention rules.

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