

The Meta-Analysis Ecosystem Model: evidence velocity, effect decay, and a Future-Proof Index across 501 Cochrane reviews

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Summary

Does the magnitude of early meta-analytic effects systematically decay as evidence accumulates across the Cochrane Library? The Meta-Analysis Ecosystem Model analysed 3,651 trajectories from 501 Cochrane reviews (≥ 5 studies each) over a median 16-year span; 2,817 of 3,062 computable trajectories gave a finite, in-range decay ratio (834 excluded as undefined or >10). It applies cumulative fixed-effect meta-analysis to binary outcomes, which understates heterogeneity, and integrates velocity, decay, and stability with publication-bias scores into a Future-Proof Index (0–100). Among the 2,817 the median decay ratio was 0.66 (IQR 0.32–1.23), 67.3% shrinking; of 3,062, 25.1% reversed sign but only 3.4% meaningfully. Decay was independent of velocity ($r=-0.002$) and bias ($r=+0.001$)—not a scaling artefact—though velocity and bias correlated weakly ($r=-0.19$). Two-thirds of pooled effects shrank as evidence matured, so early meta-analytic results should not be treated as definitive. The decay ratio is sensitive to the fixed-effect choice, and the Future-Proof Index is an expert-weighted heuristic, not a validated instrument.

Estimand and inclusion

The primary estimand is the effect-decay ratio, $|\text{final cumulative effect}| / |\text{early cumulative effect}|$, on the log-odds-ratio scale. Each analysis group with at least five dated studies yields a cumulative trajectory (3,651 from 415 reviews); groups with binary data and at least six valid effect sizes yield a cumulative fixed-effect decay trajectory (3,062 from 381 reviews). The decay-ratio distribution is summarised over the 2,817 trajectories with a finite, in-range ratio (early pooled $|\log\text{OR}| > 0$ and ratio ≤ 10); 834 of the 3,651 were excluded for having no computable trajectory, an undefined ratio (early effect ≈ 0), or an implausibly large ratio (>10). Direction-reversal rates are reported over the full 3,062 decay trajectories, because a sign reversal is defined whenever early and final effects exist.

Results

The median decay ratio was 0.66 (IQR 0.32–1.23); 67.3% of the 2,817 ratios fell below 1 (shrinkage) and 39.0% below 0.5. Across the 3,062 decay trajectories, 769 (25.1%) reversed sign, but only 105 (3.4%) did so with both early and final $|\log\text{OR}| > 0.2$ (clinically meaningful). Decay is uncorrelated with velocity (Pearson $r = -0.002$) and with publication bias ($r = +0.001$); the only non-trivial pairwise association is a weak velocity–bias correlation ($r = -0.19$, Spearman $\rho = -0.36$). Because Pearson correlation is scale-invariant, the near-zero values are not an artefact of differing scales, and rank correlations confirm decay's independence ($\rho = -0.05$ with velocity, $+0.08$ with bias).

Distribution of effect-decay ratios across 2,817 meta-analytic trajectories

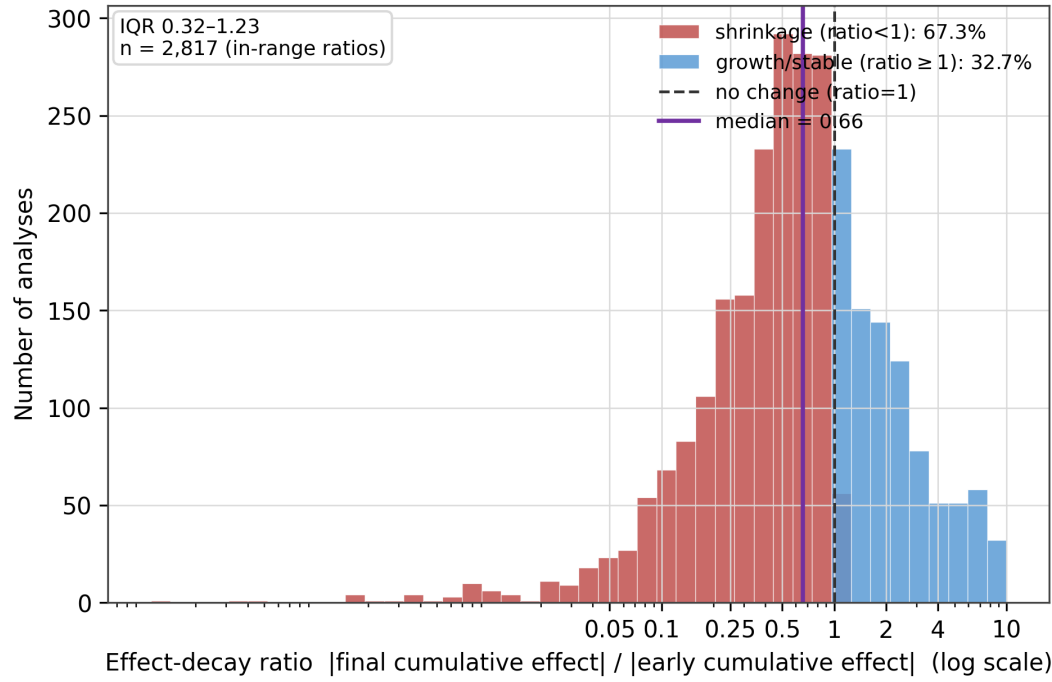
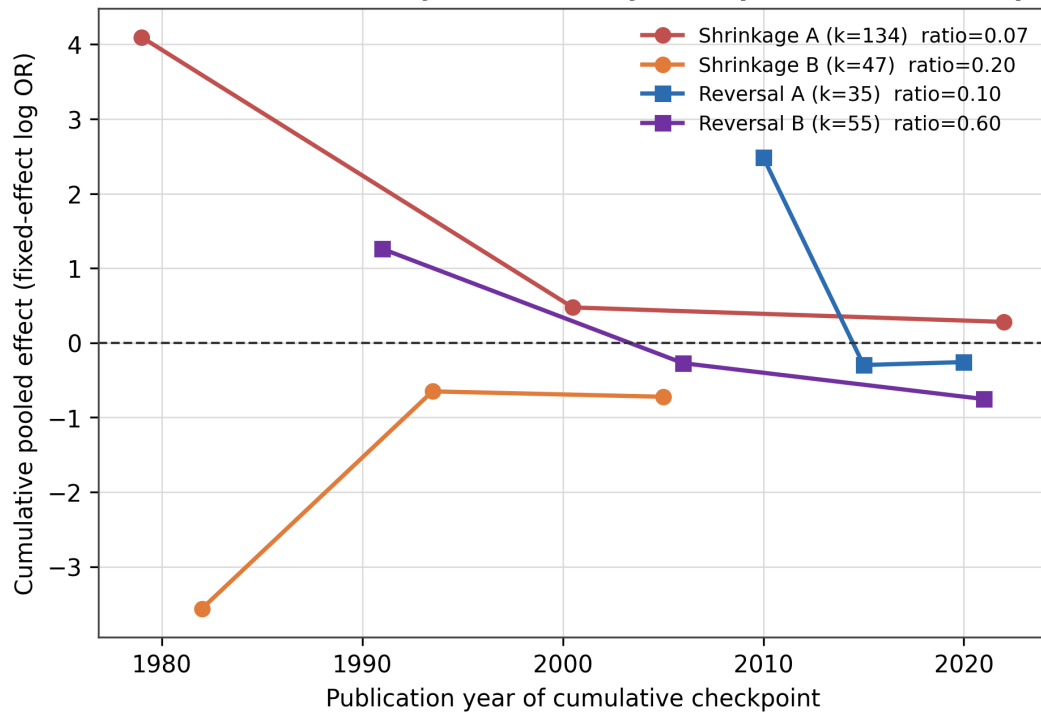


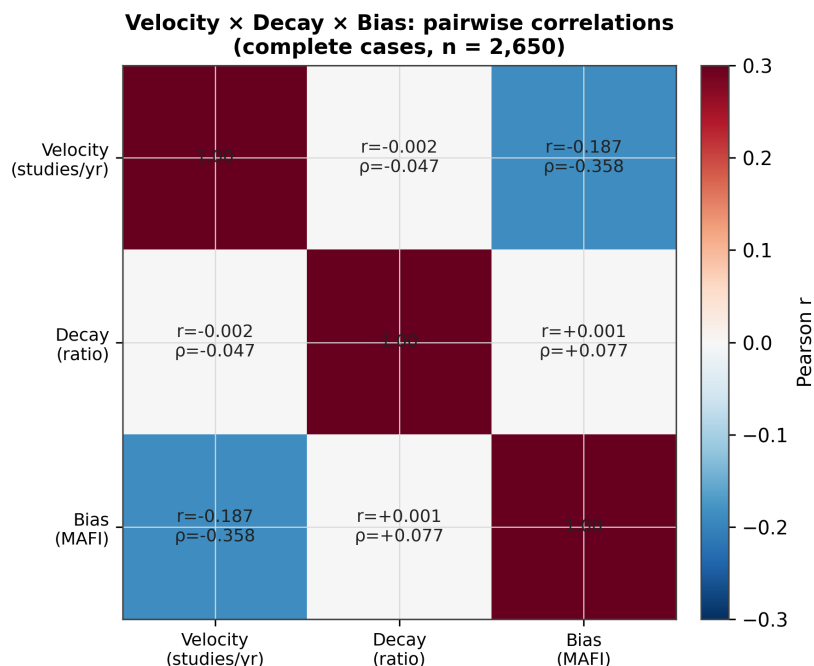
Figure 1. Distribution of the 2,817 in-range effect-decay ratios (log scale). Median 0.66; 67.3% lie below the no-change line at 1.0 (shrinkage).

Real cumulative-effect trajectories: early → midpoint → final checkpoints



Points are the three cumulative fixed-effect estimates recorded per analysis (after 3 studies, midpoint, all studies).

Figure 2. Real cumulative-effect trajectories at their three recorded checkpoints (after 3 studies, midpoint, all studies): two shrinkage cases and two sign reversals (the cumulative pooled log OR crosses zero).



Decay is independent of velocity ($r=-0.002$) and bias ($r=+0.001$), $|r|<0.01$.
The only non-trivial pair is velocity–bias ($r=-0.19$, $\rho=-0.36$).

Figure 3. Pairwise correlations among velocity, decay and bias (complete cases, $n = 2,650$). Decay is independent of both ($|r| < 0.01$); the only non-trivial pair is velocity–bias ($r = -0.19$, $\rho = -0.36$).

Modeling choices and limitations

Two deliberate modeling choices bound interpretation. First, the cumulative pool is fixed-effect inverse-variance, with no between-study variance term; this is standard for decay-trajectory work but understates heterogeneity, and the decay ratio is sensitive to the choice. Second, the Future-Proof Index combines four components (sample-size adequacy, publication-bias score, trajectory stability, decay magnitude) with expert-assigned weights (0.30, 0.25, 0.25, 0.20); these weights were not empirically optimised or validated, and a sensitivity analysis shows class shares shift materially under alternative weightings. The Future-Proof Index is therefore a transparent heuristic for triage, not a calibrated risk instrument. The analysis is restricted to binary outcomes with sufficient cumulative depth, and 834 of 3,651 trajectories were excluded for lacking a computable, in-range decay ratio.

The Meta-Analysis Ecosystem Model

Evidence velocity · effect decay · a Future-Proof Index across the Cochrane Library

QUESTION

Does the magnitude of early meta-analytic effects systematically decay as evidence accumulates across the Cochrane Library?

METHOD

3,651

cumulative trajectories

501

Cochrane reviews (≥ 5 studies)

2,817

with a defined decay ratio

Cumulative *FIXED*-effect meta-analysis on binary outcomes + Future-Proof Index (0-100)

HEADLINE RESULT

median decay ratio = 0.66

(IQR 0.32-1.23)

Two-thirds of pooled effects shrank as evidence matured.

67%

shrank (ratio < 1)

25%

reversed direction

3%

clinically meaningful

Decay is an independent dimension: uncorrelated with velocity ($r = -0.002$) and bias ($r = +0.001$).

READ WITH CARE

- ▶ Fixed-effect pooling is a deliberate choice that UNDERSTATES between-study heterogeneity; the decay ratio is sensitive to it.
- ▶ The Future-Proof Index is an expert-weighted HEURISTIC, not an empirically validated or optimised instrument.
- ▶ 834 of 3,651 trajectories lacked a defined/in-range decay ratio (excluded).

Early meta-analytic results should not be treated as definitive.

Primary estimand: effect-decay ratio · Data: 501 Cochrane reviews (Pairwise70) · Synthesis E156

Visual abstract. Question, method, headline result and read-with-care caveats.

References

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Data and code: <https://github.com/mahmood726-cyber/mem-ecosystem-model>. All numbers reproduced from the derived CSVs and independently re-computed (see package VERIFICATION.md). Primary estimand: effect-decay ratio.

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