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From modelling to description: a scientometric analysis of four decades of farm-level economic assessment in shrimp aquaculture

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Abstract

In shrimp aquaculture, methods for judging economic performance range from cost-and-profit arithmetic to discounted cash flow, efficiency frontiers and bioeconomic models. We ask how farm-level economic assessment has been conducted, which decision indicators are actually reported, and whether the field has matured towards analyses useful for investment. We combined a systematic search with scientometric mapping across Scopus and the Web of Science Core Collection, with no start-year restriction. Of 2,893 records identified, 2,000 remained after deduplication and 413 were included. The corpus tripled between 2010–2019 and 2020–2026, from 9.8 to 29.3 studies per year. An index counting the formal economic instruments each paper applies declines over time (Spearman's $\rho = -0.110$; $p = 0.025$). The decline is a composition effect, not a degradation: modelling fell from 54.2% to 10.2% of the corpus ($\rho = -0.338$; $p < 0.001$), displaced by experimental trials and farm surveys, while within every design depth does not fall. Adjusted for design, the year effect reverses sign (+0.009 points per year; $p = 0.032$). The declines in discounted cash flow and in uncertainty treatment likewise vanish under adjustment. Only 8.5% report net present value and 1.0% payback, and 85.2% remain deterministic. The field has not forgotten how to appraise investment: it has stopped producing the kind of study in which appraisal is done. We propose a minimum reporting set aimed at trials and surveys, today almost nine tenths of the literature.

Keywords Scientometrics · Bioeconomic modelling · Composition effect · Investment appraisal · Reporting standards · Technical efficiency

Clinical trial number: not applicable.

1 Introduction

Aquaculture now supplies the greater part of the world's aquatic food, and farmed crustaceans are among its highest-value groups. The Pacific white shrimp, *Penaeus vannamei* (Boone, 1931), alone reached 5.8 million tonnes in 2020, the most produced aquatic species reported by FAO that year (FAO 2022). The expansion of shrimp farming came with deep changes in production intensity, feed and energy use, health management, water exchange, recirculation, biofloc technology and inland production. These changes have made economic performance more dependent on the interaction between biological efficiency, scale, input prices, farm-gate price and capital requirements.

Economic analysis has accompanied shrimp farming since the pioneering studies of production economics, costs and returns, hatchery budgets and the viability of penaeid and freshwater prawn production (Shang et al. 1998; Ponce-Palafox et al. 2011). As early as 2001, Neiland and colleagues argued that economic perspectives were central to policy development for the sector (Neiland et al. 2001). The toolkit has broadened since: farm-level studies today use profitability measures, benefit–cost ratios, discounted cash flow indicators, data envelopment analysis, stochastic frontiers, bioeconomic optimisation, sensitivity analysis and, increasingly, explicit risk models (Cozer et al. 2020; Knowler et al. 2020; Domínguez-May et al. 2024).

Along the way the literature also specialised, and reviews came to examine energy efficiency on shrimp farms (Cozer et al. 2020), the economics of integrated multi-trophic aquaculture (Knowler et al. 2020), dynamic optimisation in aquaculture production economics (Domínguez-May et al. 2024), sustainability differences between production models (Uddin et al. 2025; Wang et al. 2026) and the methodological fragmentation of shrimp life cycle assessments (Calvo et al. 2026). These syntheses show that economic performance came to be discussed alongside environmental and social sustainability, yet none of them offers a global account of how farm-level economic assessment itself has been conducted.

The distinction matters because "economic performance" is not a single outcome. A farm may report a positive gross margin without remunerating the capital invested; a technically efficient farm may be financially unattractive at prevailing prices; and a positive net present value computed deterministically may conceal substantial downside exposure when survival, feed conversion, harvest

weight, cycle length or price are uncertain. Comparison across studies becomes harder still when fixed investment, depreciation, financing, discount rate, working capital, opportunity cost or the shrimp price–size relationship are omitted or treated inconsistently.

The question of this article is whether the recent growth of the economic literature on shrimp farming has been accompanied by a gain in methodological depth, or whether the field has grown in volume without gaining capacity to inform investment decisions. From it derive four specific questions: (1) how the volume and geographical distribution of the literature have evolved; (2) which economic methods and indicators are actually used; (3) how often studies distinguish operating profitability from investment viability and treat uncertainty explicitly; (4) which reporting gaps currently limit comparison, transferability and managerial use.

The review is a mapping exercise and did not start from pre-specified hypotheses. The analysis stratified by study design, which underpins the central finding, was incorporated as a robustness test after the first complete analysis, and is declared as such in the PRISMA checklist accompanying the supplementary material. The aim is to offer a practical framework for strengthening economic assessment in shrimp production, in the form of a minimum reporting set that editors and reviewers can verify from the manuscript itself.

2 Materials and methods

2.1 Design and protocol

The study was conducted as a scientometric analysis of a corpus assembled by systematic search. Its object is the methodological practice of the literature, coded record by record, rather than a pooled estimate of an economic effect. The identification, screening and selection of records follow PRISMA 2020 (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*, 2020 version), adopted here as the reporting standard for the search, because it sets out what a search-based study must declare in order to be auditable and reproducible (Page et al. 2021). PRISMA organises the process into four stages, identification, screening, eligibility and inclusion, and requires the number of records retained and discarded at each stage to be reported together with the corresponding reasons, which is done in Sect. 3.1 and in Fig. 1. The 27-item PRISMA 2020 checklist, completed with the location of

each item in this manuscript, accompanies the supplementary material. The scientometric layer is descriptive and relational; substantive conclusions about economic practice rest exclusively on the screened corpus of primary studies, not on the raw retrieval.

2.2 Information sources and search strategy

Scopus and the Web of Science Core Collection were searched on 17 September 2026. No restriction on starting year or language was imposed at identification. The search combined terms for farmed shrimp and prawns with terms for farm economics, profitability, financial viability, cost–benefit analysis, investment appraisal, efficiency, bioeconomics and risk. The literal expressions used in each database are given in Appendix I and in the open repository.

Coverage is therefore that of the internationally indexed literature. Work published outside Scopus and the Web of Science, in particular in national journals and in languages other than English, is not represented, and the anglophone concentration this produces is quantified in Sect. 3.2.

Of the 2,000 unique references, 881 (44.0%) were present in both databases, 751 (37.5%) only in Scopus and 368 (18.4%) only in the Web of Science, which shows that merging the two is not redundant. A design anchored in a single database would therefore lose between a fifth and a third of the eligible material.

2.3 Eligibility criteria

We included primary studies that examined farmed shrimp or prawns and quantified at least one farm-level or production-level economic outcome: production cost, revenue, profit, gross or net margin, benefit–cost ratio, break-even point, net present value, internal rate of return, payback, economic efficiency, technical or allocative efficiency linked to production economics, or a formal bioeconomic or economic risk outcome.

We excluded studies in which shrimp appear only as raw material, by-product or feed ingredient; studies of capture fisheries, stock enhancement, processing, consumer behaviour or trade without farm economics; and studies with biological, nutritional, health or environmental outcomes lacking a quantified economic component. Reviews, textbooks and syntheses without their own primary data

were retained as a contextual set, analysed separately and never mixed with the primary corpus in the methodological frequencies.

2.4 Auditable lexical pre-filter

The raw retrieval was reduced by a documented lexical pre-filter, designed for maximum sensitivity and applied to title, abstract and keywords. The pre-filter requires (i) that shrimp or prawn be the object of the study (term present in the title, in the author keywords, or with at least two occurrences in the abstract) and (ii) the presence of any economic signal, however generic. The complete dictionaries, as regular expressions, accompany the repository.

Because it is a workload-reduction step and not an inclusion decision, the pre-filter had its sensitivity estimated against a stratified random sample of 150 records coded by reading, and no eligible record was lost (sensitivity of 100%). Applied to the 1,978 records eligible by document type, the pre-filter retained 1,102 candidates and discarded 876, of which 546 did not have farmed shrimp as their object and 330 contained no economic signal at all.

We also tested whether a more elaborate lexical classifier could replace reading. A version requiring strong economic vocabulary or a formal methodological family reached a sensitivity of 0.890, but a precision of only 0.476 when set against the reading-based decision on the 1,102 candidates. In other words, more than half of the records that a lexical classifier would label "economic" are not: economic vocabulary appears incidentally in studies whose object is disease, nutrition, water quality or engineering. This is the methodological reason why screening cannot be automated in this field, and it is also a substantive result in its own right.

2.5 Screening and extraction

The 1,102 candidates were assessed individually by reading title, abstract and keywords. For each record we coded the domains listed in Table 1: inclusion decision; reason for exclusion in eight categories; methodological family; study design; economic indicators reported; and level of uncertainty treatment. Records without an abstract (13 cases) were decided on title and outlet.

Coding consistency was estimated by blind test-retest: the 150 records of the stratified sample had been coded in a first pass, independently and in a different order, before the full screening. Observed

agreement between the two passes was 98.7% (148 of 150), with Cohen's κ of 0.962. This is **intra-rater** reliability (test-retest), not agreement between independent reviewers: it measures the stability with which one person applies the protocol at two moments, and does not remove systematic interpretation error common to both passes.

Once screening was complete, the full set of 419 included records was re-checked by a second reviewer, working from the same title, abstract and keyword material and with access to the reason recorded in the first pass. The re-check altered no inclusion decision, and the matrix analysed corresponds to the set confirmed by both reviewers. Exclusion decisions remain covered by the test-retest estimate described above.

Two consequences of this material follow for the reading of the results. Because the evidence is what each study declares in title, abstract and keywords, the frequencies reported here are estimates of declared salience and constitute a lower bound on presence in the full text: a study may apply a discount rate without announcing it in the indexing material. The relative frequencies between categories, which carry the comparative conclusions, are less sensitive to this than the absolute levels. And because independent double coding of all 1,102 candidates was not performed, the reliability of the attributes coded among the excluded records was not measured directly; the complete record-by-record decision matrix is deposited for audit.

The methodological families were defined as: (F1) budget and costs–returns, including enterprise budgets, cost structure, margins and benefit–cost ratios; (F2) discounted cash flow, including net present value, internal rate of return, payback and capital budgeting; (F3) efficiency frontier, including data envelopment analysis, stochastic production and cost frontiers, and total factor productivity indices; (F4) bioeconomic modelling and optimisation, including mathematical programming, optimal control and decision models coupling biology and economics; (F5) risk and uncertainty, including Monte Carlo simulation, stochastic dominance, outcome probability distributions and formal risk analysis. The families are not mutually exclusive.

Uncertainty treatment was coded on an ordinal ladder: 0, deterministic; 1, sensitivity analysis; 2, scenario analysis; 3, stochastic or probabilistic treatment.

Table 1 Extraction and coding domains applied to the 1,102 records submitted to reading-based screening.

Domain	Coded categories	Analytical purpose
Eligibility decision	Include; exclude (eight reasons)	PRISMA flow and characterisation of the boundary of the field
Methodological family	Budget and costs–returns; discounted cash flow; efficiency frontier; bioeconomic modelling; risk and uncertainty (not mutually exclusive)	Distinguish operational, investment, efficiency and risk assessment
Study design	Farm survey; experimental; model or simulation; operating commercial farm	Identify the structural origin of methodological depth
Indicators reported	Production cost; margin or profit; benefit–cost ratio; break-even point; efficiency score; NPV; IRR; payback; risk distribution	Measure the decision funnel of the literature
Uncertainty treatment	0 deterministic; 1 sensitivity; 2 scenarios; 3 stochastic	Ordinal ladder of variability propagation to the outcome
Financial conventions	CAPEX; depreciation; discount rate; opportunity cost; working capital; financing; price–size relationship; currency and base year	Assess comparability and reproducibility of results
Context	Study country; region; species; production system; outlet; year; citations	Scientometric layer and analysis of asymmetries

2.6 Methodological depth index

To allow comparison across periods, regions and systems, we built a composite methodological depth index ranging from 0 to 6, adding one point for each of the following attributes: presence of discounted cash flow; presence of an efficiency frontier; presence of bioeconomic modelling; presence of formal risk analysis; any uncertainty treatment above deterministic; and reporting of three or more distinct economic indicators. The index is deliberately simple, additive and unweighted: it treats the presence of an efficiency frontier and of discounted cash flow as equivalent, although they answer distinct questions. It measures the breadth of economic instrumentation, not the quality of execution. Its correct reading is comparative, not absolute.

2.7 Analysis

Analyses were carried out in Python 3.11 (pandas, SciPy, matplotlib). Temporal trends were tested by Spearman correlation and linear regression; differences in proportion between periods by Pearson's chi-square; differences in depth between regions by Kruskal–Wallis with pairwise Mann–Whitney comparison.

Because study design is a strong predictor of depth and its share of the corpus varies over time, every temporal trend was submitted to a two-step robustness test. First, the trend was recalculated within each design stratum holding at least 25 studies. Second, a linear model was fitted with year of publication and design indicator variables, comparing the year coefficient before and after adjustment.

The same procedure was applied to the regional comparison. This pair of analyses separates a change in the practice of each type of study from a change in the composition of the set of studies, which are substantively different interpretations of the same aggregate figure. Two properties of this adjustment should be kept in view when reading the coefficients. It rests on the coding of study design, which is itself derived from title, abstract and keywords; misclassification in that variable would attenuate the adjustment and bring the adjusted coefficient closer to the crude one, which makes the observed result conservative, since the adjusted coefficient does not merely vanish but reverses sign. And the adjustment is observational: it controls composition by design, not every unmeasured determinant that may have varied alongside it, such as the availability of farm microdata.

The study country was extracted from the text of the abstract and title, with affiliation as a fallback when the study location was not identifiable; this choice avoids attributing the geography of the production system analysed to the host institution. The co-occurrence network uses author keywords, kept in their original language. Journal names were normalised for case and spacing before any count, because Scopus and the Web of Science render the same title differently; without this step, four journals in the corpus would appear split across two entries each, with their frequencies undercounted.

2.8 Reproducibility

The deduplicated bibliographic database, the eligibility matrix with record-by-record decisions, the pre-filter dictionaries and the analysis and figure-generation scripts are deposited in an open repository under DOI 10.5281/zenodo.23344245. The analysis reproduces exactly from the deposited files. Raw database exports are retained in accordance with the licensing conditions of the sources.

2.9 Use of generative artificial intelligence

A generative artificial intelligence tool (Claude, Anthropic; used between September and October 2026) was employed in three roles, all of them within the research design described above. The first was the writing and execution of the computational code for deduplication, lexical pre-filtering, statistical analysis and figure generation; that code is deposited in full and the analysis reproduces exactly from the deposited files, so every operation it performed is open to inspection. The second was a first-pass coding of the 1,102 screened candidates against the protocol of Sect. 2.5. That pass was not

accepted as final: its output was submitted to the blind test-retest of 150 records reported in Sect. 2.5, and all 419 included records were re-checked record by record by a second reviewer, with the complete decision matrix deposited for audit. The third was language editing, translation between Portuguese and English, and consistency checking across text, tables and figures.

No tool was used as a source of data, and none generated results, references or interpretations. The eligibility criteria, the coding rules, the analytical decisions, the numerical results, the references, the interpretations and the conclusions were defined, reviewed and validated by the authors, who take full responsibility for the accuracy, originality and integrity of the work. Artificial intelligence tools do not fulfil the role of authors and are not listed as such.

3 Results

3.1 Selection flow

The search identified 2,893 records (1,643 in Scopus and 1,250 in the Web of Science). After removal of 893 duplicates, 2,000 unique records remained; 22 were excluded by document type (erratum, retraction, editorial, letter, note, conference abstract). The pre-filter retained 1,102 candidates, of which 683 were excluded on reading and 419 included. The final corpus comprises 413 primary studies and 6 reviews with their own quantitative synthesis; a further 88 reviews and syntheses form the contextual set (Fig. 1).

The structure of the field shows through in the reasons for exclusion. The dominant category, with 314 records or 46.0% of exclusions, is studies on farmed shrimp that use economic vocabulary without quantifying any economic outcome. Next come reviews and syntheses without their own data (88), studies of policy, governance and livelihoods without an economic outcome (74), studies whose object is another species (62), environmental and ecosystem valuation studies (53), market and trade studies (38), capture fisheries and stock enhancement (29) and processing and by-products (25).

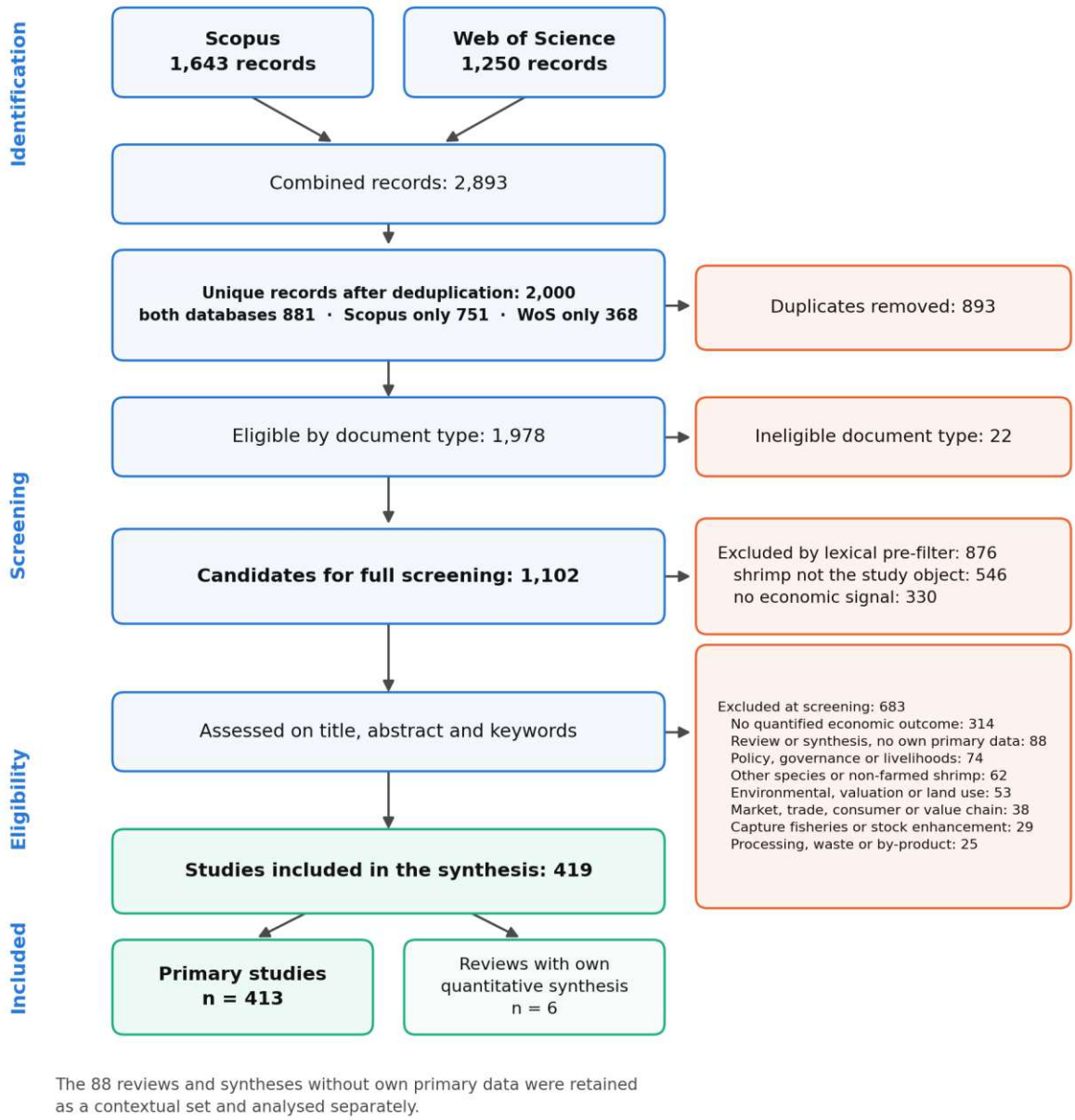


Fig. 1 Study selection flow following PRISMA 2020. The lexical pre-filter is a documented, auditable workload reduction, not an inclusion decision: its sensitivity, estimated against a stratified sample coded by reading, was 100%.

3.2 Growth of the corpus

The primary corpus spans 1977 to 2026. Half of it (205 of 413; 49.6%) was published from 2020 onwards. The annual mean of primary studies rose from 9.8 in 2010–2019 to 29.3 in 2020–2026, a threefold increase in little more than half a decade (Fig. 2a). The raw retrieval grew at the same pace, and the ratio of screened candidates to included studies remained stable, indicating that the growth is real and not an indexing artefact.

Output is concentrated in established aquaculture journals: *Aquaculture* (50 studies), *Aquaculture International* (36), *Aquaculture Research* (29), *Aquaculture Economics & Management* (27) and *Journal of the World Aquaculture Society* (19) (Engle et al. 2017). The simultaneous presence of generalist production journals and of the specialist economics journal indicates that economic questions are not peripheral to shrimp research, but are distributed across production, engineering, sustainability and economics outlets. Individual impact is modest: the median is 9 citations per study (mean 15.8) and 47 studies (11.4%) remain uncited. The most cited study in the corpus has accumulated 114 citations (Gunawardena and Rowan 2005). International collaboration rose from 12.5% of studies up to 1999 to 41.5% in 2020–2026.

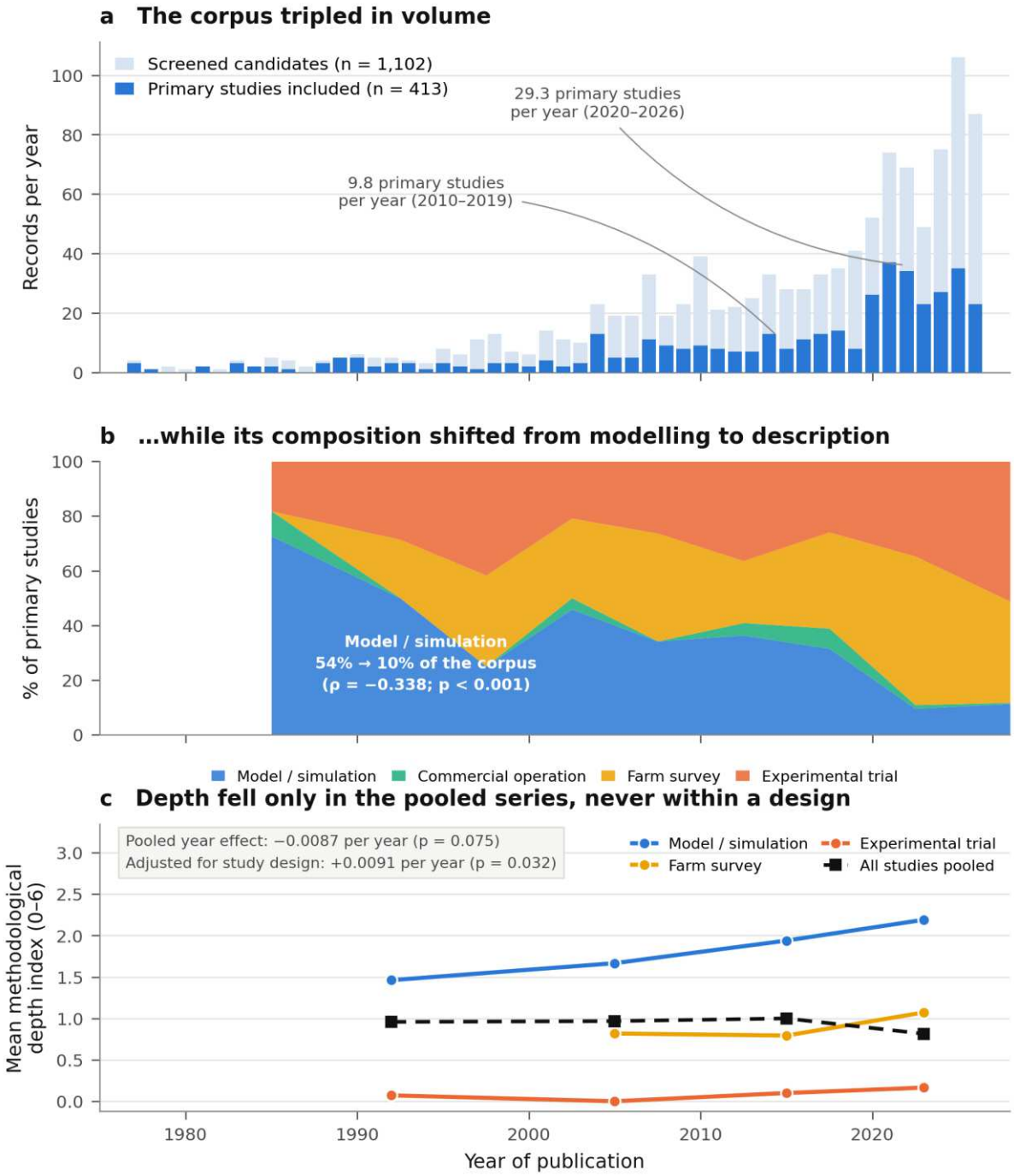


Fig. 2 Growth, composition and depth. (a) Records per year of publication: candidates submitted to reading-based screening and primary studies included. (b) Composition of the corpus by study design, in five-year bins holding at least eight studies. (c) Composite methodological depth index by period, within each design and for the pooled set; the decline appears only in the pooled series. The box gives the coefficient of year of publication before and after adjustment for study design. The last period is partial (2020–2026).

3.3 The central paradox and its origin: a change of composition

In the aggregate, the methodological depth index did not keep pace with the growth in volume. The correlation between year of publication and depth is negative and significant (Spearman's $\rho = -0.110$; $p = 0.025$), although the corresponding linear slope is modest and only marginal (−0.009 points per

year; $p = 0.075$). The mean by period was 0.96 up to 1999, 0.97 in 2000–2009, 1.00 in 2010–2019 and 0.81 in 2020–2026. Almost half of the corpus (199 studies; 48.2%) meets none of the six criteria of the index, that is, it is confined to deterministic budgeting with few indicators; only 47 studies (11.4%) meet three or more.

This aggregate reading is misleading, however, and the reason for that is what constitutes the central finding of this review. What changed over four decades was not the depth of each type of study, but the proportion between the types of study that make up the literature. The share of modelling and simulation fell from 54.2% of the corpus up to 1999 to 10.2% in 2020–2026 ($\rho = -0.338$; $p < 0.001$), while experimental trials rose from 29.2% to 41.5% ($\rho = +0.181$; $p < 0.001$) and farm surveys from 14.6% to 47.3% ($\rho = +0.141$; $p = 0.004$). The change in composition is highly significant ($\chi^2 = 68.22$; $df = 9$; $p < 0.001$) and is shown in Fig. 2b. Because mean depth differs greatly between designs, from 1.81 in modelling and 1.50 in studies on commercial farms to 0.97 in surveys and 0.12 in experimental trials, the substitution of one design for another is enough to produce a fall in the mean value of the set without any type of study having become worse.

And in none of them is there evidence of deterioration. Within each design stratum holding enough studies, the correlations between year and depth are positive and none reaches significance: experimental trials $\rho = +0.143$ ($p = 0.087$), surveys $\rho = +0.130$ ($p = 0.107$), modelling $\rho = +0.117$ ($p = 0.236$). What is to be recorded is absence of evidence of decline within each design, not evidence of improvement. In a linear model with year and design indicator variables, the year coefficient **reverses sign and becomes significant in the opposite direction**: +0.0091 points per year ($p = 0.032$; $R^2 = 0.348$), against −0.0087 ($p = 0.075$) in the unadjusted model. Fig. 2c contrasts the two readings and Table 2 gathers the tests before and after adjustment.

One alternative explanation was tested explicitly and does not hold. If the fall in depth reflected a migration of the literature towards outlets without an economic tradition, outlet category should account for it; it does not. A model with outlet category alone explains 2.2% of the variance in depth, against 34.8% for the design model, and adding outlet to design raises R^2 from 0.348 only to 0.355, with no outlet coefficient reaching significance at 5%. The year effect remains at +0.0095 per year ($p = 0.028$).

The paradox therefore dissolves and is restated in more precise terms. Shrimp farming attracted, in the first half of this decade, three times as many economic studies per year as in the preceding decade, and the average study is today analytically shallower. But this happens because the field shifted its centre of gravity from modelling towards empirical description, not because it has forgotten how to model. Those who still model do so at least as well as before; what became rare was the act of modelling itself.

Table 2 Effect of year of publication before and after adjustment for study design (n = 413 primary studies).

Outcome	Year coefficient, unadjusted (p)	Year coefficient, adjusted for design (p)	Spearman's ρ within each design
Methodological depth index (0–6)	−0.0087 (0.075)	+0.0091 (0.032)	trials +0.143; surveys +0.130; modelling +0.117
Discounted cash flow	−0.0051 (0.001)	+0.0009 (0.521)	trials constant; surveys +0.075; modelling +0.096
Efficiency frontier	+0.0056 (0.001)	+0.0022 (0.126)	trials constant; surveys +0.122; modelling constant
Any uncertainty treatment	−0.0040 (0.009)	−0.0002 (0.881)	trials −0.014; surveys −0.044; modelling −0.008

Note: coefficients from linear models; the outcome is the composite index in the first row and the presence of the attribute (0/1) in the others. The adjustment includes study design indicator variables. Among the 144 experimental trials, none applies discounted cash flow or an efficiency frontier in any period, and among the 104 modelling studies none applies an efficiency frontier; the attribute is therefore constant in those strata. None of the within-stratum correlations is significant at 5%.

3.4 Methodological substitution, not accumulation

Decomposed by methodological family (Fig. 3a), the corpus shows simple costs-and-returns budgeting to be dominant and stable, present in 86.7% of primary studies (358 of 413) and with no relevant temporal trend. On that stable base, two formal families exchanged positions.

Studies using discounted cash flow accounted for 27.1% of the corpus up to 1999 and fell to 8.3% in 2020–2026 (χ^2 = 18.03; p = 0.0004), so that investment appraisal regressed in the aggregate. The trajectory is not linear, since there was a partial recovery in 2010–2019 (21.4%), but the current level is the lowest in the series, and it is reached precisely when the volume of studies is at its maximum.

This fall, like that of the depth index, does not survive adjustment for design. The year coefficient on the presence of discounted cash flow moves from −0.0051 per year (p = 0.0006) in the crude model to +0.0009 (p = 0.52) once the design indicators are included. Within strata, the trend is null or slightly positive: surveys ρ = +0.075 (p = 0.35) and modelling ρ = +0.096 (p = 0.33); among the 144 experimental trials, no study in any period applies discounted cash flow. The aggregate fall measures

the retreat of the designs that use the technique, not the abandonment of the technique by those who do that type of study.

Efficiency frontiers advanced in the opposite direction, from 2.1% up to 1999 to 22.4% in 2020–2026 (χ^2 = 14.50; p = 0.0023); studies such as that of Kumaran et al. (2017), estimating the technical efficiency of Indian *Penaeus vannamei* farms by stochastic frontier, are today representative of recent output. This advance is also largely compositional: the year coefficient falls from +0.0056 (p = 0.0005) to +0.0022 (p = 0.126) after adjustment, which mainly reflects the expansion of farm surveys, the design in which the technique is applicable. Bioeconomic modelling retreated from 20.8% to 8.3% and formal risk analysis from 14.6% to 9.3%. The retreat of bioeconomic modelling is particularly costly, because it is the family that explicitly couples biological performance and financial outcome, a tradition established since the work on optimal harvesting strategies (Pascoe et al. 2002).

The critical point about this exchange is that it is not cumulative. Of the 68 applications of efficiency frontiers in the corpus, 48 (70.6%) report no monetary indicator at all: neither cost, nor margin, nor profit. The recent growth of the economic literature on shrimp farming is, to a large extent, growth in technical efficiency studies that answer a different question from the one an investment decision requires: how much output is extracted from a given set of inputs, rather than whether the capital employed is remunerated.

The correct reading of this section is therefore not that of a change of methodological preference within a stable field. It is that of a field whose composition changed, and in which each design brings with it the instrumentation proper to it. What has been called substitution is, in large measure, the statistical signature of a migration of designs.

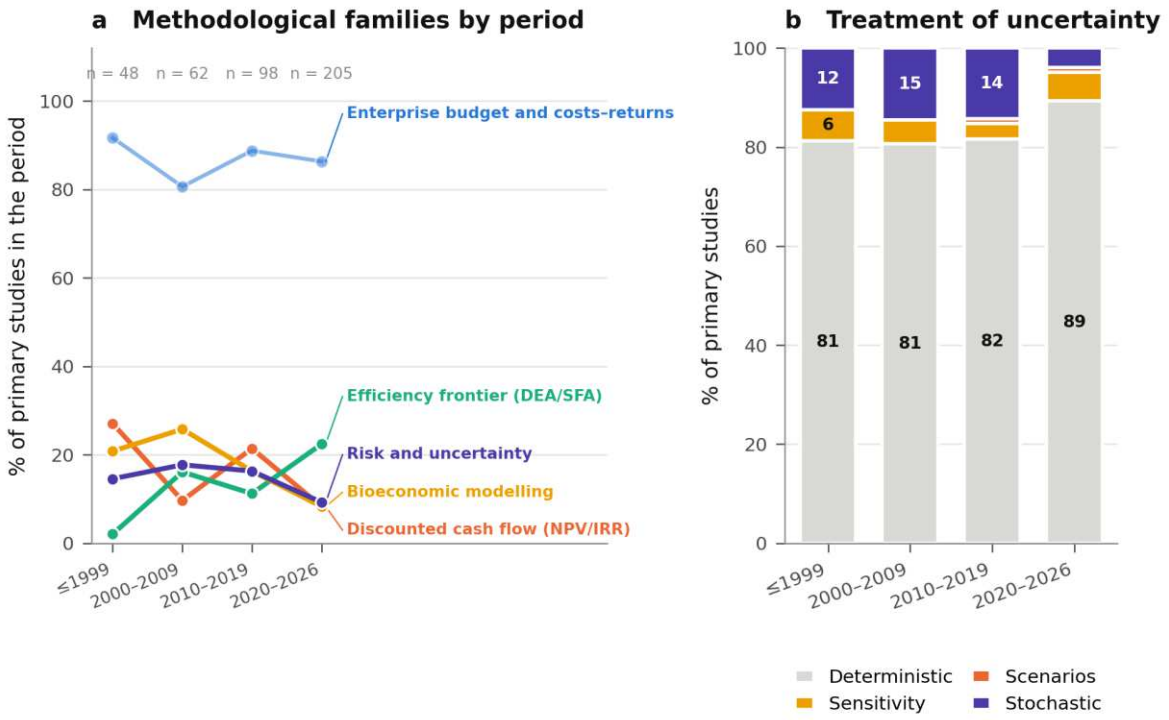


Fig. 3 Methodological change by period. (a) Percentage of primary studies in each period applying each methodological family; families are not mutually exclusive. (b) Distribution of the level of uncertainty treatment. The aggregate changes shown here are largely an effect of the compositional shift documented in Fig. 2b: none of them survives adjustment for study design (Table 2).

3.5 The decision funnel

What the literature actually reports traces a sharp funnel (Fig. 4). Operational performance indicators are frequent: margin or profit in 68.5% of studies (283) and production cost or unit cost in 64.4% (266). From there, frequency collapses. Benefit–cost ratio appears in 10.9% (45), efficiency score in 14.5% (60) and outcome probability distribution in 11.1% (46). Investment viability indicators are rare: net present value in 8.5% (35), internal rate of return in 6.8% (28), break-even point in 2.2% (9) and payback in 1.0% (4).

In terms of combinations, 219 studies (53.0%) use budgeting exclusively, without any formal economic method. The set applying at least one formal family totals 194 studies (47.0%), but that set is heterogeneous: 43 studies apply an efficiency frontier in isolation, without any declared budgeting component.

Interpretative caution is called for on that last frequency, because cost efficiency or allocative efficiency estimates use input prices by construction, even when they do not announce a monetary indicator in title, abstract or keywords. What the data support is that these studies do not make a

monetary outcome visible to the reader consulting the indexing material, not that they failed to handle values in their full text. The distinction matters for comparability and for synthesis, which is the object of this review, but does not license the conclusion that economic content is absent.

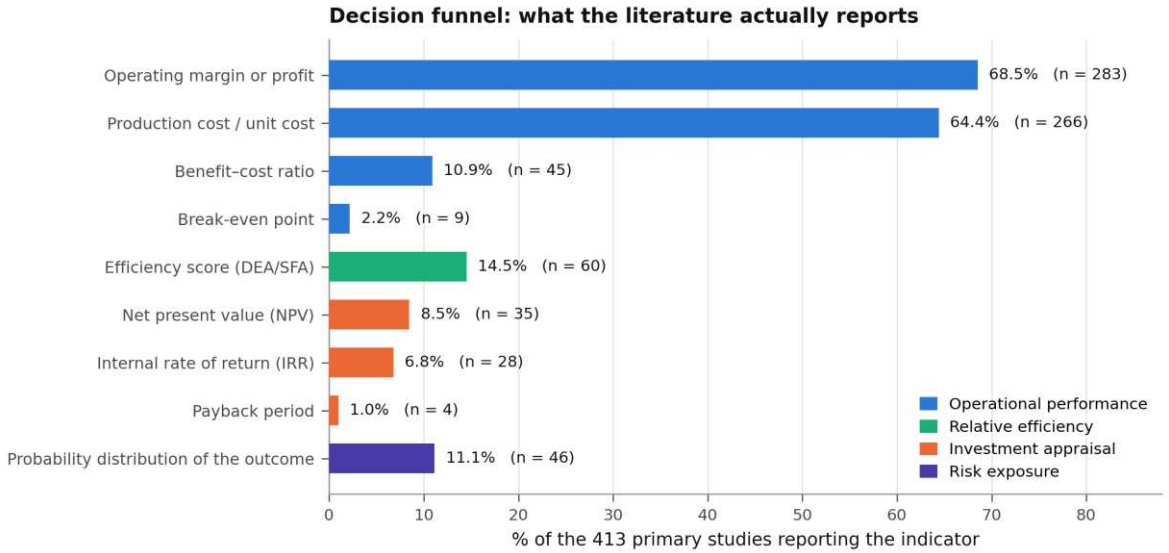


Fig. 4 Economic indicators actually reported by the 413 primary studies, grouped by the decision domain they address. A single study may report more than one indicator.

3.6 Financial conventions are rarely declared

The weakness deepens when the subset that explicitly sets out to appraise investment is examined (57 studies). Even there, the conventions that make a discounted cash flow result interpretable are rarely declared (Fig. 5): fixed investment or CAPEX in 19.3%, financing or credit in 10.5%, depreciation in 7.0%, discount rate in 5.3%, opportunity cost in 5.3% and working capital in 1.8%. None of the 57 studies declares a monetary base year, and none declares the price–size relationship at harvest.

Two readings follow. The first is methodological: these frequencies were measured in title, abstract and keywords, and therefore measure the declared salience of the conventions, not necessarily their absence from the full text. The second is substantive and independent of the first: a net present value whose discount rate is announced nowhere in the material a reader consults before accessing the article is, for all practical purposes of comparison and synthesis, a number without a unit. Since the price–size relationship is the main mechanism through which biological performance converts into revenue in shrimp farming (larger shrimp command substantially higher prices per kilogram), its universal absence in this subset is especially limiting.

The universal absence of the price–size relationship and of the base year has a practical explanation, and the two reasons differ. On a commercial farm, the price table by size class is a negotiating document with the buyer and is rarely released for publication; the researcher who gains access to the records usually receives total revenue and total weight, not the table. The monetary base year, by contrast, is not omitted because of restricted access: it is simply not required at submission. Correcting the first omission requires negotiating the data with the company; correcting the second requires one line of text. This reading comes from practice with commercial farm records and is not testable with the database coded here, which does not record the origin of the price data in each study.

Still within the investment subset, 46 of the 57 studies (80.7%) incorporate no formal risk treatment. That is, most viability appraisals of world shrimp farming produce a single NPV or IRR figure for an activity whose variability in survival and price is notorious.

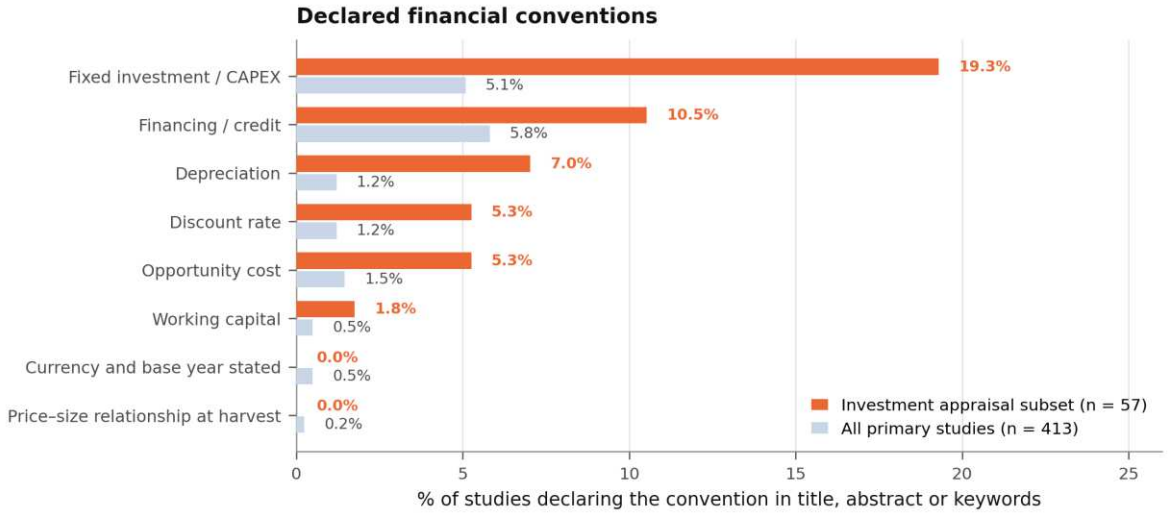


Fig. 5 Frequency with which financial conventions are declared, in the full set and in the subset applying discounted cash flow. Frequencies measure declared salience in title, abstract and keywords and constitute a lower bound on presence in the full text.

3.7 Uncertainty has not advanced within any design

The distribution of uncertainty treatment is the most uncomfortable evidence in the corpus (Fig. 3b). Among the 413 primary studies, 352 (85.2%) are entirely deterministic, 21 (5.1%) perform sensitivity analysis, 3 (0.7%) use scenarios and 37 (9.0%) adopt stochastic or probabilistic treatment. The proportion of studies with any uncertainty treatment was 18.8% up to 1999, 19.4% in 2000–2009, 18.4% in 2010–2019 and 10.7% in 2020–2026.

This series calls for two tests, and they do not say the same thing. A chi-square of four periods by four categories does not reject homogeneity ($\chi^2 = 5.30$; df = 3; $p = 0.151$), but the test is diffuse and insensitive to a monotonic trend; an ordinal test on the same data rejects it ($\rho = -0.146$; $p = 0.003$). The aggregate decline therefore exists. It disappears entirely, however, under adjustment for design: the year coefficient moves from −0.0040 ($p = 0.009$) to −0.0002 ($p = 0.88$), and within each stratum the trend is indistinguishable from zero (trials $\rho = -0.014$; surveys $\rho = -0.044$; modelling $\rho = -0.008$; all with $p > 0.58$).

The defensible statement is thus both stronger than originally intended and more specific: over four decades, no type of study came to treat uncertainty more often than it already did, and the decline visible in the aggregate follows from the corpus filling with experimental trials, a design in which formal uncertainty treatment is all but absent (1.4% of the 144 studies).

Four decades of literature have therefore produced no measurable progress in propagating uncertainty to the economic outcome. The studies that do it well have existed from early on: the financial risk analysis of Malaysian prawn culture in Hawaii (Samples and Leung 1985) and the investment simulation with variability in growth, survival and hurricanes in Texas (Hanson et al. 1985) date from 1985, and the practice simply did not spread. Later exemplars exist and are methodologically sound: the risk analysis of Honduran farms with enterprise budgets and outcome distributions (Valderrama and Engle 2001), the economic risk scenarios of acute hepatopancreatic necrosis in Mexico (Estrada-Pérez et al. 2020) and the stochastic estimate of the cost of *Enterocytozoon hepatopenaei* on Indian farms by Monte Carlo simulation (Geetha et al. 2022). They remain, however, isolated cases in a predominantly deterministic set.

3.8 Study design determines depth

The origin of the problem appears in the distribution by design (Fig. 7): farm surveys total 155 studies (37.5%), experimental trials 144 (34.9%), models and simulations 104 (25.2%) and studies on operating commercial farms only 10 (2.4%).

The association between design and depth is strong ($\chi^2 = 164.8$; df = 3; $p < 0.001$). Among modelling studies, 84.6% apply at least one formal family; among surveys, 58.1%; among experimental ones,

only 6.2%. Of the 144 experimental studies, 135 (93.8%) apply no formal economic method and 142 (98.6%) remain deterministic.

The source of the aggregate methodological shallowness is thereby identified: the growth of the economic literature on shrimp farming is, to a large extent, growth in husbandry trials (diets, densities, additives, biofloc systems) that append a cost-and-revenue spreadsheet to the end of the experiment, and in surveys describing observed cost structures. Both designs produce short-horizon outcomes, without capital, without a project life and without variability.

The reason for this practice is one of incentives, not of competence. The husbandry trial is designed, funded and judged by its biological outcome; the cost-and-revenue spreadsheet is appended at the end to argue applicability, using the prices prevailing during the experiment and the inputs actually spent in the experimental units. None of this was collected to answer a question about capital, and there is therefore no fixed investment, project horizon or variability to report. The missing data were not lost: they never entered the study design. This reading is a hypothesis rather than a result of the coding: the database does not record the funding source or the declared primary outcome of the trial, which would be the variables needed to test it in the full text.

It is worth separating the result from the judgement here. The result is that these designs, by construction, generate a low depth index, and that their share has grown. The judgement, which is the authors' and does not follow directly from the data, is that treating the cost-and-revenue balance of an eight-week trial as evidence of the economic viability of a capital-intensive activity conflates two distinct objects. That judgement is arguable and the reader may dissent from it without the results of this section changing.

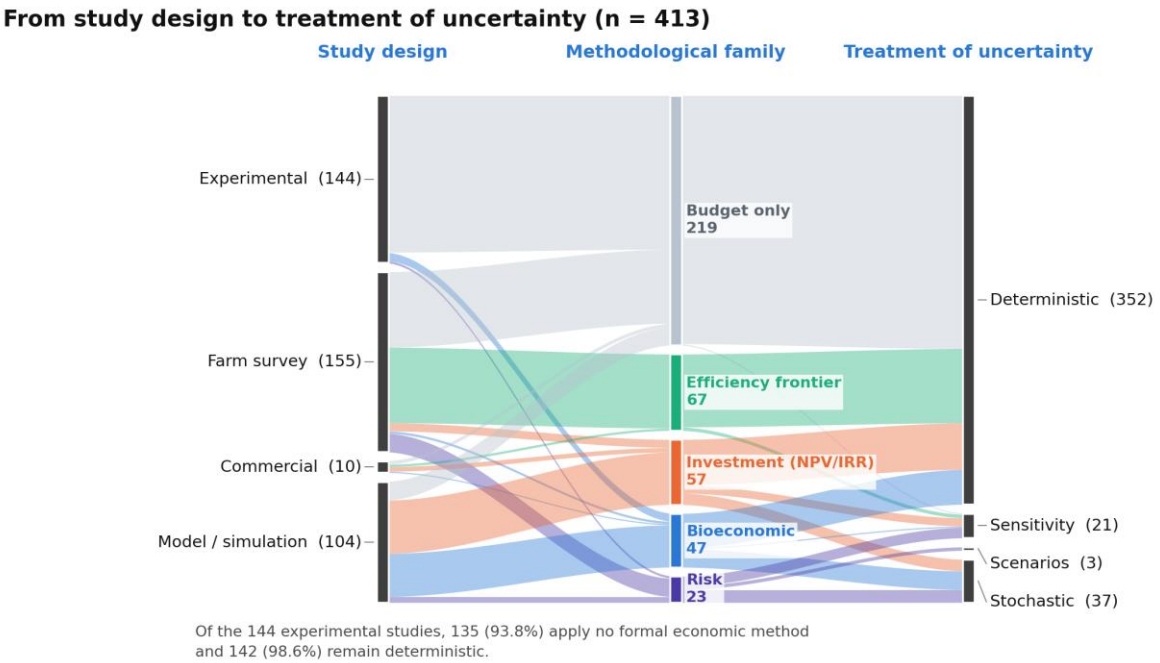


Fig. 7 Flow from study design to methodological family and to uncertainty treatment (n = 413). Ribbon width is proportional to the number of studies.

3.9 Asymmetry between where shrimp is produced and where it is analysed

The corpus covers 1977–2026 and is concentrated in Bangladesh (58 studies), Vietnam (54), the United States (53), India (49), Brazil (49), Indonesia (44), Mexico (33) and China (24). Asia accounts for 247 of the 413 studies (59.8%), Latin America and the Caribbean for 94 (22.8%) and North America for 46 (11.1%); Africa (7), Oceania (10) and Europe (6) are marginal.

Mean methodological depth differs markedly between regions (Kruskal–Wallis $H = 27.9$; $p < 0.001$): Latin America and the Caribbean 1.37, Europe 1.33, North America 1.20, Oceania 1.10, Asia 0.68 and Africa 0.14 (Fig. 6a). The difference between Asia and Latin America is statistically robust (Mann–Whitney; $p < 0.001$).

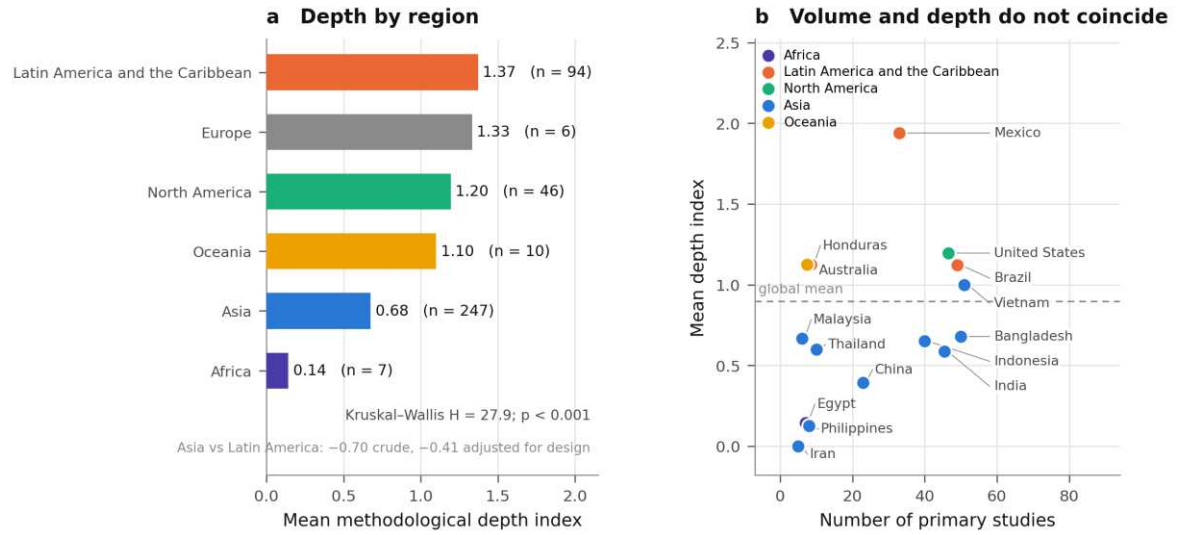
Unlike the temporal trends, this difference survives adjustment for design, though reduced. Composition contributes: Latin America and the Caribbean devotes 44.7% of its studies to modelling against 8.5% for Asia, while Asia concentrates 55.9% in surveys against 13.8% for Latin America. Adjusted for design, the depth differential for Asia remains at −0.412 points ($p = 0.001$; 95% CI −0.661 to −0.164), against −0.696 in the crude contrast. About 41% of the observed difference is composition of designs and the remaining 59% is a difference in practice within comparable designs.

The same asymmetry appears in the vocabulary of the field: the co-occurrence network of author

keywords (Fig. 8) organises into four clusters, and the economic core links profitability, economic analysis and production cost with the terms of technical efficiency and data envelopment analysis, while risk appears as a peripheral, weakly connected node. The distribution by outlet, production system and species is given in Fig. S1 (supplementary material).

The pattern is the inverse of physical production: the region accounting for most of the world's farmed shrimp output is also the one analysing that output with the most restricted economic instrumentation (Fig. 6b). Mexico, Brazil and the United States combine a reasonable volume of studies with depth above the global mean; Bangladesh, India, Indonesia and China combine high volume with depth below it. The most plausible reading is not one of technical capacity but of agenda: in the higher-producing Asian regions the literature has organised itself around technical efficiency and system performance rather than around capital allocation decisions. This is a hypothesis and not a result. The coded database records neither the funding source of each study nor its link to sectoral productivity programmes, which are the variables needed to test it.

Penaeus vannamei dominates the corpus (147 studies), followed by *Macrobrachium* spp. (72) and the giant tiger prawn, *Penaeus monodon* (Fabricius, 1798) (48). Among systems, intensive (91 studies) and semi-intensive (53) show the highest proportions of formal method (61.5% and 62.3%), while polyculture and IMTA (66) and biofloc (34) show the lowest (25.8% and 26.5%). The technologically more recent systems are therefore precisely the least assessed with investment instrumentation, despite being those that require the greatest capital outlay per unit area. The risk analysis of recirculating systems published by Liu and Asche (2026) is one of the few exceptions, and illustrates well what the rest lack: it explicitly recognises that the risk profile of capital-intensive systems differs from that of traditional ones.



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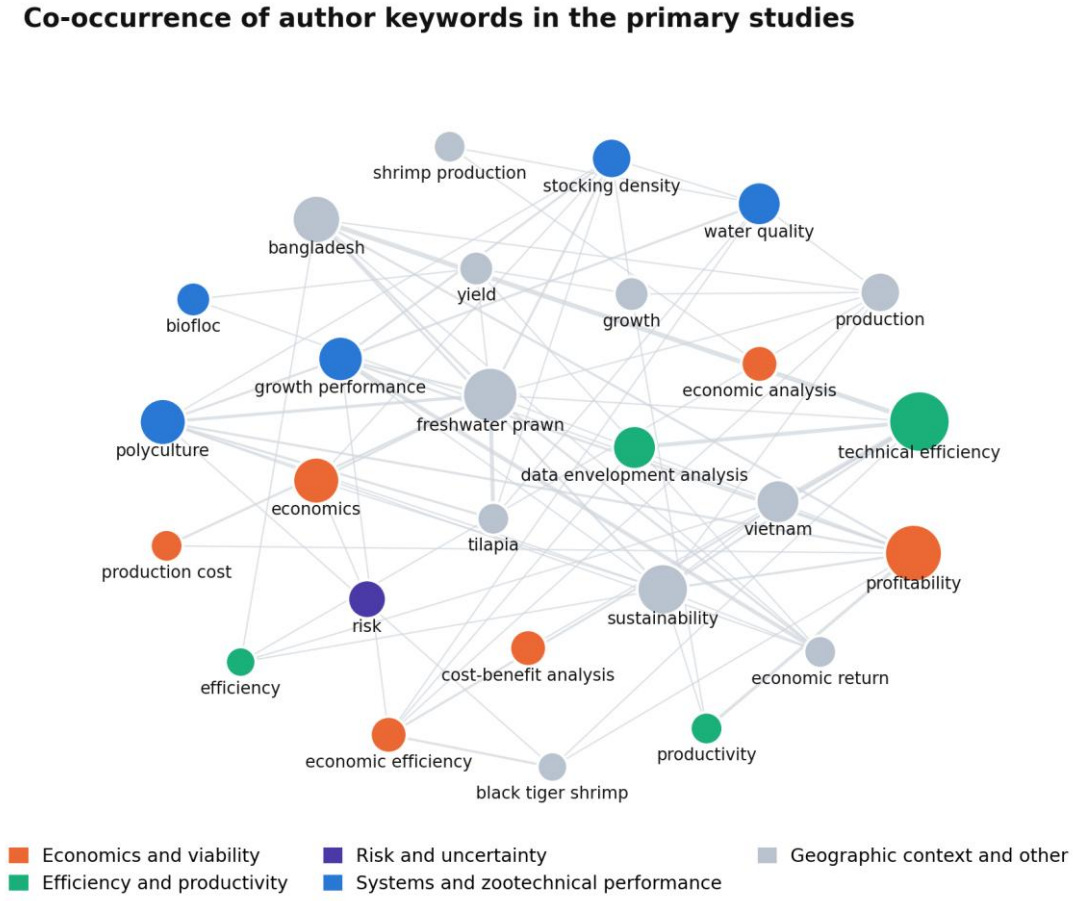
485 **Fig. 6** Geography of analytical depth. (a) Mean index by region, restricted to regions with at least five studies;
486 the footer compares the crude Asia–Latin America contrast with the same contrast adjusted for study design. (b)
487 Relationship between number of studies and mean index by country, restricted to countries with at least five
488 studies; the dashed line marks the global mean of the corpus.



489

490 **Fig. 8** Co-occurrence network of author keywords in the primary studies. Node size is proportional to term
491 frequency and edge thickness to co-occurrence frequency; keywords are kept in their original language of
492 publication.

4 Discussion

4.1 A field that grows while changing its nature

The evidence assembled supports an uncomfortable conclusion, but a different one from what the aggregate reading suggested at first sight. The economic literature on shrimp farming is growing fast and, at the same time, the average study offers less basis for an investment decision. This does not happen because the practice of each type of study has degraded, but because the field replaced the design that carried investment instrumentation with designs that do not carry it.

The distinction is not merely technical, because four aggregate results that appeared independent (the fall in the composite index, the fall in discounted cash flow, the rise of efficiency frontiers and the fall in uncertainty treatment) reduce, under adjustment, to a single phenomenon: modelling and simulation shrank from more than half to one tenth of the corpus. Presenting them as four distinct findings would be to multiply one observation. Presenting them as four manifestations of a change in composition is what the data license, and it is also more informative, because it points to a single cause and therefore to a single point of intervention.

Why modelling became rare is a question this review raises and does not answer. Three competing explanations are compatible with what was observed: the wider availability of farm microdata, which made surveys feasible where only models were possible before; the falling cost of a publishable experimental trial relative to building and calibrating a bioeconomic model; and a shift in the composition of the outlets themselves, which was tested and does not hold as the main explanation (Sect. 3.3). Distinguishing the first two would require coding the origin of each study's data and the size of the research teams, which was not done here.

Earlier syntheses reached diagnoses distinct from this one. Neiland et al. (2001) offered an economic and policy perspective when modern shrimp farming was still expanding rapidly. Later reviews examined specific themes: the economics of IMTA (Knowler et al. 2020), energy efficiency (Cozer et al. 2020), dynamic optimisation (Domínguez-May et al. 2024), sustainability models (Uddin et al. 2025; Wang et al. 2026) and life cycle assessment (Calvo et al. 2026). The gap that remained was a synthesis centred on the method of farm economics itself: what is counted as a cost, how capital is treated, how price and biological performance connect, which decision indicators are reported and how

uncertainty is propagated. It is that gap the present review occupies, and the result is that the field is worse served than the volume of publications would suggest.

It is worth separating internal from external validity at this point. Internally, the results hold for the corpus defined by the criteria of Sect. 2.3, retrieved from Scopus and the Web of Science on 17 September 2026 and coded from title, abstract and keywords. Externally, what generalises is the procedure, not the magnitudes: the lesson that an aggregate temporal trend in a scientometric corpus can reverse sign under stratification by study design holds for any analysis comparing literatures whose composition changes over time, and analyses of this kind should report the stratified version even when the aggregate one is the quantity of interest. The values obtained here, the fall from 54.2% to 10.2% in the share of modelling and the adjusted coefficient of +0.009 points per year, are specific to farm economics in shrimp aquaculture and should not be carried over to other literatures.

The parallel with the shrimp life cycle assessment literature is worth drawing, where Calvo et al. (2026) showed that methodological choices can dominate the apparent differences between production systems. Economics faces a structurally identical problem: two farms with similar biological performance may report very different "profitabilities" depending on whether depreciation, opportunity cost, financing, project life or risk are included. The difference is that, in life cycle assessment, the community recognised the problem and built reporting conventions; in shrimp farming economics, this has not yet happened.

4.2 Methodological substitution and what it costs

The exchange of discounted cash flow for efficiency frontiers deserves a careful reading, because it is not in itself a step backwards. Data envelopment analysis and stochastic frontiers are legitimate and informative instruments: they reveal how much additional output would be obtained from the same inputs and identify the determinants of inefficiency. Their advance reflects the growing availability of large farm samples and econometric maturity.

The problem is that these tools answer a different question and, in the corpus examined, tend to substitute rather than complement. A farm may sit on the technical efficiency frontier of its sample and still generate insufficient return on the capital invested, because the frontier is relative to the observed

set and not to an opportunity cost of capital. When 70.6% of frontier studies make no monetary indicator visible in the indexing material, the field loses the ability to translate efficiency into decision, even if prices were used internally in estimation. The practical recommendation is simple and cheap: frontier studies should report, alongside the efficiency score, at least the unit cost and the mean operating margin of the sample, which would anchor relative efficiency in quantities comparable across studies. Work that articulates efficiency and economic outcome, such as the analysis of trade-offs between economic and environmental efficiency in the Mekong delta (Trang et al. 2024), shows that this integration is feasible without relevant additional methodological cost.

4.3 Where to intervene: trials and surveys

The finding that 93.8% of experimental studies apply no formal economic method and 98.6% remain deterministic pinpoints where an editorial intervention would have the greatest effect. Together with farm surveys, these studies rose from 43.8% of the corpus up to 1999 to 88.8% in 2020–2026, and are today almost the whole of the economic literature on shrimp farming. The marginal cost of improving them is low.

From this follows the most important practical consequence of the composition analysis: a requirement aimed at modelling would today reach one tenth of the field. A requirement aimed at trials and surveys reaches nine tenths of it, which is why the minimum set proposed in Sect. 4.5 has its core designed to be met without econometric instrumentation.

A stocking density trial, a fishmeal replacement trial or a biofloc management trial that reports cost and revenue has already gathered the difficult information. What is missing is almost always negligible in effort: declaring the price basis and the monetary base year; stating explicitly whether the result is an operating margin or profit after capital; indicating the commercial scale to which the experimental result would be extrapolated; and subjecting the result to a minimal sensitivity analysis on shrimp price, feed price and survival. None of these steps demands additional econometric capacity, and all substantially increase the usefulness of the study.

4.4 The production–analysis asymmetry

The combination of high volume and low depth in Asia, and the opposite pattern in Latin America, has policy implications, and is the only one of the asymmetries documented here that does not dissolve under adjustment for design. About 41% of the differential is composition, because Latin America models more and Asia runs more surveys, but 59% remains as a difference in practice between studies of the same type. The capital financing the expansion of Asian shrimp farming (rural credit, public programmes, private investment) depends on appraisals that the region's academic literature supplies only in part. The concentration on technical efficiency is understandable given productivity agendas, but it leaves unattended the decisions on intensification, on adoption of closed systems and on conversion of extensive systems, all of them capital-intensive.

There is, however, an alternative reading that the present review cannot rule out: part of that appraisal may take place outside the indexed literature, in sector reports, development agency documents and grey literature in local languages. The indexed base is predominantly anglophone (95.6% of the corpus in English), and a review restricted to Scopus and the Web of Science measures the internationally visible literature, not necessarily all existing analytical practice. That is a real limitation, and also a testable hypothesis.

4.5 A minimum reporting set

Before detailing the minimum set, it is useful to make explicit the decision architecture it is meant to support. A farm-level economic assessment answers, in increasing order of commitment, four distinct questions: whether the farm covers its costs in one cycle, how far it stands from the best observed practice, whether committing capital over the project's life is worthwhile, and how likely the expected result is not to materialise. Each question has its own methods and indicators, and each logically presupposes the previous one (Fig. 9). The corpus answers the first in 86.7% of studies, but this falls to 14.5% for the second, 9.7% for the third and 11.1% for the fourth, and only 14.8% go beyond a point estimate. Reading these four coverages together is the most direct way of stating the central finding of this work: the domains operate as substitutes for one another rather than as successive layers.

We propose a minimum reporting set for farm-level economic assessments in shrimp farming, organised so as to be met by studies of any size (Table 3). The principle is graduated: a mandatory

core, applicable even to experimental trials, and additional layers required according to the study's claims.

Without starting from scratch or aiming to replace existing guidelines, the proposal transposes to farm economics the logic that the life cycle assessment community already adopted in the face of a structurally identical comparability problem (Calvo et al. 2026), and differs from generic reporting checklists by being specific about the variables that, in shrimp farming, determine the conversion of biological performance into financial outcome: survival, harvest weight, feed conversion and, above all, the price–size relationship at harvest. No general economic reporting guideline captures these items, and it is precisely their absence that prevents synthesis across studies.

The core requires that any study reporting an economic result declare species, location, system, area or volume, stocking density, cycle length, survival, harvest weight, yield and feed conversion; the source of the farm-gate price, the currency and base year, and whether price varies with shrimp size; the composition of operating costs; and, as a minimum, unit cost and operating margin, with an explicit distinction between operating margin and profit after remuneration of capital.

The investment layer adds, for studies that set out to appraise viability: itemised fixed investment, depreciation method, working capital, financing assumptions, project horizon, residual value and a justified discount rate. The uncertainty layer requires, as a minimum, sensitivity analysis on shrimp price, feed price and survival, and preferably scenarios or stochastic simulation with the distribution of the outcome. The reproducibility layer requires equations or a spreadsheet and code to be available.

Studies already approaching this standard exist and serve as practical references: the stochastic bioeconomic optimisation of pond size for intensive commercial production (González-Romero et al. 2014), reporting NPV, IRR and return per unit of risk; the bioeconomic modelling of hatchery, grow-out and integrated business for the Australian tiger prawn (Marín-Riffo et al. 2021), itemising 318 input parameters; and the analysis of price volatility and sustained profitability in India (Bhargavi et al. 2024), which treats the price series as an explicit source of risk. A study meeting the core already becomes comparable with others; one meeting core and investment layer becomes usable for decision; one meeting all four becomes synthesisable in meta-analysis. None of the requirements is onerous and all can be verified by editors and reviewers from the manuscript itself.

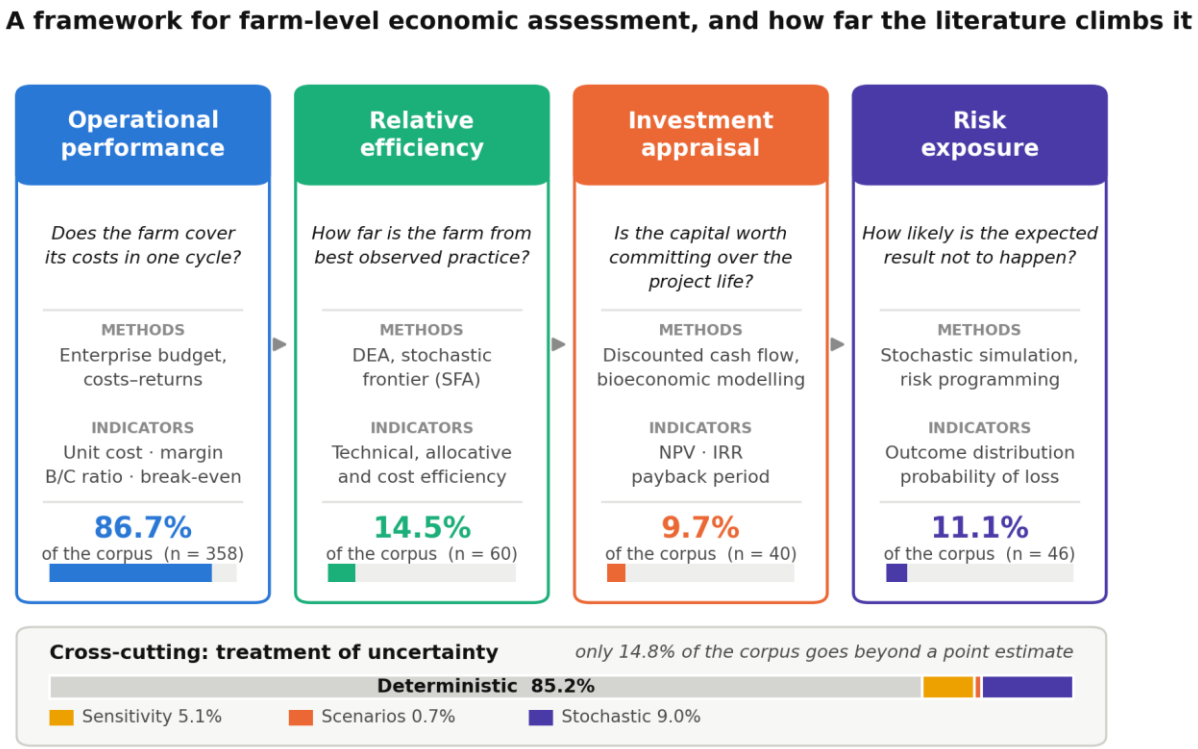


Fig. 9 Decision architecture of farm-level economic assessment and the coverage observed in the corpus. Each domain answers a distinct question and logically presupposes the previous one; the bar on each card gives the percentage of the 413 primary studies reporting at least one indicator of that domain. The lower band shows uncertainty treatment, which cuts across all four domains.

Table 3 Minimum reporting set proposed for farm-level economic assessments in shrimp aquaculture.

Layer	Required elements	Applies to
Core: comparability	Species; location; system; area or volume; stocking density; cycle length; survival; harvest weight; yield; feed conversion. Source of the farm-gate price; currency and base year; whether price varies with size. Composition of operating costs. Unit cost and operating margin, with an explicit distinction between operating margin and profit after remuneration of capital.	Every study reporting any economic result, including experimental trials
Investment: capital decision	Itemised fixed investment; depreciation method; working capital; financing assumptions; project horizon; residual value; justified discount rate. Decision indicators (NPV, IRR, payback) reported together, never in isolation.	Studies claiming to appraise viability or investment attractiveness
Uncertainty: robustness	As a minimum, sensitivity analysis on shrimp price, feed price and survival. Preferably scenarios or stochastic simulation, with the distribution of the outcome and the probability of a negative economic result.	Every study reporting an investment indicator; recommended for the others
Reproducibility	Equations, spreadsheet or code available; explicit distinction between measured, assumed and calibrated parameters; supporting database.	All

Note: the core layer was designed to be met without additional economic instrumentation by studies whose primary aim is husbandry-oriented, which make up 34.9% of the corpus examined and most of its recent growth.

5 Conclusions

Farm-level economic assessment in world shrimp aquaculture is abundant, geographically broad and, on average, methodologically shallow. Fewer than one tenth of studies report net present value, one hundredth report payback, and more than four fifths remain deterministic, a proportion that has not improved in any study design over four decades.

What changed was not the competence of the field, but its composition. Modelling and simulation, the design that concentrates investment and risk instrumentation, fell from 54.2% to 10.2% of the literature, giving way to experimental trials and farm surveys. Once study design is taken into account, none of the negative temporal trends holds, and the year effect on depth even reverses sign. The field has not forgotten how to appraise investment: it has stopped producing, in proportion, the type of study in which that appraisal is done.

The address of the recommendation changes with this diagnosis. Were the gap a degradation of practice, the answer would be methodological training. Since it is a displacement of composition, the answer is editorial and directed at the designs that now dominate: trials and surveys account for almost nine tenths of recent output, and it is in them that a modest requirement produces the greatest aggregate gain. Not a new method, but the systematic declaration of price basis, base year, the nature of the margin reported and a minimal sensitivity analysis.

Shrimp farming is a capital-intensive activity, exposed to biological and price shocks, and undergoing rapid technological intensification. The literature that accompanies it needs to distinguish clearly between operating profitability, investment viability, relative efficiency and risk exposure, which are related but not equivalent domains. The minimum reporting set proposed here is an attempt to make that distinction routine, verifiable and cheap. Table 4 summarises the findings that support this recommendation.

Table 4 Summary of the main quantitative findings (n = 413 primary studies).

Dimension	Result	Test
Volume	9.8 studies/year in 2010–2019; 29.3 in 2020–2026	—
Composition by design	Modelling 54.2% (≤1999) → 10.2% (2020–2026); trials 29.2% → 41.5%; surveys 14.6% → 47.3%	$\chi^2 = 68.22$; df = 9; $p < 0.001$
Methodological depth	Aggregate decline (mean 1.00 in 2010–2019 and 0.81 in 2020–2026; 48.2% scoring zero); **the year effect reverses sign under adjustment for design**	crude $\rho = -0.110$; $p = 0.025$. Adjusted b = +0.009/year; $p = 0.032$

Dimension	Result	Test
Discounted cash flow	27.1% (≤1999) → 8.3% (2020–2026); the fall **disappears** under adjustment	crude $p < 0.001$. Adjusted b = +0.001/year; p = 0.52
Efficiency frontier	2.1% (≤1999) → 22.4% (2020–2026); 70.6% with no declared monetary indicator; rise attenuated under adjustment	crude $p < 0.001$. Adjusted b = +0.002/year; p = 0.13
Investment indicators	NPV 8.5%; IRR 6.8%; payback 1.0%	—
Uncertainty treatment	85.2% deterministic; aggregate decline real, but null within each design	ordinal $\rho = -0.146$; p = 0.003. Adjusted b = −0.000/year; p = 0.88
Conventions in the investment subset (n = 57)	CAPEX 19.3%; discount rate 5.3%; base year and price–size relationship 0.0%; 80.7% with no risk treatment	—
Study design	Modelling 84.6% with a formal method; experimental 6.2%	$\chi^2 = 164.8$; df = 3; $p < 0.001$
Regional asymmetry	Asia 0.68 (n = 247); Latin America and the Caribbean 1.37 (n = 94); differential persists under adjustment (41% is composition)	H = 27.9; $p < 0.001$. Adjusted −0.412; p = 0.001

Statements and Declarations

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Competing interests The authors have no relevant financial or non-financial interests to disclose. Three studies co-authored by one of the authors are among the 413 primary studies of the corpus; they were retrieved by the same search, screened under the same protocol and coded by the same rules as every other record, and are identifiable in the deposited decision matrix.

Ethics approval No approval of a research ethics committee was required. The study analyses exclusively published and indexed literature. It involves no human participants, no personal data and no animal experimentation.

Consent to participate Not applicable. The study involved no human participants.

Consent for publication Not applicable. The study contains no individual personal data.

Data availability The deduplicated bibliographic database, the eligibility matrix with record-by-record decisions, the data dictionary, the pre-filter dictionaries and the result tables behind every figure and table are deposited in Zenodo at https://doi.org/10.5281/zenodo.23344245 (version 1.0.0), under a CC BY 4.0 licence for data and documentation and an MIT licence for code. The analysis reproduces exactly from the deposited files. Raw Scopus and Web of Science exports are retained in accordance with the licensing conditions of those sources, and abstracts, cited references and index keywords were removed from the deposited files for the same reason.

Code availability The deduplication, lexical pre-filtering, analysis, stratification and figure-generation scripts are included in the deposit cited above, under an MIT licence.

Author contributions O.R.M.F. and M.X.P.F. conceived the study. O.R.M.F., M.X.P.F. and R.M.V.F. designed the methodology. O.R.M.F. wrote the search strings, assembled the screening database, coded the 413 primary studies, wrote the analysis and figure-generation code, and prepared Figs. 1 to 9, Fig. S1 and Tables 1 to 4. O.R.M.F. and R.M.V.F. performed the statistical analysis, including the stratified robustness analysis. M.X.P.F. carried out the independent record-by-record re-check of the included studies. M.X.P.F., R.M.V.F. and L.O.B. validated the coding protocol and the interpretation of the results. M.X.P.F. and L.O.B. supervised the work, and L.O.B. acquired the funding. O.R.M.F. wrote the main manuscript text. All authors reviewed and approved the manuscript.

Clinical trial number: not applicable.

Use of generative artificial intelligence The authors used generative artificial intelligence (Claude, Anthropic; used between September and October 2026) to support the development and execution of the deduplication, pre-filtering, analysis and figure-generation code, a documented first-pass coding of the 1,102 screened candidates against the protocol of Sect. 2.5, language editing and translation, and consistency checks across text, tables and figures. The first-pass coding was not accepted as final: it was submitted to the blind test-retest reported in Sect. 2.5, and all 419 included records were re-checked record by record by a second reviewer. No tool was used as a source of data, and none generated results, references or interpretations. The authors confirm that they have reviewed and

verified the content generated by the AI tool for accuracy and integrity. Artificial intelligence tools do not fulfil the role of authors and are not listed as such.

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Appendix I Search strategy

Scopus (17 September 2026): TITLE-ABS-KEY combining the organism block (shrimp, prawn, Penaeus, Litopenaeus, Macrobrachium, Fenneropenaeus, Metapenaeus, carciniculture) with the economic block (economic*, financial*, profitab*, cost*, "cost-benefit", "benefit-cost", "net present value", NPV, "internal rate of return", IRR, payback, "break-even", bioeconomic*, "data envelopment", "stochastic frontier", "technical efficiency", investment*, risk*), with no restriction on year or language.

Web of Science Core Collection (17 September 2026): TS with the same two blocks and the same operators. The literal expressions, as executed, accompany the data repository, together with the export files and the date and time stamp of each query.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 05OnlineResource1FigureS1.docx
- 06OnlineResource2PRISMA2020checklist.docx