The Optimal Budget Generator: A Causal Inference Protocol for Maximizing Median Health and Wealth Through Public Goods Funding

Generating Integrated Public Budget Recommendations Using Diminishing Returns Modeling and Cost-Effectiveness Analysis

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Abstract

20-40% of public goods funding is misallocated relative to outcome-maximizing benchmarks, representing trillions annually in foregone welfare gains. Budget processes respond to lobbying intensity and historical precedent rather than causal evidence of effectiveness.

The Optimal Budget Generator (OBG) applies causal inference, diminishing returns modeling, and cost-effectiveness analysis to determine optimal public goods funding levels that maximize two welfare metrics: real after-tax median income growth and median healthy life years. For each spending category, OBG estimates an Optimal Spending Level (OSL) identifying where marginal returns equal opportunity cost.

The Budget Impact Score (BIS) measures confidence in each OSL estimate based on study quality, statistical precision, and temporal recency of the underlying causal evidence. The result is a gap analysis showing which categories are over- or underfunded relative to evidence-based benchmarks, enabling systematic reallocation from low-return to high-return public investments.

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Abstract

This specification describes the **Optimal Budget Generator (OBG)** framework, a systematic approach to generating integrated budget recommendations that maximize welfare as measured by two metrics: **real after-tax median income growth** and **median healthy life years**.

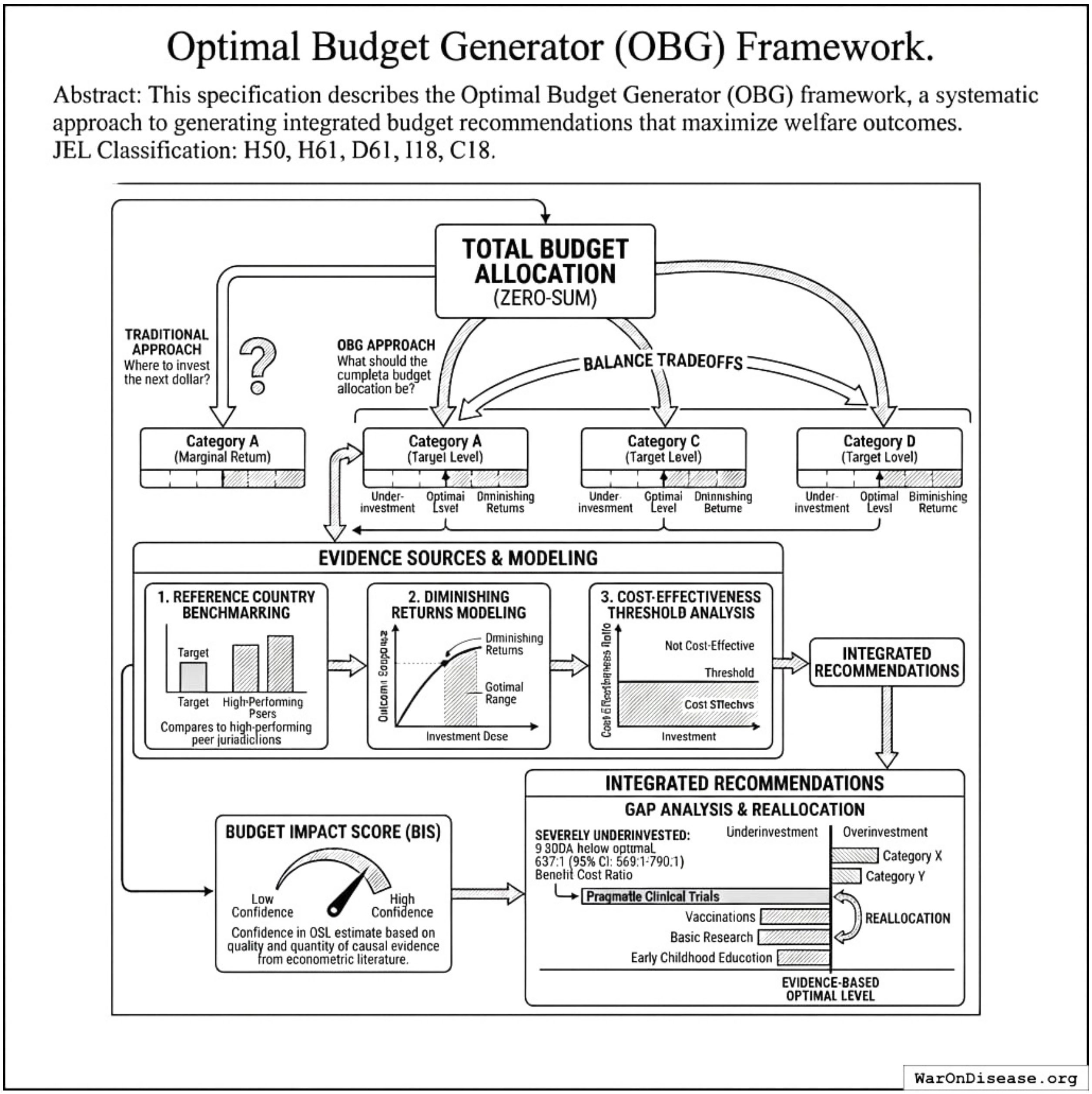

Figure 1: A conceptual diagram of the Optimal Budget Generator (OBG) framework showing how three evidence sources (benchmarking, returns modeling, and threshold analysis) integrate to create a gap analysis between current and evidence-based optimal funding levels.

JEL Classification: H50, H61, D61, I18, C18

Unlike marginal-return frameworks that ask "where should we invest the next dollar?", OBG asks "what should the complete budget allocation be?" Each category has a target level - too little means underinvestment, too much means diminishing returns. But unlike the Recommended Daily Allowance for nutrients (where you can meet all targets simultaneously), budget allocation is zero-sum: spending more on one category means less for others. OBG generates integrated recommendations that balance these tradeoffs.

The framework combines two evidence sources: (1) **diminishing returns modeling** from cross-country dose-response studies, and (2) **cost-effectiveness threshold analysis** from health economics. The **Budget Impact Score (BIS)** measures our *confidence* in each category's OSL estimate based on the quality and quantity of causal evidence from the econometric literature.

The result is a gap analysis showing which categories are underfunded relative to evidence-based optimal levels, enabling systematic reallocation from overinvestment to underinvestment. Applied to the US federal budget, the framework identifies pragmatic clinical trials as the most severely underinvested category (9,900% below optimal with 637:1 (95% CI: 569:1-790:1) benefit-cost ratio), followed by vaccinations, basic research, and early childhood education.

1 System Overview

1.1 What Policymakers See

A dashboard showing spending gaps by category, with clear recommendations:

Illustrative Example: US Federal Budget Gap Analysis

The following table demonstrates how OBG output would appear. OSL estimates for fully derived categories (pragmatic trials, vaccinations) come from the worked examples in Sections 6-7. Remaining OSL estimates are preliminary and based on cross-country benchmarking; full derivations are future work.

Category	Current	OSL	Gap	Evidence	Income Effect	Health Effect	Action
Pragmatic clinical trials	$0.5B	$50B	**+$49.5B**	A (RCTs)	++	+++	**Scale 100x**
Vaccinations	$8B	$35B	+$27B	A (RCTs)	+	+++	Increase
Basic research	$45B	$90B	+$45B	B (spillovers)	++	++	Increase
Early childhood (0-5)	$50B	$70B	+$20B	A (RCTs)	+++	+	Increase
Military (discretionary)	$850B	$459B	-$391B	C (benchmarks)	–	–	Decrease

Agricultural subsidies	$25B	$0B	-$25B	A (welfare analysis)	–	–	Eliminate

Positive gaps indicate underinvestment; negative gaps indicate overinvestment. Income Effect: impact on real after-tax median income growth. Health Effect: impact on median healthy life years. Scale: +++ strong positive, ++ moderate positive, + weak positive, – negative.

1.2 What Budget Analysts See

- **OSL estimates** with confidence intervals and methodology notes
- **Cross-country spending data** showing spending-outcome relationships
- **Diminishing returns curves** identifying optimal spending levels
- **Evidence quality scores** (BIS) for each category
- **Sensitivity analysis** showing how OSL changes with different assumptions
- **Priority rankings** by gap size weighted by evidence confidence

1.3 Where This Fits

```
+-------------------------------------------------------------+
|                    OPTIMOCRACY FRAMEWORK                     |
+-------------------------------------------------------------+
|                                                              |
|  +---------------------+    +-----------------------------+  |
|  |  Budget Generator   |    |  Policy Generator           |  |
|  |  (OBG/BIS Framework)|    |  (OPG/PIS Framework)        |  |
|  |                     |    |                             |  |
|  |  Answers:           |    |  Answers:                   |  |
|  |  "How should we     |    |  "What policies should      |  |
|  |  allocate the       |    |  we adopt/change?"          |  |
|  |  budget?"           |    |                             |  |
|  |                     |    |                             |  |
|  |  Primary output:    |    |  Primary output:            |  |
|  |  Integrated budget  |    |  Enact/Replace/Repeal       |  |
|  |  recommendations    |    |  recommendations            |  |
|  +---------------------+    +-----------------------------+  |
|                                                              |
|  Both feed into: Constitutional Layer (outcome-optimizing rules)  |
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The OBG/BIS framework answers: "Given what we know about returns to spending, what are the optimal allocation levels?"

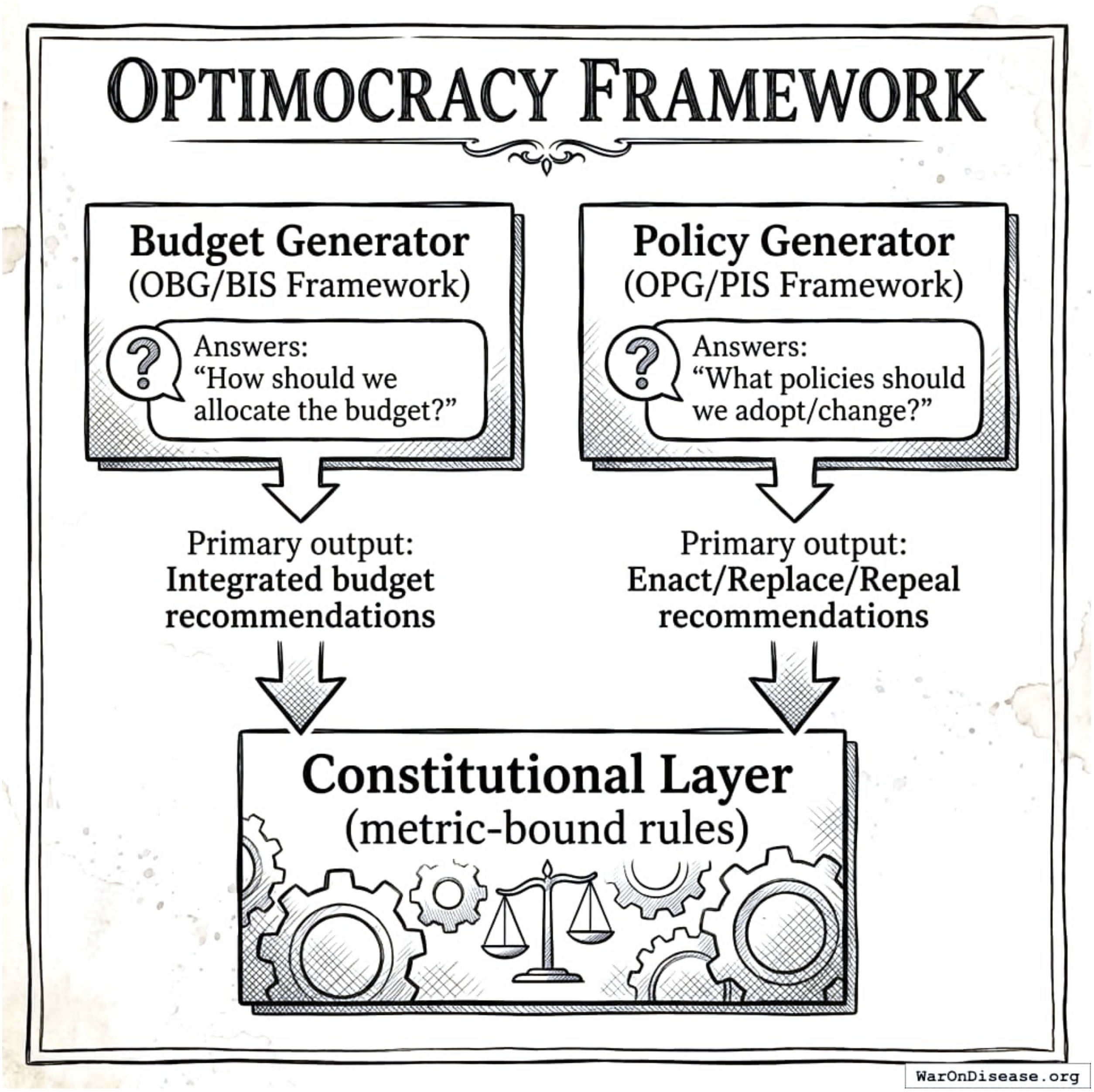

Figure 2: Architecture of the Optimocracy Framework showing the parallel inputs of budget (OBG) and policy (OPG) generators feeding into the Constitutional Layer.

The OPG framework (see Optimal Policy Generator Specification) answers: "Which policy reforms beyond budget allocation would most improve welfare?"

1.4 Implementation Mechanism

This specification focuses on generating evidence-based budget recommendations. Political implementation mechanisms are discussed separately in Incentive Alignment Bonds.

2 Introduction

2.1 Why Budget Allocation Fails Today

Budget allocation is fundamentally a problem of social choice under uncertainty[132]. The challenge is not simply technical but institutional: current budget processes systematically diverge from welfare-optimal allocations due to political economy dynamics[133,134].

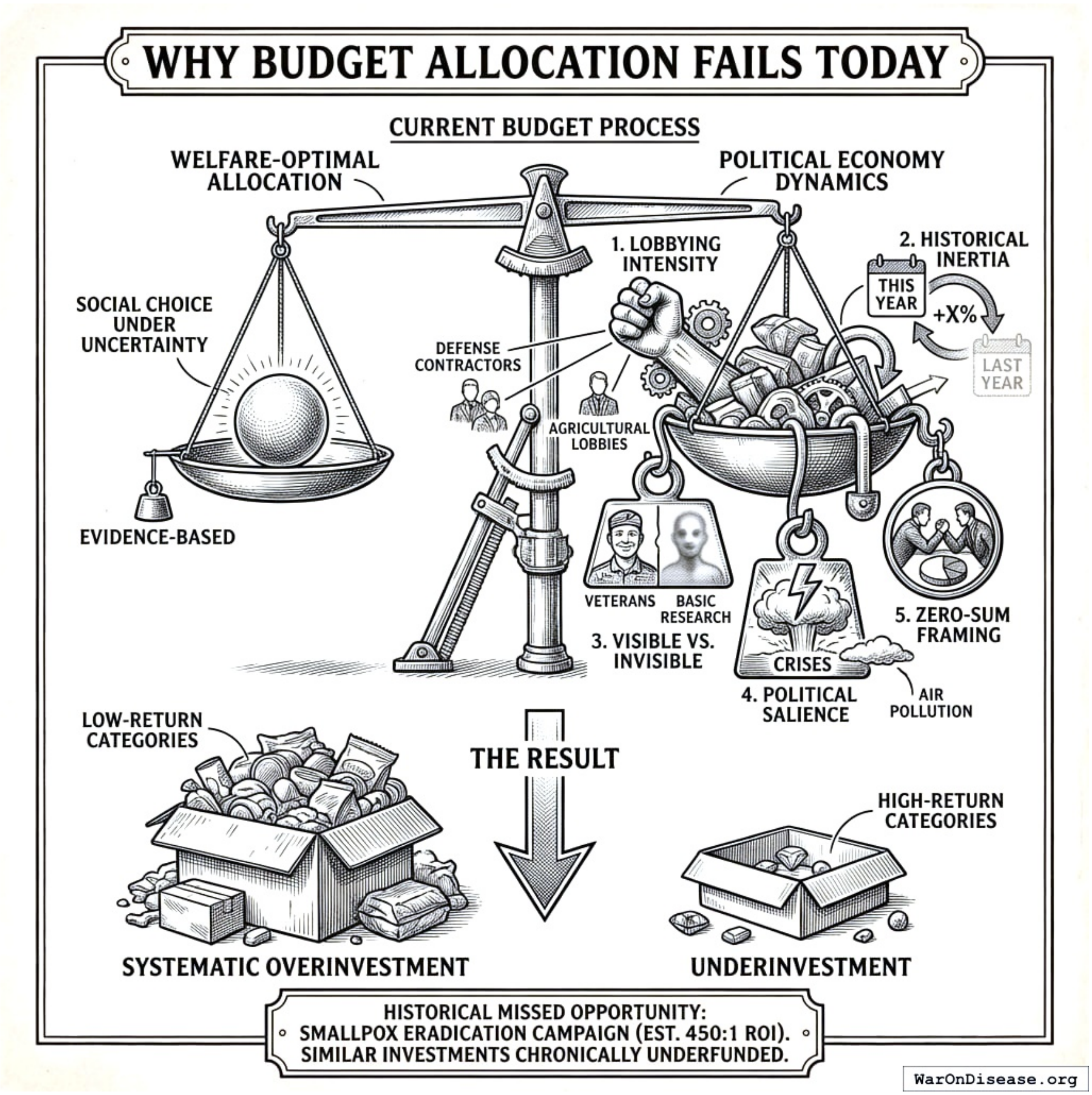

Figure 3: A comparison between the political drivers of current budget allocation (such as lobbying and historical inertia) and the resulting gap between low-return and high-return public investments.

Current budget allocation follows a process dominated by:

1. **Lobbying intensity**: Categories with organized beneficiaries (military contractors, agricultural lobbies) receive disproportionate funding regardless of evidence
2. **Historical inertia**: This year's budget is last year's budget plus a percentage, not a fresh optimization
3. **Visible vs. invisible beneficiaries**: Programs with identifiable beneficiaries (veterans) outcompete programs with diffuse beneficiaries (basic research)
4. **Political salience**: Crises drive spending regardless of cost-effectiveness (terrorism vs. air pollution)
5. **Zero-sum framing**: Budget debates treat all categories as competing rather than asking which ones are at optimal levels

The result: systematic overinvestment in low-return categories and underinvestment in high-return categories. Historical examples demonstrate the scale of missed opportunities: the smallpox eradication campaign returned an estimated 450:1 ROI[89], yet similar high-return public health investments remain chronically underfunded.

2.2 The RDA Analogy: Optimal Levels, Not Just Marginal Returns

Nutrition science doesn't just say "eat more vitamins." It specifies **Recommended Daily Allowances** - target intake levels where:

- **Below RDA**: Deficiency symptoms, reduced function
- **At RDA**: Optimal health benefits
- **Above RDA**: Diminishing returns, potential toxicity

Budget allocation should work the same way. For each spending category:

- **Below OSL**: Foregone welfare gains (underinvestment)
- **At OSL**: Optimal welfare return per dollar
- **Above OSL**: Diminishing or negative returns (overinvestment)

infinite spending on any category doesn't make sense, even one with high returns. Early childhood education has excellent returns - but spending $10 trillion on it wouldn't produce 10x the benefits of spending $1 trillion. There's an optimal level.

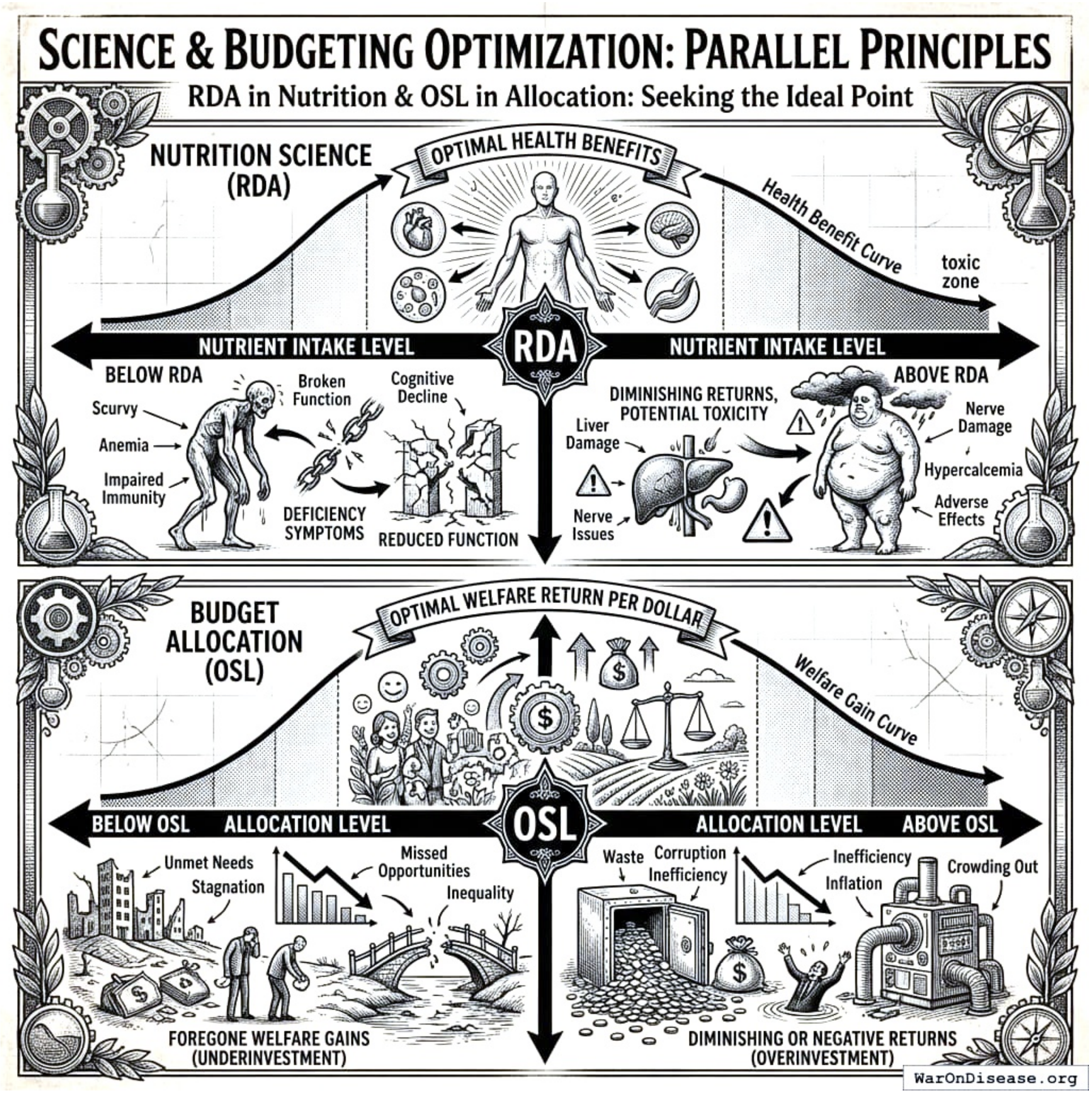

Figure 4: Conceptual comparison between Recommended Daily Allowances (RDA) in nutrition and Optimal Spending Levels (OSL) in public finance.

2.3 What This Framework Provides

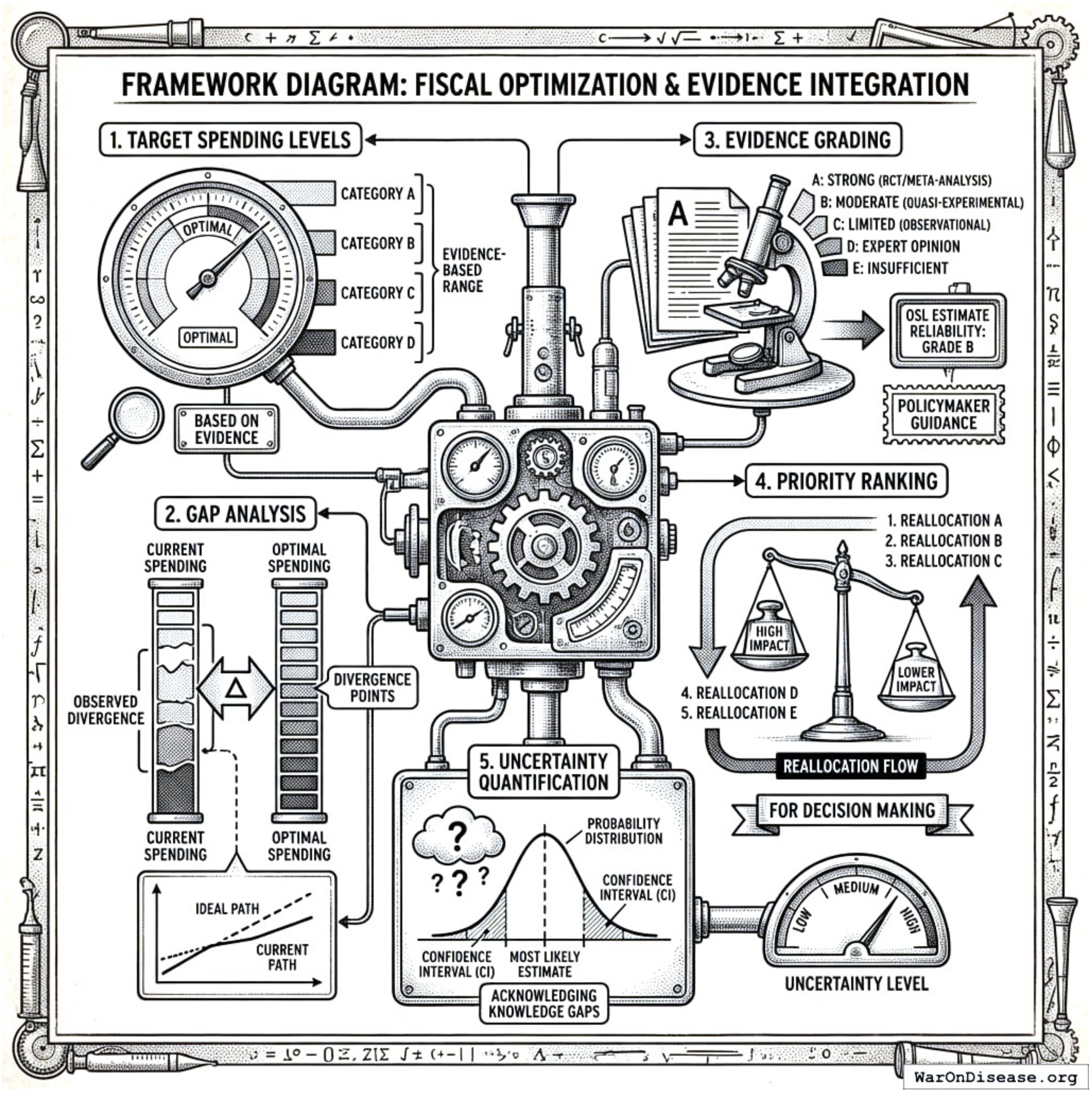

Figure 5: A conceptual diagram showing the five core components of the budget framework, illustrating how evidence-based targets and gap analysis inform priority ranking and uncertainty assessment.

1. **Target spending levels** for each budget category based on evidence
2. **Gap analysis** showing where current spending diverges from optimal
3. **Evidence grading** so policymakers know which OSL estimates are reliable
4. **Priority ranking** for reallocation decisions
5. **Uncertainty quantification** acknowledging what we don't know

2.4 Outcome Metrics: What We're Optimizing

All OBG recommendations ultimately aim to maximize two welfare metrics:

1. **Real after-tax median income growth** (pp/year): Year-over-year percentage change in inflation-adjusted, post-tax median household income. Sources: Census Bureau, BLS.
2. **Median healthy life years** (years): Expected years of life in good health at the population median. Sources: WHO Global Health Observatory, national health surveys.

The welfare function combines these with equal weight by default:

$$W = 0.5 \cdot \text{IncomeGrowth} + 0.5 \cdot \text{HealthyYears}$$

Why these two metrics? Most policy effects eventually show up in one or both. Economic policies (taxes, regulations, trade) primarily affect income growth. Health policies (healthcare access, public health, safety) primarily affect healthy life years. Education and infrastructure affect both. See Two-Metric Welfare Function for the complete framework.

Every spending category's OSL is ultimately justified by its expected impact on these two metrics. The gap analysis and priority rankings reflect which reallocations would most improve the combined welfare function.

3 Related Work

The OBG framework builds on and extends several established traditions in public finance and evidence-based policy.

3.1 Budget Analysis Frameworks

Congressional Budget Office (CBO) Scoring. The CBO provides cost estimates for proposed legislation, projecting fiscal impacts over 10-year windows[135]. However, CBO scoring focuses on *cost* rather than *welfare optimization* - it answers "what will this cost?" not "what should we spend?" OBG complements CBO analysis by providing evidence-based spending targets against which proposals can be evaluated.

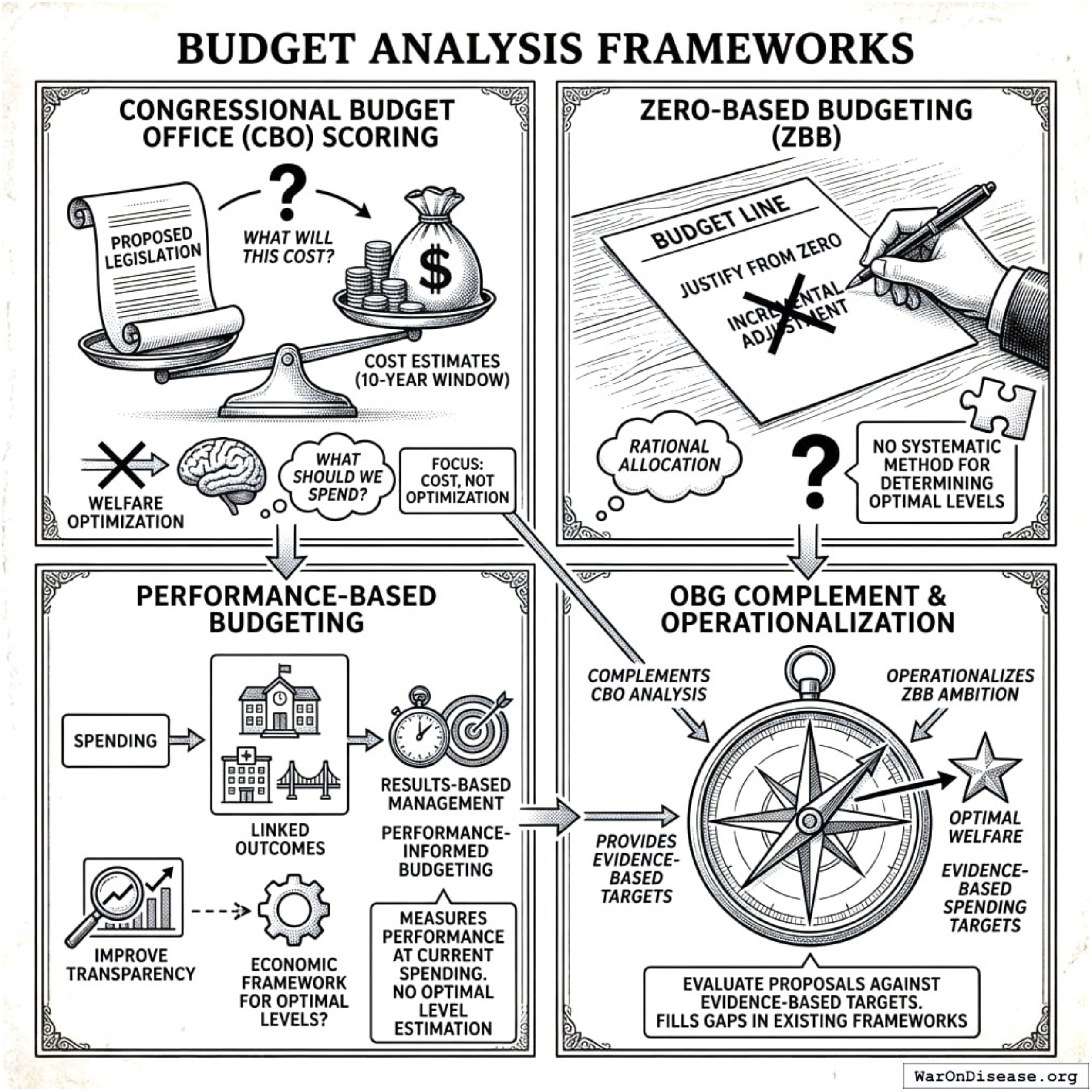

Figure 6: A comparison matrix of budget analysis frameworks showing the focus of CBO Scoring, Performance-Based Budgeting, and Zero-Based Budgeting relative to the evidence-based targets of the OBG framework.

Performance-Based Budgeting. Since the Planning-Programming-Budgeting System (PPBS) of the 1960s, governments have attempted to link spending to outcomes. Modern variants include Results-Based Management and Performance-Informed Budgeting. These approaches improve transparency but typically lack the economic framework for determining *optimal* levels - they measure performance at current spending without estimating what spending *should* be.

Zero-Based Budgeting. ZBB requires justifying each budget line from zero rather than incremental adjustment. While philosophically aligned with OBG's goal of rational allocation, ZBB provides no systematic method for determining optimal levels. OBG operationalizes ZBB's ambition with evidence-based targets.

3.2 Evidence-Based Policy Movement

What Works Clearinghouses. Organizations like the What Works Clearinghouse (education), Cochrane Collaboration (health), and Campbell Collaboration (social policy) synthesize intervention evidence through systematic reviews. OBG draws on these evidence bases but extends beyond intervention evaluation to budget-level optimization. While clearinghouses answer "does this work?", OBG answers "how much should we spend?"

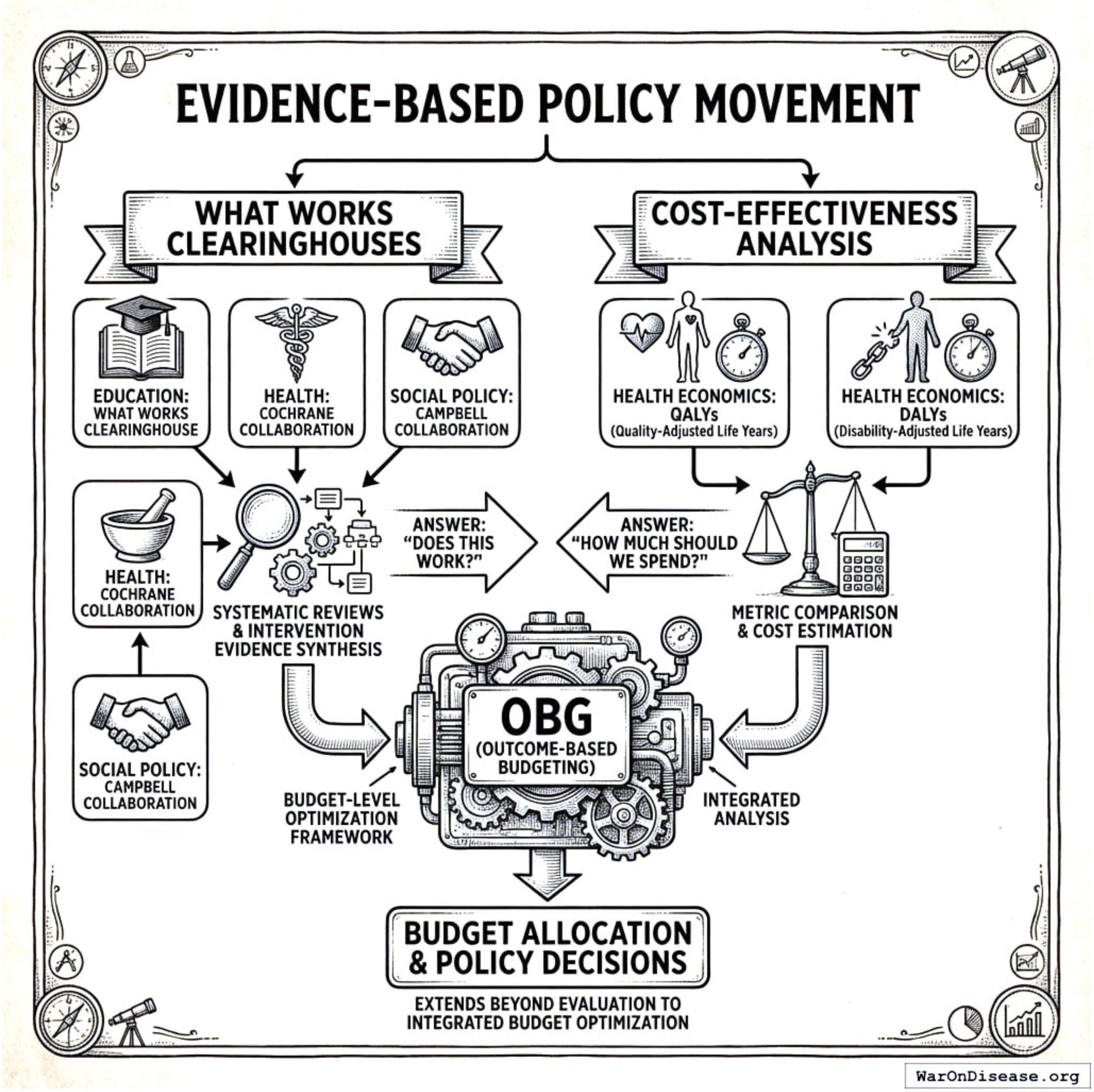

Figure 7: A comparison showing how Outcome-Based Governance (OBG) builds upon traditional evidence synthesis and cost-effectiveness analysis by shifting from intervention evaluation to budget-level optimization.

Cost-Effectiveness Analysis. Health economics has developed methods for comparing interventions using metrics like QALYs (Quality-Adjusted Life Years) and DALYs (Disability-Adjusted Life Years)[136]. OBG incorporates cost-effectiveness as one of two estimation methods but applies it within an integrated budget optimization framework rather than intervention-by-intervention.

3.3 Comparative Public Finance

OECD Government Spending Analysis. The OECD publishes extensive cross-country spending comparisons and outcome data[95,112]. OBG leverages this data infrastructure for diminishing returns analysis while adding the conceptual framework of optimal levels and evidence-weighted confidence.

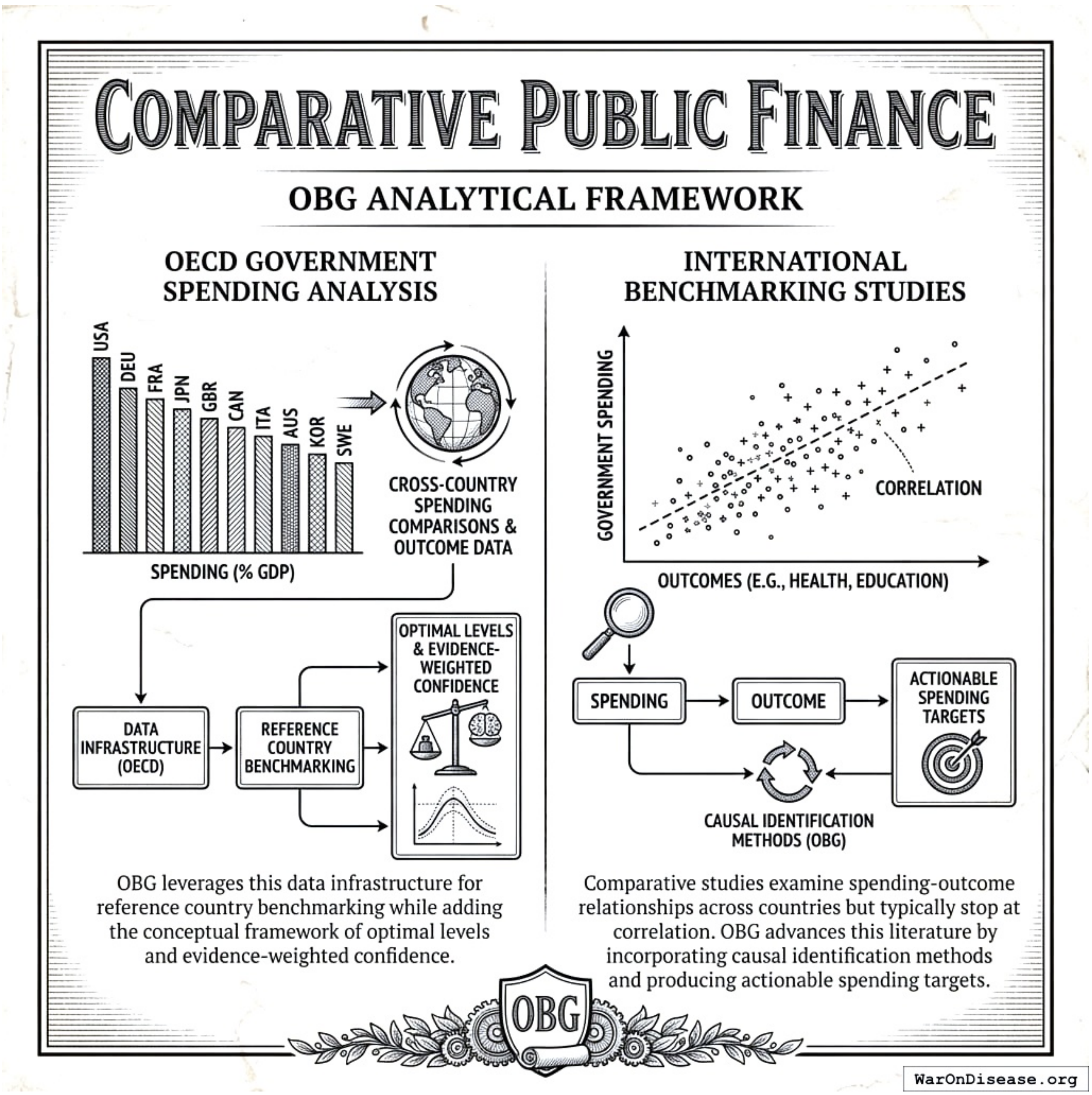

Figure 8: A conceptual model showing the methodological progression from standard OECD benchmarking to OBG's causal identification framework and actionable spending targets.

International Benchmarking Studies. Comparative studies examine spending-outcome relationships across countries but typically stop at correlation. OBG advances this literature by incorporating causal identification methods and producing actionable spending targets.

3.4 How OBG Differs

The OBG framework advances existing approaches in three key ways:

1. **Integrated multi-method estimation.** Rather than relying on a single approach, OBG combines OSL estimates from diminishing returns modeling and cost-effectiveness analysis. This provides robustness and identifies where methods agree or conflict.

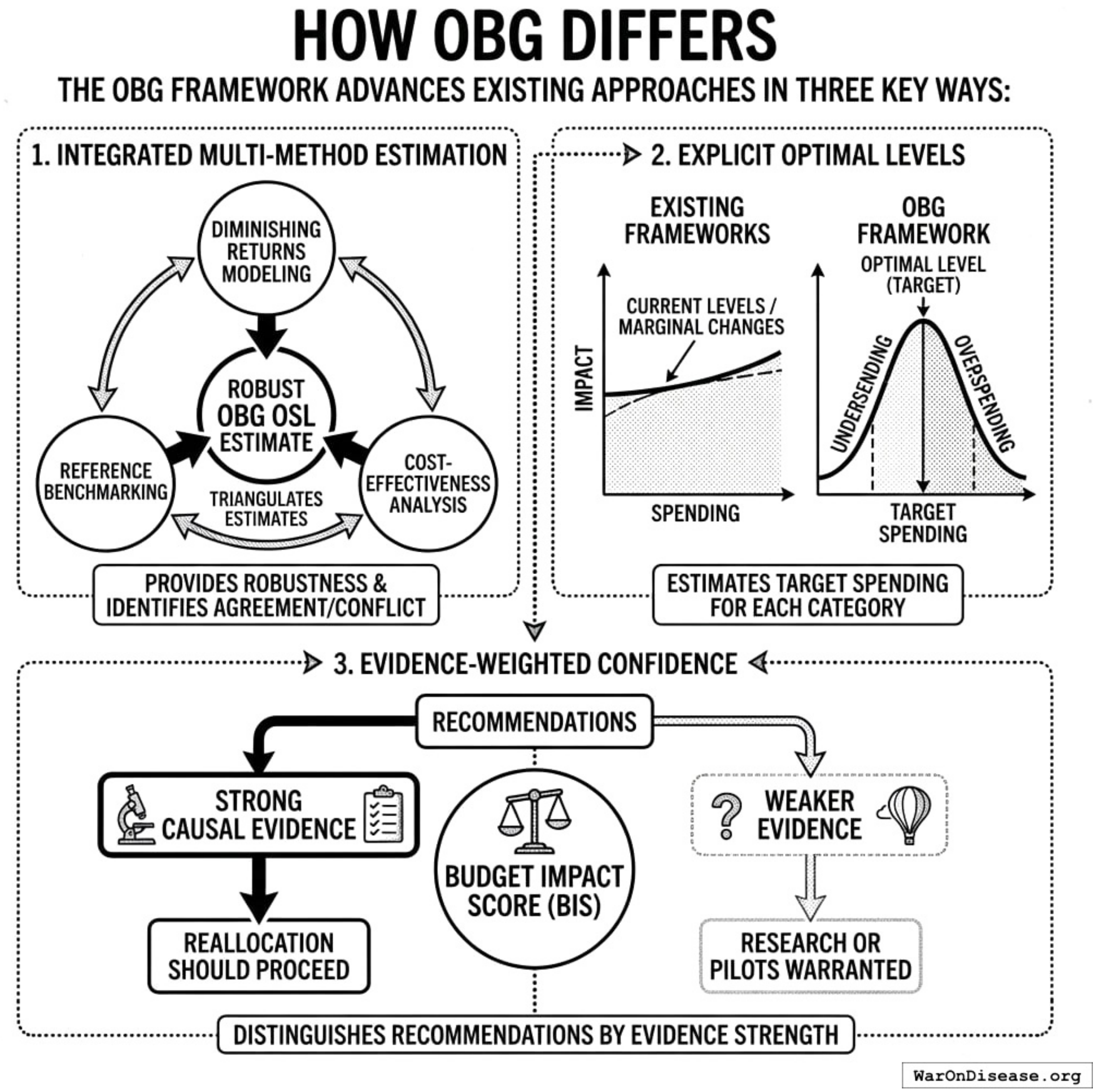

Figure 9: A conceptual overview of the OBG framework illustrating the triangulation of estimation methods, the identification of optimal spending targets, and the categorization of recommendations based on evidence strength via the Budget Impact Score.

2. **Explicit optimal levels.** Unlike frameworks that analyze spending at current levels or propose marginal changes, OBG estimates target spending levels for each category - acknowledging

that both underspending and overspending are suboptimal.

3. **Evidence-weighted confidence.** The Budget Impact Score (BIS) distinguishes recommendations supported by strong causal evidence (where reallocation should proceed) from those based on weaker evidence (where research or pilots are warranted).

4 Theoretical Framework

This section formalizes the OBG framework as a social planner's optimization problem, establishing the theoretical foundations for optimal spending levels and evidence-weighted allocation.

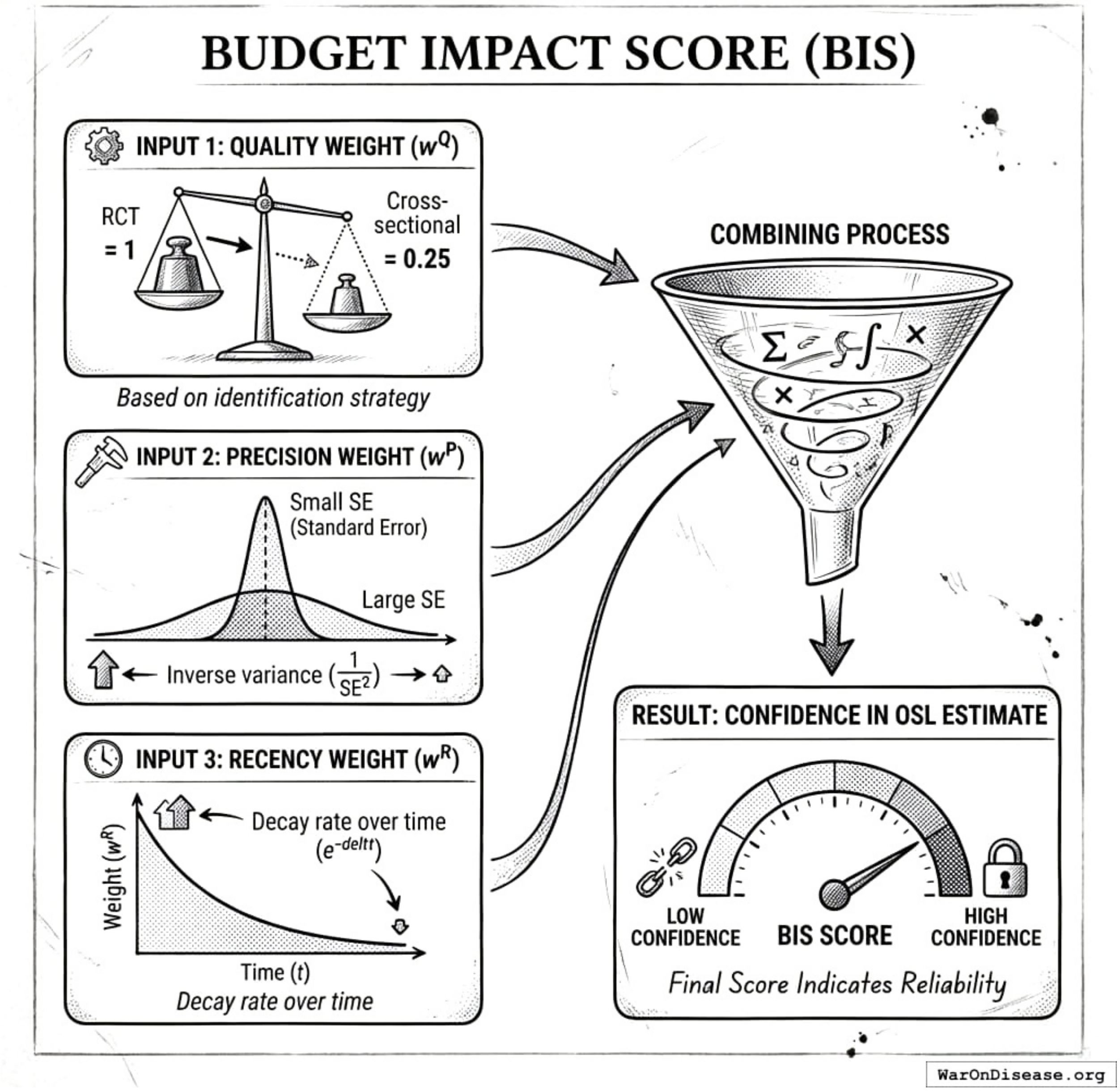

Figure 10: A conceptual diagram illustrating the social planner's optimization process, showing how evidence-weighted inputs lead to optimal spending levels and resource allocation within the OBG framework.

4.1 The Social Planner's Problem

Consider a benevolent social planner allocating a fixed budget B across n spending categories. Each category generates welfare measured using the two-metric framework: **real after-tax median income growth** and **median healthy life years**.

Why these specific metrics? They are universal instrumental goods: virtually everyone wants higher purchasing power and longer healthy life, regardless of other values. They are hard to game (improving them requires actually helping typical citizens), measured by independent statistical agencies, and capture most policy effects. GDP can rise while median income stagnates; this framework correctly identifies such outcomes as low-welfare.

Let s_i denote spending on category i, with $\sum_{i=1}^{n} s_i = B$. Each category produces effects on both welfare metrics:

- $\beta_i^{inc}(s_i)$: Effect on real after-tax median income growth (pp/year)
- $\beta_i^{hlth}(s_i)$: Effect on median healthy life years (years)

Total welfare from category i follows the two-metric welfare function:

$$W_i(s_i) = \alpha \cdot \beta_i^{inc}(s_i) + (1 - \alpha) \cdot \beta_i^{hlth}(s_i)$$

where $\alpha = 0.5$ by default (equal weight to economic and health welfare). All welfare calculations in this framework flow through these two metrics.

Assumption 1 (Diminishing Returns). For each category i, both effect functions β_i^{inc} and β_i^{hlth} are twice continuously differentiable with positive first derivatives and negative second derivatives for all $s > 0$.

The social planner maximizes aggregate welfare:

$$\max_{\{s_i\}_{i=1}^n} \sum_{i=1}^{n} W_i(s_i) \quad \text{subject to} \quad \sum_{i=1}^{n} s_i = B, \quad s_i \geq 0 \ \forall i$$

Proposition 1 (Equimarginal Principle). *At the optimal allocation $\{s_i^*\}$, marginal welfare is equalized across all categories with positive spending:*

$$W_i'(s_i^*) = \lambda^* \quad \forall i \text{ with } s_i^* > 0$$

where λ^* is the shadow price of the budget constraint.

Proof. The Lagrangian is $\mathcal{L} = \sum_i W_i(s_i) - \lambda(\sum_i s_i - B)$. First-order conditions yield $W_i'(s_i^*) = \lambda$ for interior solutions. By strict concavity of W_i, the second-order conditions are satisfied. ☐

4.2 Optimal Spending Levels Under Uncertainty

In practice, the welfare functions $W_i(\cdot)$ are not known with certainty. Let $\hat{W}_i(s)$ denote the planner's estimate of welfare, with associated uncertainty $\sigma_i^2(s)$.

Definition 1 (Optimal Spending Level). The Optimal Spending Level for category i is:

$$\text{OSL}_i \equiv \arg\max_{s_i} \mathbb{E}[\hat{W}_i(s_i)] - \frac{\rho}{2}\text{Var}[\hat{W}_i(s_i)]$$

where $\rho \geq 0$ is the planner's risk aversion parameter.

For risk-neutral planners ($\rho = 0$), OSL reduces to the spending level that maximizes expected welfare. For risk-averse planners, OSL accounts for estimation uncertainty.

Proposition 2 (OSL Characterization). *Under Assumption 1, with estimated marginal welfare $\hat{W}_i'(s)$ and estimation variance $\sigma_i^2(s)$, the OSL satisfies:*

$$\mathbb{E}[\hat{W}_i'(\text{OSL}_i)] = r + \rho \cdot \left.\frac{\partial \sigma_i^2}{\partial s}\right|_{s=\text{OSL}_i}$$

where r is the social discount rate (opportunity cost of public funds).

Proof. The first-order condition for the uncertainty-adjusted maximization problem yields the result. The term r represents the marginal value of funds in alternative uses; the second term adjusts for risk. □

4.3 Budget Impact Score as Precision Weighting

The Budget Impact Score formalizes the precision of OSL estimates, enabling evidence-weighted reallocation decisions.

Definition 2 (Budget Impact Score). For category i with n_i effect estimates $\{\hat{\beta}_{ij}\}_{j=1}^{n_i}$, the Budget Impact Score is:

$$\text{BIS}_i = \min\left(1, \frac{1}{K}\sum_{j=1}^{n_i} w_j^Q \cdot w_j^P \cdot w_j^R\right)$$

where:

- $w_j^Q \in (0, 1]$ = quality weight based on identification strategy (RCT = 1, cross-sectional = 0.25)
- $w_j^P = 1/\text{SE}(\hat{\beta}_j)^2$ = precision weight (inverse variance)
- $w_j^R = e^{-\delta(t_{now} - t_j)}$ = recency weight with decay rate δ
- K = calibration constant

Proposition 3 (BIS as Inverse Variance). *Under standard meta-analytic assumptions, BIS is proportional to the precision of the pooled effect estimate:*

$$\text{BIS}_i \propto \frac{1}{\text{Var}(\hat{\beta}_i^{pooled})}$$

where $\hat{\beta}_i^{pooled}$ is the quality-weighted pooled estimate of spending effects.

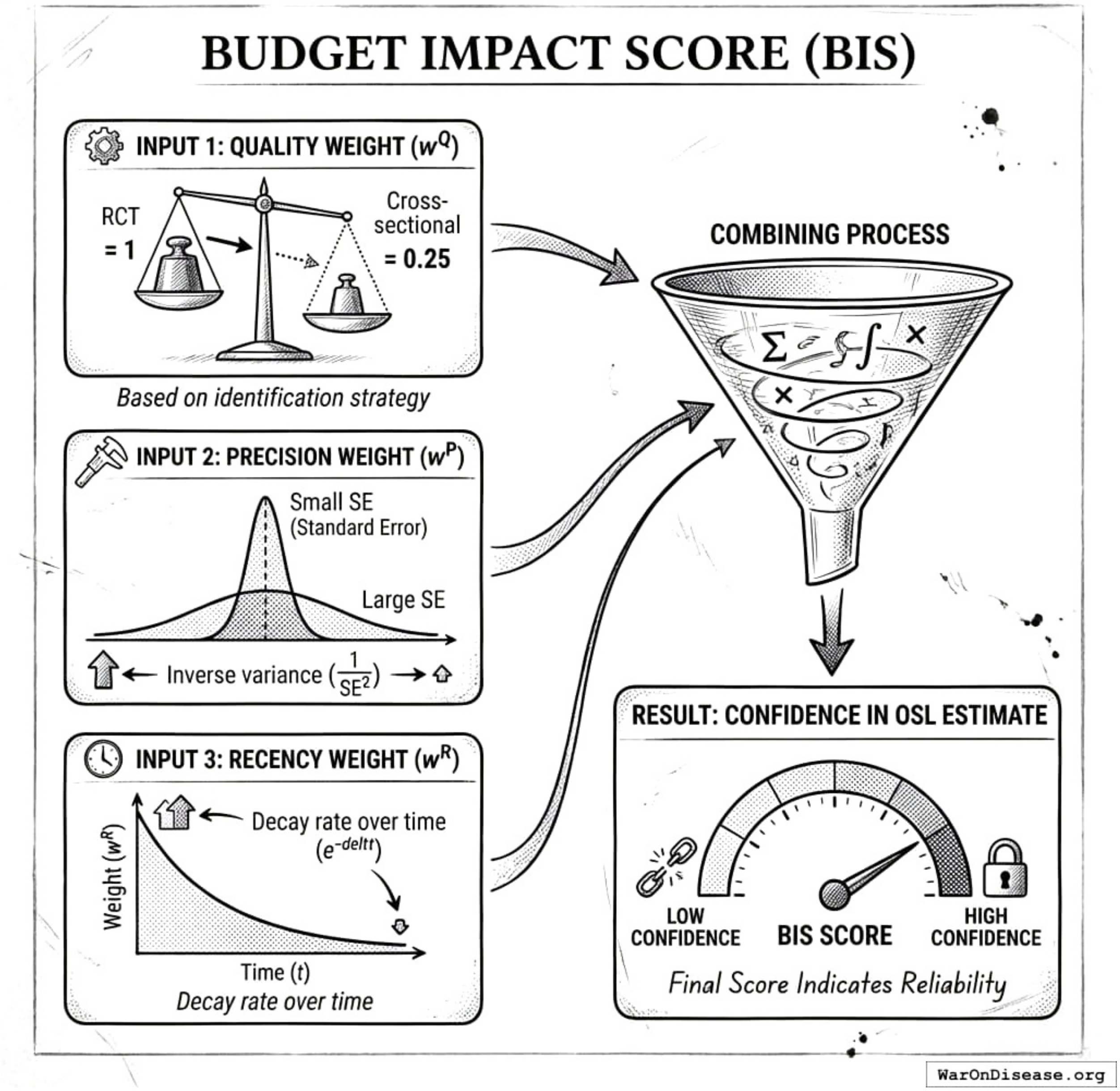

Figure 11: Breakdown of the Budget Impact Score (BIS) components, showing how quality, precision, and recency weights combine to quantify confidence.

4.4 Gap Analysis and Welfare Gains

Definition 3 (Spending Gap). The spending gap for category i is:

$$\text{Gap}_i = \text{OSL}_i - s_i^{current}$$

Proposition 4 (Welfare Gains from Gap Closure). *For small gaps, the welfare gain from moving spending from current level to OSL is approximately:*

$$\Delta W_i \approx W_i'(s_i^{current}) \cdot \text{Gap}_i - \frac{1}{2}|W_i''(\bar{s})| \cdot \text{Gap}_i^2$$

where $\bar{s}$ is between $s_i^{current}$ and OSL_i.

Proof. Taylor expansion of $W_i(\text{OSL}_i) - W_i(s_i^{current})$ around $s_i^{current}$. □

Corollary 1 (Priority Ranking). *Categories should be prioritized for reallocation in order of:*

$$\text{Priority}_i = |\text{Gap}_i| \times \text{BIS}_i \times |W_i'(s_i^{current})|$$

This ranks categories by expected welfare gain adjusted for estimation confidence.

Note: In the simplified implementation (Section 10.2), we normalize by setting $|W_i'(s_i^{current})| = 1$ for all categories, reducing the priority formula to $\text{Priority}_i = |\text{Gap}_i| \times \text{BIS}_i$. This assumes equal marginal welfare weights across categories as a first approximation. Future iterations could incorporate category-specific marginal welfare estimates.

4.5 Welfare Bounds Under Model Uncertainty

When the functional form of $W_i(\cdot)$ is uncertain, we can establish bounds on welfare gains.

Proposition 5 (Welfare Bounds). *Let $\underline{W}_i$ and $\overline{W}_i$ denote lower and upper bounds on the welfare function consistent with available evidence. Then:*

$$\underline{\Delta W} = \sum_{i:\text{Gap}_i>0} \underline{W}_i'(s_i) \cdot \text{Gap}_i \leq \Delta W \leq \sum_{i:\text{Gap}_i>0} \overline{W}_i'(s_i) \cdot \text{Gap}_i = \overline{\Delta W}$$

The OBG framework reports both point estimates and these bounds via sensitivity analysis.

4.6 Summary of Theoretical Results

Result	Implication for OBG
Proposition 1	Optimal allocation equalizes marginal returns
Proposition 2	OSL accounts for both expected returns and uncertainty
Proposition 3	BIS captures estimation precision
Proposition 4	Gap closure yields quantifiable welfare gains
Corollary 1	Priority ranking optimizes reallocation sequence
Proposition 5	Welfare bounds enable robust recommendations

5 Core Methodology

5.1 Spending Category Data Structure

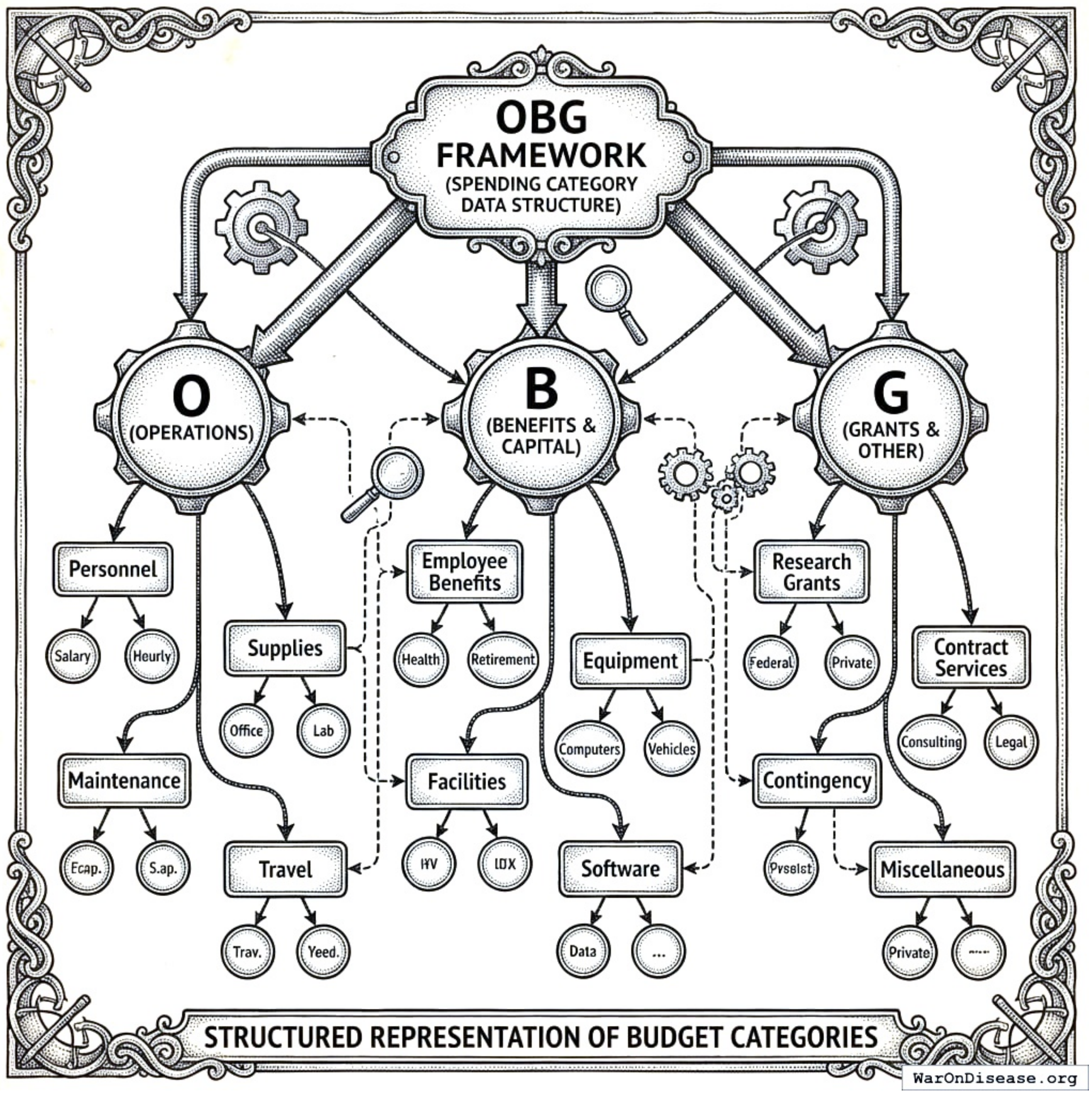

Figure 12: An entity-relationship diagram illustrating the data structure of the OBG framework, connecting spending categories to reference data, optimal estimates, and gap analysis.

The OBG framework uses a structured representation of budget categories:

```
-- Spending categories
spending_categories (
    id, name, parent_category_id,
    spending_type, -- 'program', 'transfer', 'investment', 'regulatory'
```

```
    outcome_categories, -- which welfare outcomes this affects
    current_spending_usd, fiscal_year,
    data_source, last_updated
)

-- Cross-country spending data
reference_spending (
    category_id, country_code, year,
    spending_usd, spending_per_capita,
    spending_pct_gdp, population, gdp,
    data_source
)

-- Optimal spending level estimates
osl_estimates (
    category_id, estimation_method,
    osl_usd, osl_per_capita, osl_pct_gdp,
    confidence_interval_low, confidence_interval_high,
    evidence_grade, bis_score,
    methodology_notes, last_updated
)

-- Gap analysis
spending_gaps (
    category_id, current_spending_usd,
    osl_usd, gap_usd, gap_pct,
    priority_score, -- gap * BIS confidence
    recommended_action
)
```

5.2 Two Methods for OSL Estimation

Method	Use Case	Data Required	Strengths	Limitations
Diminishing returns modeling	Categories with cross-country spending-outcome data	Effect estimates at multiple spending levels	Theoretically grounded, finds optimal "knee"	Requires sufficient country variation
Cost-effectiveness threshold	Health/life-saving interventions	Cost per QALY/DALY, willingness-to-pay	Links to standard health economics[24]	Limited to monetizable outcomes

Each method is detailed below.

6 Diminishing Returns Modeling

6.1 The Core Concept

The fiscal multiplier literature establishes that spending effects vary systematically with scale[137,138]. At low spending levels, each additional dollar produces substantial welfare gains. At high spending levels, marginal returns diminish. The OSL is where marginal return equals opportunity cost.

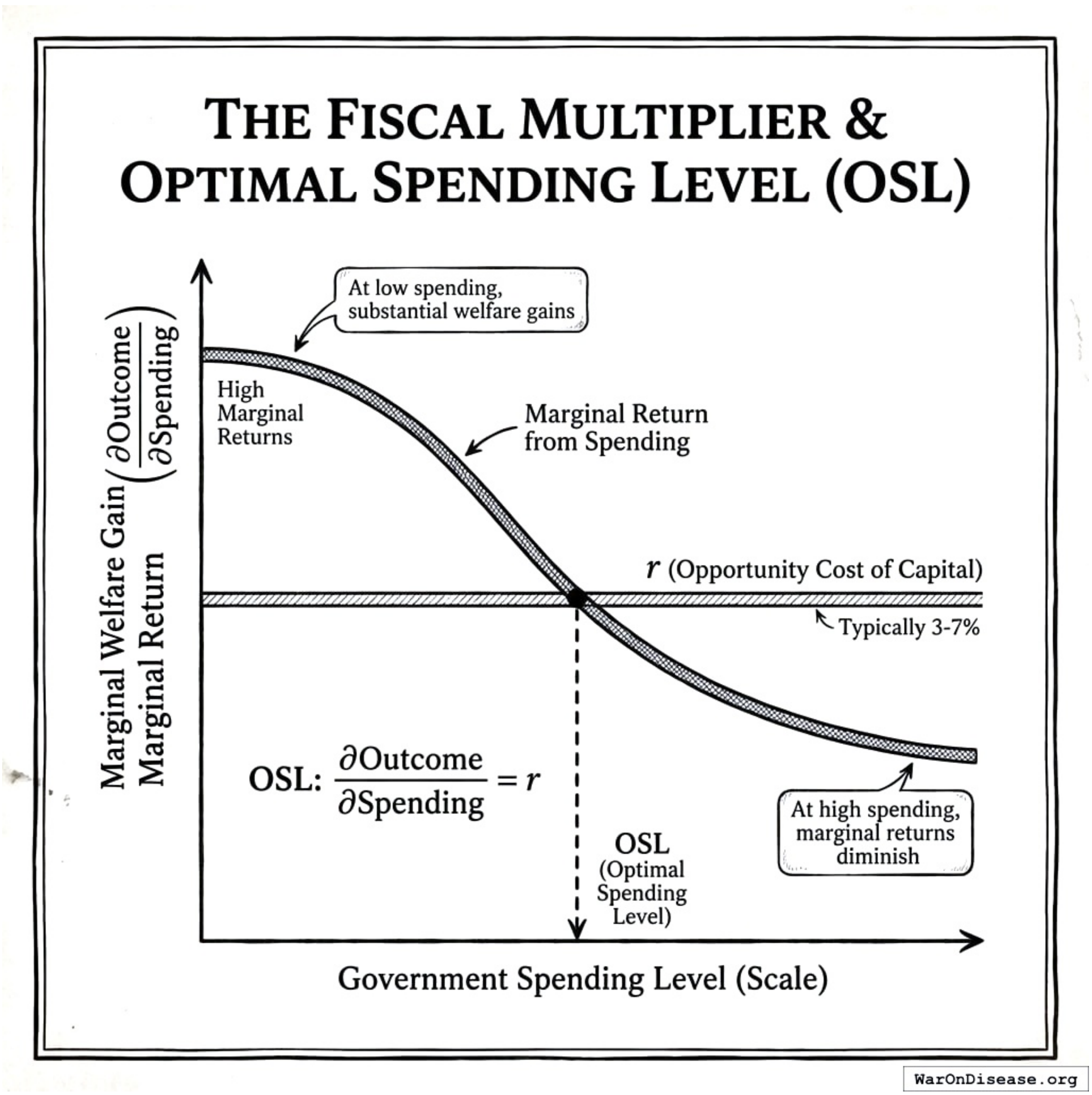

Figure 13: A graph showing a downward-sloping marginal return curve intersecting with a horizontal line representing the opportunity cost (r) to identify the Optimal Spending Level (OSL).

$$\text{OSL} : \frac{\partial \text{Outcome}}{\partial \text{Spending}} = r$$

Where r is the discount rate or opportunity cost of capital (typically 3-7%).

6.2 Finding the "Knee" of the Curve

Empirically, we look for the point where the outcome-spending relationship flattens:

```
Outcome
   ^
   |                    -----------
   |                 __/
   |               _/
   |             _/
   |           _/   <- OSL is around here
   |         _/
   |       _/
   |     _/
   |   _/
   | _/
   |/
   +-----------------------------------> Spending
         Low            High
```

6.3 Estimation Methods

1. Nonlinear regression on cross-country data

Fit diminishing returns functions:

$$\text{Outcome} = \alpha + \beta \cdot \log(\text{Spending}) + \epsilon$$

Or with saturation:

$$\text{Outcome} = \alpha + \beta \cdot \frac{\text{Spending}}{\text{Spending} + \gamma}$$

Where γ is the half-saturation constant.

2. Piecewise linear estimation

Estimate separate slopes for different spending ranges to identify where returns diminish.

3. Meta-regression of effect estimates

If multiple studies estimate effects at different spending levels, meta-regression can identify how effects vary with baseline spending. The credibility of such estimates depends critically on identification strategy[139].

6.4 Worked Example: K-12 Education Spending

Primary metric affected: Real after-tax median income growth (via higher wages from improved skills).

[140] exploited court-ordered school finance reforms to estimate causal effects of K-12 spending. Key finding: a 10% increase in per-pupil spending increases adult earnings by 7% for students from low-income families.

Does this effect diminish at higher spending levels?

Evidence from cross-state variation suggests:

Baseline spending (per pupil)	Effect of 10% increase	Implied marginal return
$8,000	+8% earnings	$0.80 per $1
$12,000	+5% earnings	$0.50 per $1
$16,000	+3% earnings	$0.30 per $1
$20,000	+1% earnings	$0.10 per $1

OBG estimation: At $16,000/pupil, the marginal return (~0.30) roughly equals the social discount rate. This suggests:

- Current US average: ~$15,000/pupil
- OSL: ~$16,000-$18,000/pupil (modest underinvestment)
- Gap: ~$50B nationally

Evidence grade: B (strong causal identification, moderate extrapolation uncertainty)

7 Worked Example: Pragmatic Clinical Trials

7.1 The Highest-Return Public Investment

Metrics affected: Both real after-tax median income growth (via reduced healthcare costs and improved productivity) and median healthy life years (via better treatments). This dual impact contributes to the exceptionally high returns.

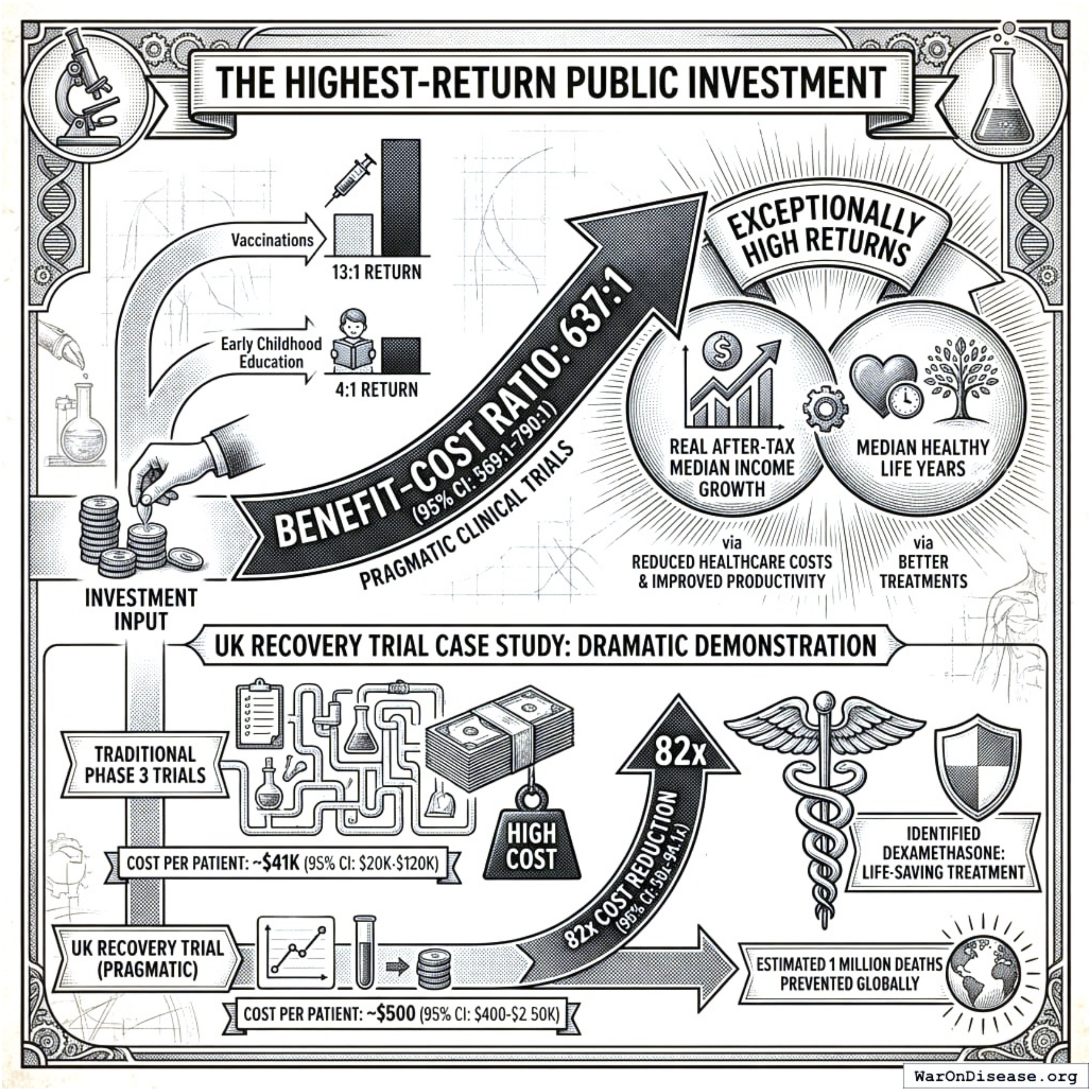

Figure 14: A comparison of return on investment across different public sectors and a cost-efficiency breakdown between pragmatic and traditional clinical trials.

Pragmatic clinical trials represent perhaps the single highest-return category of public investment identified in the literature. While vaccinations return 13:1 and early childhood education returns 4:1, pragmatic trials demonstrate benefit-cost ratios of **637:1 (95% CI: 569:1-790:1)**[141].

The UK's RECOVERY trial demonstrated this dramatically during COVID-19: it cost approximately $500 (95% CI: $400-$2.50K) versus $41K (95% CI: $20K-$120K) for traditional Phase 3 trials, a 82x (95% CI: 50x-94.1x) cost reduction[142]. This single trial identified dexamethasone as a life-saving treatment, preventing an estimated 1 million deaths globally.

7.2 OSL Estimation

Pragmatic trials represent an *innovation frontier* where no country has achieved optimal investment. We estimate OSL from cost-effectiveness analysis:

1. **Unmet medical need**: Approximately 2.88 billion DALYs/year (95% CI: 2.63 billion DALYs/year-3.13 billion DALYs/year) DALYs annually from conditions lacking adequate treatment
2. **Cost per DALY averted**: Pragmatic trials cost $929 (95% CI: $929-$1.40K) (ADAPTABLE trial) vs. $41K (95% CI: $20K-$120K) traditional
3. **Scale-up potential**: Current global clinical trial spending is approximately $60B (95% CI: $50B-$75B)/year, but only ~$500M goes to pragmatic/embedded designs

Data Point	Value	Source
Current pragmatic trial spending (US)	~$500M	NIH Common Fund
Traditional trial spending (global)	$60B (95% CI: $50B-$75B)	Industry + NIH
Cost per patient (pragmatic)	$929 (95% CI: $929-$1.40K)	ADAPTABLE trial
Cost per patient (traditional Phase 3)	$41K (95% CI: $20K-$120K)	Industry average
Cost reduction factor	**44.1x (95% CI: 39.4x-89.1x)**	Calculated

7.3 Diminishing Returns Analysis

Unlike most spending categories, pragmatic trials show **increasing returns at current spending levels** due to:

1. **Network effects**: Each additional participant improves statistical power for all trials
2. **Infrastructure leverage**: Platform trials amortize fixed costs across multiple interventions
3. **Learning effects**: Evidence accumulation improves trial design efficiency

The "knee" of the diminishing returns curve is estimated at **$50-100B annually** (vs. current ~$500M), suggesting we are operating far below optimal.

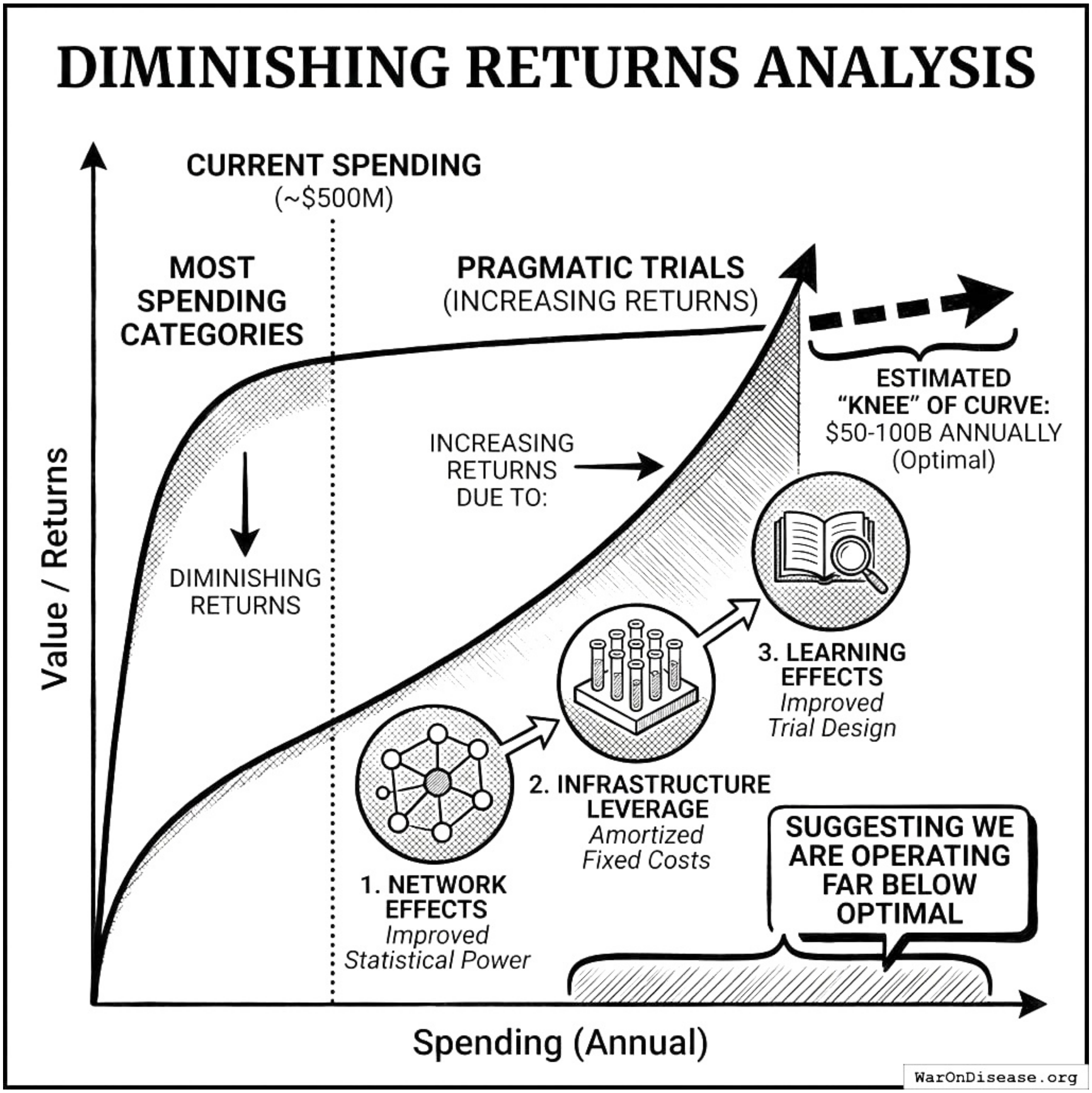

Figure 15: A conceptual line graph showing returns versus spending for pragmatic trials, highlighting the 'knee' of the curve at 50-100B and the current position at 500M within the increasing returns phase.

7.4 Cost-Effectiveness Calculation

Using standard health economics methodology:

Component	Value	Calculation
Cost per pragmatic trial participant	$929 (95% CI: $929-$1.40K)	ADAPTABLE benchmark
QALYs gained per participant	0.05-0.2	Evidence generation value

Component	Value	Calculation
Cost per QALY	\$4,600-\$18,600	Well below \$50K threshold
Scale-up population	50M patients/year	10% of treatable conditions
OSL estimate	**\$50B/year**	Conservative

7.5 Gap Analysis

Metric	Value
Current spending (pragmatic trials)	~\$500M
OSL	\$50B
Gap	**+\$49.5B (99x underinvestment)**
Gap % of current	+9,900%
Opportunity cost	637:1 (95% CI: 569:1-790:1) foregone returns

Evidence grade: A (RCT evidence from RECOVERY, ADAPTABLE; strong theoretical foundation)

7.6 Why This Category Dominates

Pragmatic clinical trials have the highest priority score of any category analyzed:

$$\text{Priority} = |\text{Gap}| \times \text{BIS} = \$49.5B \times 0.90 = 44.6$$

Among categories requiring increased investment, this is the highest priority score, exceeding basic research (31.5), vaccinations (25.7), and early childhood (17.0). Military spending has a larger absolute priority score (195.5) due to its massive gap, but represents overinvestment requiring reduction.

8 Cost-Effectiveness Threshold Analysis

8.1 The Standard Health Economics Approach

Cost-effectiveness analysis has become the standard framework for health resource allocation decisions[136]. The QALY (Quality-Adjusted Life Year) metric enables comparison across diverse health interventions by monetizing health outcomes at a consistent threshold[143].

For health interventions, cost-effectiveness analysis provides OSL estimates:

$$\text{OSL} = \sum_{\text{interventions}} \text{Scale}_i \times \text{Cost}_i \quad \text{where } \frac{\text{Cost}_i}{\text{QALY}_i} < \text{WTP}$$

Where:

- Scale_i = target population for intervention i
- Cost_i = per-person cost of intervention i
- QALY_i = QALYs gained per person from intervention i
- WTP = willingness-to-pay threshold (typically \$50K-\$150K per QALY)

8.2 Building Up from Intervention-Level Data

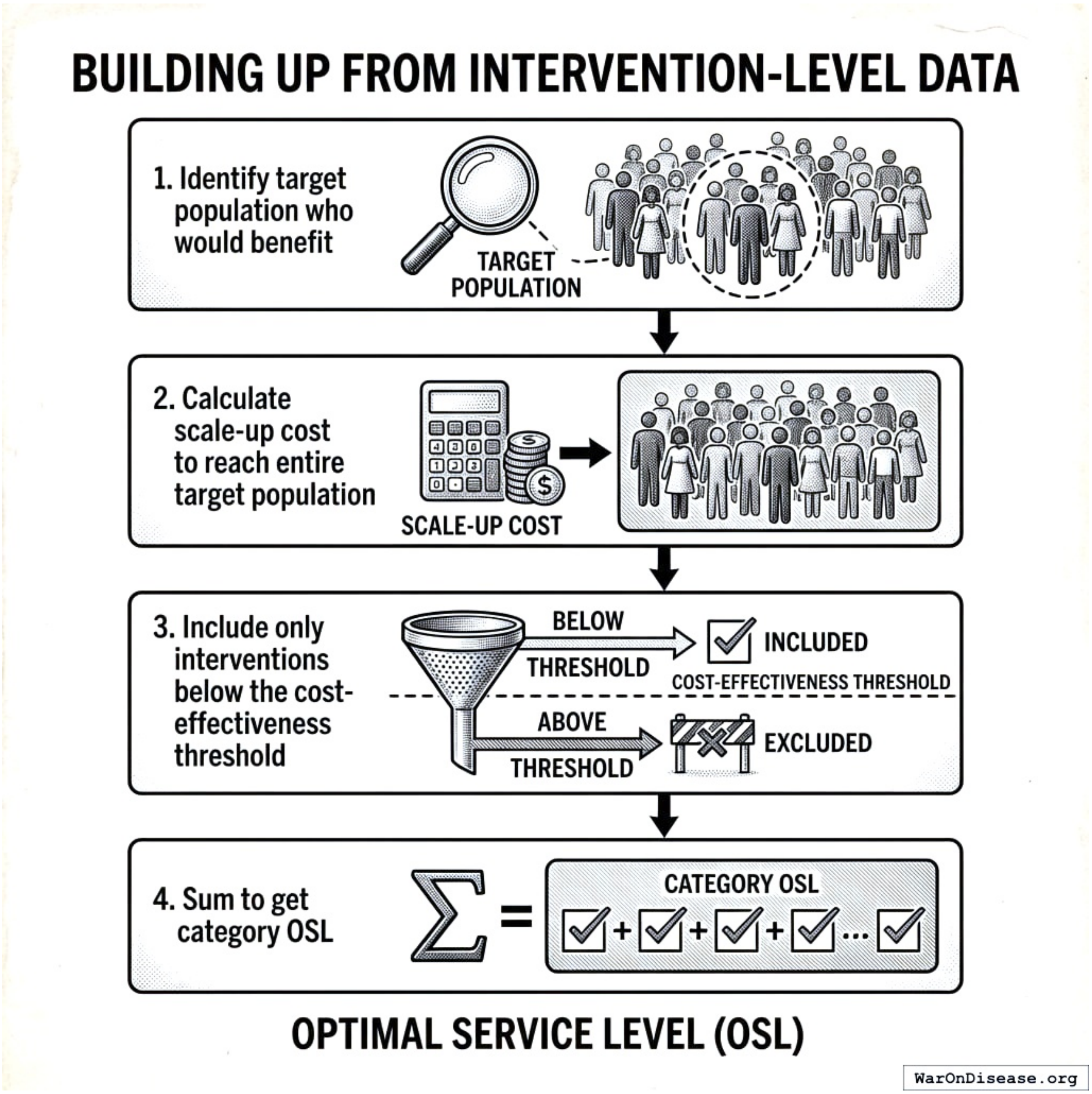

Figure 16: A sequential flowchart illustrating the four-step process of aggregating intervention-level data into a category-level Optimal Service Level (OSL).

For each health intervention with cost-effectiveness data:

1. **Identify target population** who would benefit
2. **Calculate scale-up cost** to reach entire target population
3. **Include only interventions** below the cost-effectiveness threshold
4. **Sum to get category OSL**

8.3 Worked Example: Vaccinations

Primary metric affected: Median healthy life years (via disease prevention and mortality reduction).

Vaccinations represent one of the highest-return public health investments, with estimated returns of 44:1 for routine childhood immunization[8,144]. The economic benefits include avoided medical costs, productivity gains, and reduced mortality[7].

Cost-effectiveness estimates from CEA Registry and CDC vaccination cost studies. QALY estimates reflect average health gains across target populations; costs include vaccine acquisition, administration, and program overhead.

Intervention	Target pop.	Cost/person	QALY/person	Cost/QALY	Source	Include?
Childhood routine	4M births	$500	0.1	$5,000	CDC VFC	Yes
HPV vaccination	4M teens	$300	0.05	$6,000	CEA Registry	Yes
Flu (elderly)	50M elderly	$40	0.01	$4,000	CDC	Yes
Shingles	40M eligible	$200	0.02	$10,000	CEA Registry	Yes
COVID boosters	100M adults	$30	0.005	$6,000	CDC	Yes

All interventions fall well below the conventional $50,000-$150,000 per QALY cost-effectiveness threshold, indicating strong economic justification for full scale-up.

OBG calculation:

- Childhood routine: 4M × $500 = $2.0B
- HPV: 4M × $300 = $1.2B
- Flu (elderly): 50M × $40 = $2.0B
- Shingles: 40M × $200 = $8.0B
- COVID boosters: 100M × $30 = $3.0B
- **Total OSL: ~$16B** (vs. current ~$8B)

Gap: +$8B (underinvestment)

Evidence grade: A (RCT evidence for most vaccines, well-established cost-effectiveness)

9 Budget Impact Score (BIS)

The Budget Impact Score measures **confidence** in each category's OSL estimate based on the quality and quantity of causal evidence. The scoring methodology draws on the established evidence hierarchy from the econometrics literature[139,145].

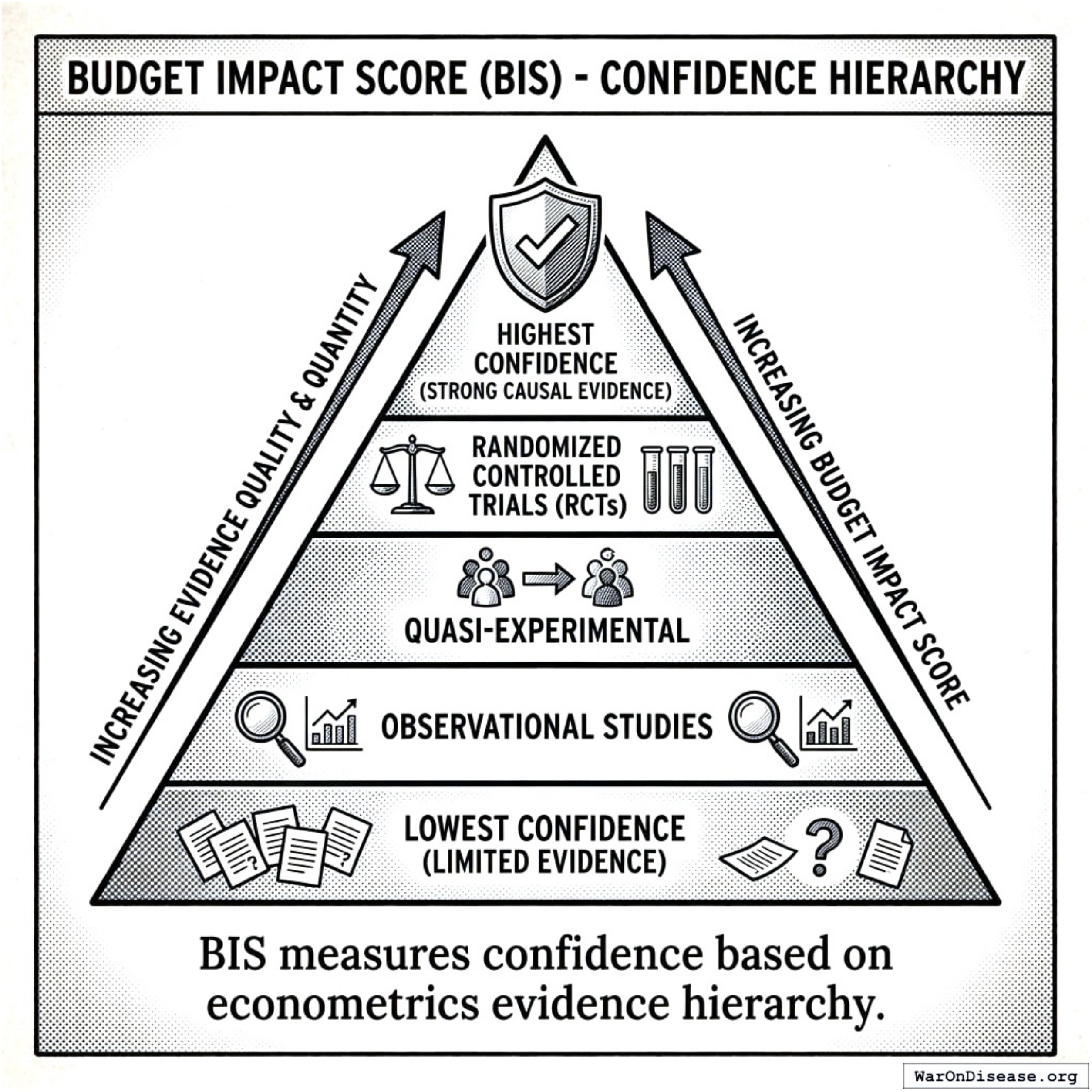

Figure 17: A diagram illustrating the hierarchy of causal evidence, showing how different levels of evidence quality determine the Budget Impact Score and overall confidence levels.

9.1 BIS Calculation

For each spending category i:

Step 1: Gather effect estimates

Collect all available causal effect estimates $\{\beta_{i,1}, \beta_{i,2}, ..., \beta_{i,n_i}\}$ from the econometric literature.

Step 2: Compute quality weights

Identification Method	Quality Weight (w^Q)
Randomized controlled trial	1.00
Natural experiment (difference-in-differences, regression discontinuity)	0.85
Instrumental variables	0.70
Panel with fixed effects	0.55
Cross-sectional regression	0.25

Step 3: Compute precision weights

$$w_j^P = \frac{1}{\mathrm{SE}(\beta_j)^2}$$

Step 4: Compute recency weights

$$w_j^R = e^{-0.03(t_{now} - t_j)}$$

Step 5: Compute confidence score

$$\mathrm{BIS}_i = \min\left(1, \frac{\sum_j w_j^Q \cdot w_j^P \cdot w_j^R}{K}\right)$$

Where K is a calibration constant.

9.2 Evidence Grading from BIS

BIS Range	Grade	Interpretation	OSL Confidence
0.80 - 1.00	A	Strong causal evidence	High - proceed with reallocation
0.60 - 0.79	B	Good evidence	Moderate - consider with caveats
0.40 - 0.59	C	Mixed evidence	Low - pilot before scaling
0.20 - 0.39	D	Weak evidence	Very low - research priority
0.00 - 0.19	F	Insufficient evidence	Unknown - cannot estimate OSL

10 Gap Analysis and Priority Ranking

10.1 Computing Gaps

For each category i:

$$\mathrm{Gap}_i = \mathrm{OSL}_i - \mathrm{Current}_i$$

- **Gap > 0**: Underinvestment (increase spending)
- **Gap = 0**: At optimal (maintain)
- **Gap < 0**: Overinvestment (decrease spending)

10.2 Priority Score

Prioritize reallocation by gap size weighted by confidence:

$$\text{Priority}_i = |\text{Gap}_i| \times \text{BIS}_i$$

Categories with large gaps AND high confidence should be addressed first.

10.3 Illustrative Example: Priority Ranking

The following uses the same illustrative data from the dashboard example above. OSL estimates for pragmatic trials, vaccinations, and K-12 education are derived in Sections 5-7. Other OSL values are preliminary estimates based on cross-country benchmarking and should be treated as order-of-magnitude approximations. BIS scores reflect the author's assessment of available causal evidence quality rather than formal calculation from the BIS formula.

Category	Current	OSL	Gap	BIS	Inc	Hlth	Priority	Action
Pragmatic trials	\$0.5B	\$50B	+\$49.5B	0.90	++	+++	**44.6**	**Scale 100x**
Basic research	\$45B	\$90B	+\$45B	0.70	++	++	31.5	Increase
Vaccinations	\$8B	\$35B	+\$27B	0.95	+	+++	25.7	Increase
Early childhood	\$50B	\$70B	+\$20B	0.85	+++	+	17.0	Increase
Military	\$850B	\$459B	-\$391B	0.50	−	−	195.5	**Decrease**
Ag subsidies	\$25B	\$0B	-\$25B	0.90	−	−	22.5	**Eliminate**

Inc = effect on real after-tax median income growth. Hlth = effect on median healthy life years. Scale: +++ strong, ++ moderate, + weak, − negative.

Reallocation plan: Cut military discretionary (-\$391B) and agricultural subsidies (-\$25B) to fund pragmatic clinical trials (+\$49.5B), basic research (+\$45B), vaccinations (+\$27B), and early childhood (+\$20B). Pragmatic trials have the highest priority score among positive-gap categories due to extreme underinvestment combined with strong evidence, and they improve both welfare metrics.

11 Multi-Unit Reporting

11.1 The Problem with Abstract Scores

Composite scores (like 0-1 BIS values) obscure interpretability. Policymakers and citizens understand dollars, lives, and years - not abstract indices.

11.2 Reporting at Multiple Levels

Level	Units	Use Case	Example
0. Core metrics	pp/year income growth, healthy life years	Primary welfare outcomes	"+0.1 pp income growth, +0.05 healthy years"
1. Natural	Domain-specific	Interpretation within domain	"Education: $2,100/student gap"
2. Monetized	$ equivalent	Cross-domain comparison	"Expected welfare gain: $4.00 per $1"
3. Health	QALYs/DALYs	Health-weighted comparison	"12,000 QALYs per $1B invested"
4. Composite	0-1 score	Ranking when monetization uncertain	"BIS = 0.85"

Level 0 (Core Metrics) reports expected changes to the two welfare metrics directly. All other levels are derived from or convertible to these core outcomes. QALYs (Level 3) translate directly to median healthy life years. Monetized values (Level 2) combine income effects with health effects valued at standard rates.

11.3 Conversion Factors

Conversion	Value	Source	Notes
Value of Statistical Life (VSL)	~$10M	EPA, DOT	US regulatory standard
Value per QALY	$50K-$150K	ICER, WHO	Context-dependent
QALY → $	$100K/QALY	Mid-range estimate	For cross-domain
Life-year → QALY	~0.8-1.0	Age/health adjusted	Quality weighting

11.4 Worked Example: Multi-Unit Output

Category: Early Childhood Education

Unit Level	Value	Interpretation
Natural	+$20B gap	Current: $50B, OSL: $70B
Per-child	+$833/child gap	24M children
Monetized ROI	4:1 NPV return	[146]
Health (QALYs)	+8K QALYs/year	Per $1B additional
Composite (BIS)	0.85	High-quality RCT evidence

Recommendation: Moderate underinvestment with strong evidence. Closing the gap would yield ~$80B in NPV returns.

12 Quality Requirements and Validation

12.1 Minimum Thresholds for OBG Estimation

Criterion	Minimum	Rationale
Reference countries	5+	Avoid outlier bias
Dose-response studies	3+	Identify diminishing returns
Causal effect estimates	2+	Cross-validate
Data recency	Within 10 years	Relevance
BIS for reallocation	> 0.40	Sufficient confidence

12.2 Robustness Checks

For each OSL estimate, report:

1. **Leave-one-country-out**: Does excluding any single country change OSL by >20%?
2. **Method comparison**: Do diminishing returns and cost-effectiveness methods agree?
3. **Time stability**: Has OSL changed substantially over past 5 years?
4. **Sensitivity to assumptions**: How does OSL change with ±20% parameter variation?

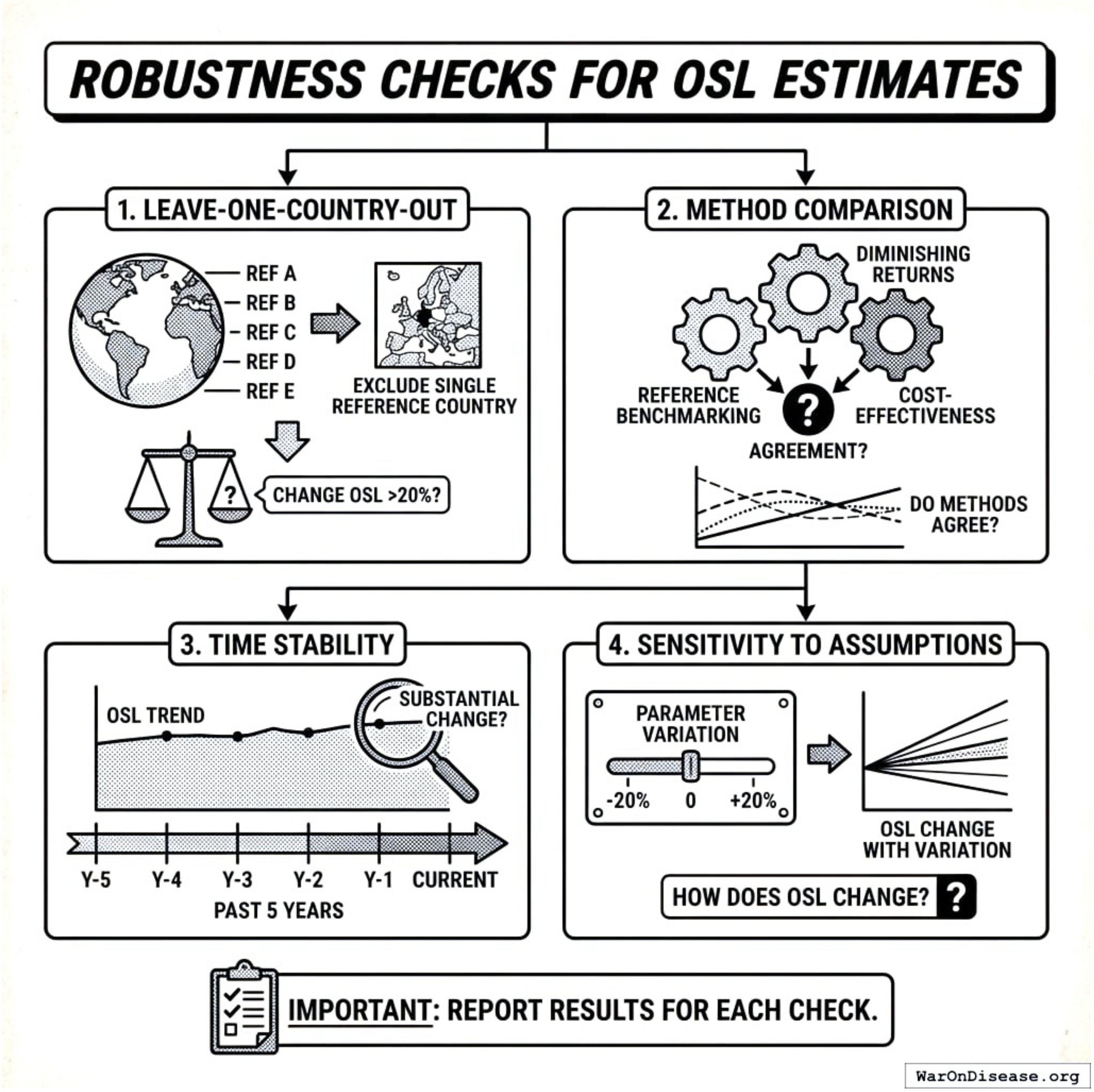

Figure 18: A conceptual framework illustrating the four essential robustness checks for OSL estimates: outlier analysis, methodological consistency, temporal stability, and parameter sensitivity.

13 Interpreting Results

13.1 Gap Ranges and Recommended Actions

Gap (% of current)	Interpretation	Recommended Action
> +50%	Severe underinvestment	Immediate scale-up
+20% to +50%	Moderate underinvestment	Phased increase
-10% to +20%	Near optimal	Monitor, fine-tune

Gap (% of current)	Interpretation	Recommended Action
-50% to -10%	Moderate overinvestment	Gradual reduction
< -50%	Severe overinvestment	Urgent reallocation

13.2 What the Algorithm Cannot Tell You

Factor	OBG Captures	OBG Does Not Capture
Evidence-optimal spending level	Yes	
Confidence in estimates	Yes	
Direction of reallocation	Yes	
Political feasibility		No
Implementation capacity		No
Transition costs		No
Distributional effects		No
Novel interventions		No

OBG provides evidence-based targets. Political judgment is still required for implementation strategy.

14 Pilot Program Prioritization

14.1 Value of Information for Uncertain Categories

Categories with low BIS but potentially high returns warrant research investment:

$$\text{VOI}_i = \text{Potential Gap}_i \times (1 - \text{BIS}_i) \times P(\text{high return})$$

High-VOI categories should receive pilot funding to generate better evidence.

14.2 Recommended Pilot Designs

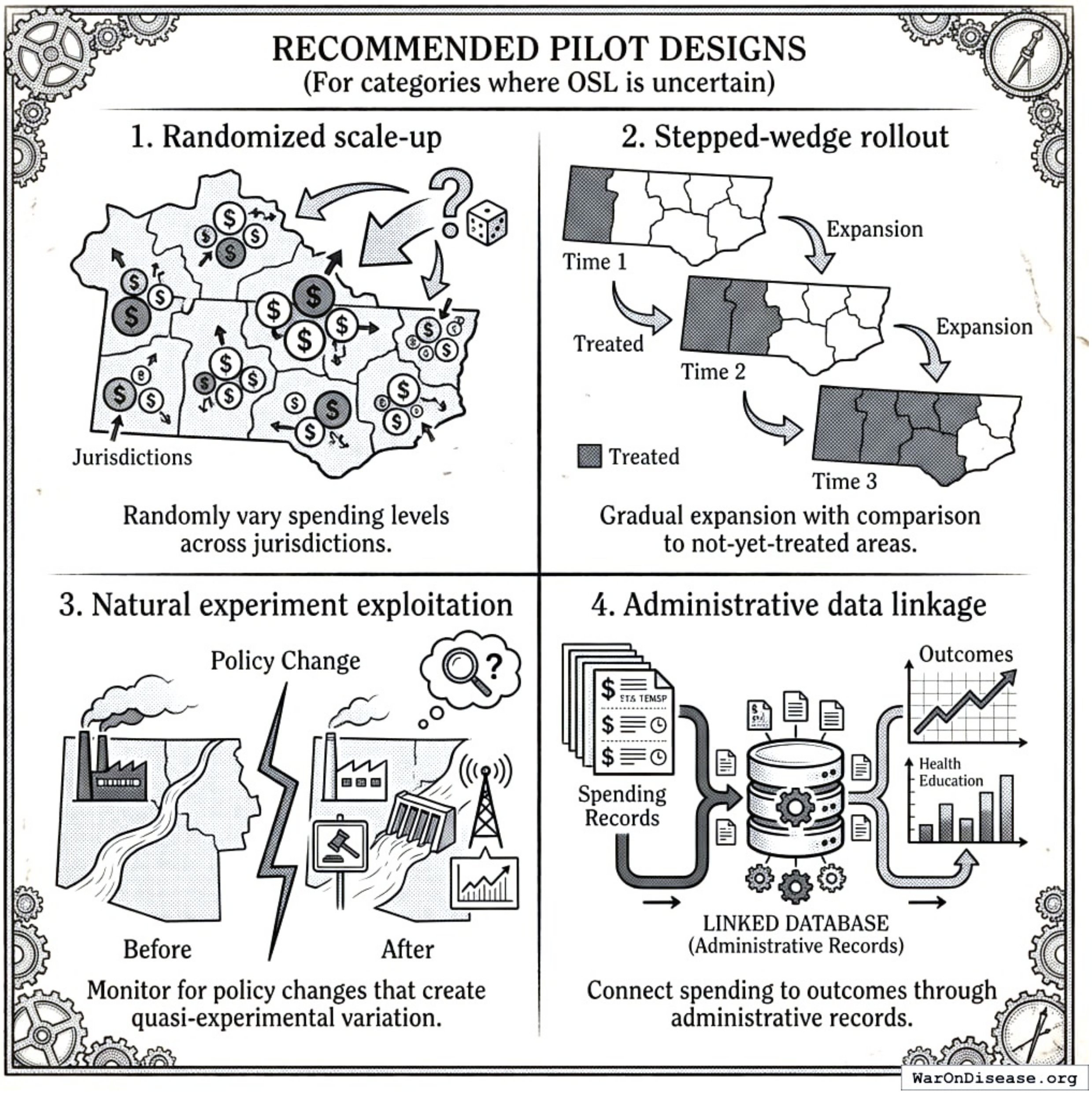

Figure 19: A conceptual comparison of four pilot design strategies: randomized scale-up, stepped-wedge rollout, natural experiment exploitation, and administrative data linkage.

For categories where OSL is uncertain:

1. **Randomized scale-up**: Randomly vary spending levels across jurisdictions
2. **Stepped-wedge rollout**: Gradual expansion with comparison to not-yet-treated areas
3. **Natural experiment exploitation**: Monitor for policy changes that create quasi-experimental variation
4. **Administrative data linkage**: Connect spending to outcomes through administrative

records

14.3 Learning Feedback Loop

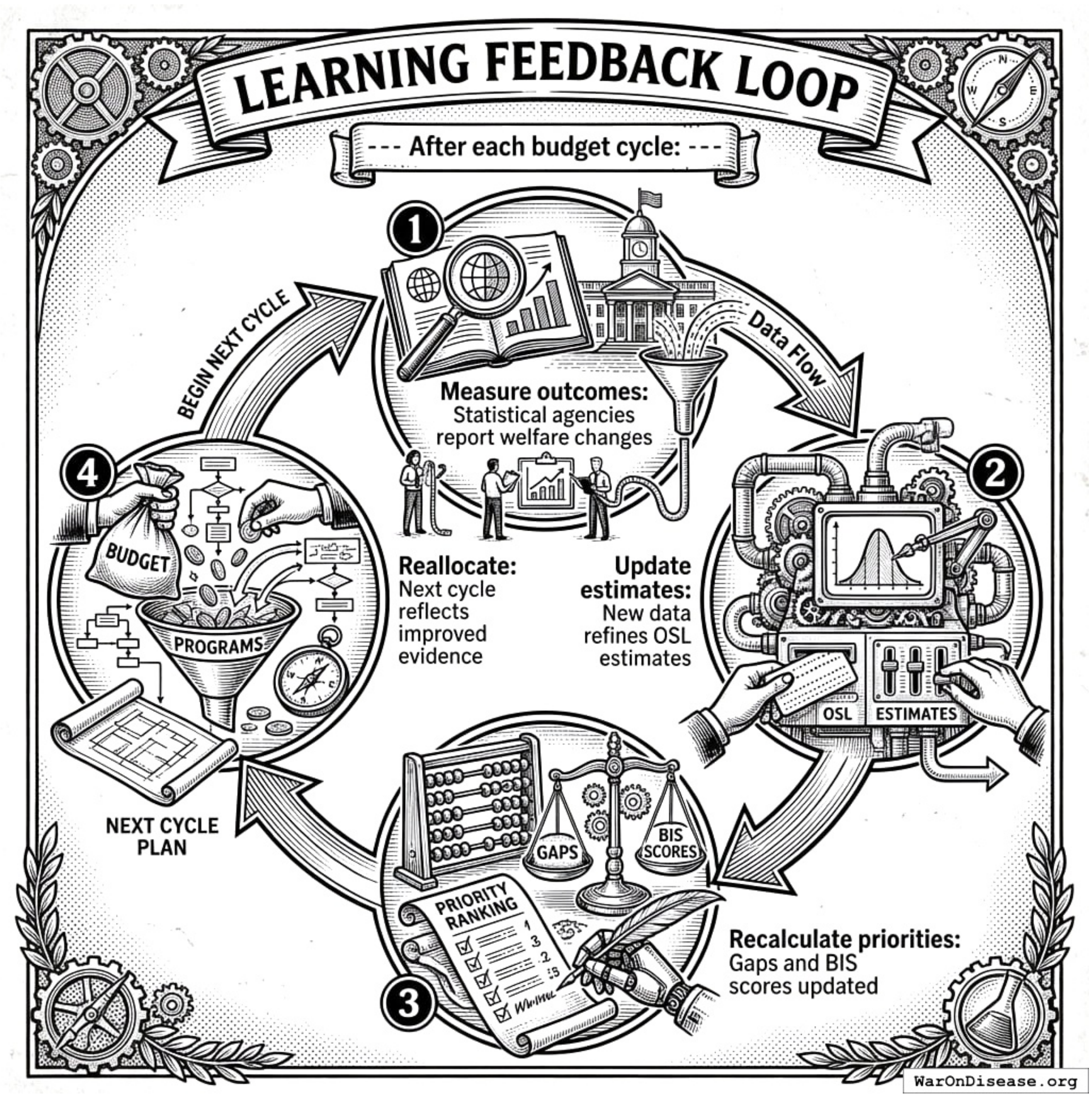

Figure 20: A circular diagram illustrating the continuous four-step learning feedback loop used to refine budget priorities based on statistical outcomes and updated data.

After each budget cycle:

1. **Measure outcomes**: Statistical agencies report welfare changes
2. **Update estimates**: New data refines OSL estimates
3. **Recalculate priorities**: Gaps and BIS scores updated

4. **Reallocate**: Next cycle reflects improved evidence

15 Data Sources

15.1 Cross-Country Databases

International organizations maintain standardized cross-country spending and outcome data essential for diminishing returns analysis. The OECD provides the most comprehensive harmonized data for high-income countries[95].

Database	Coverage	URL	Use Case
OECD iLibrary	38 OECD members	oecd-ilibrary.org	Education, health, social spending
World Bank WDI	217 countries	data.worldbank.org	Broad spending and outcomes
SIPRI	Global	sipri.org	Military spending
WHO GHED	194 countries	who.int/data/gho	Health expenditure
UNESCO UIS	Global	uis.unesco.org	Education spending

15.2 Cost-Effectiveness Databases

Database	Coverage	URL	Use Case
CEA Registry	8,000+ analyses	cearegistry.org	Health cost-effectiveness
Disease Control Priorities	LMICs	dcp-3.org	Global health priorities
Cochrane Library	8,000+ reviews	cochranelibrary.com	Health intervention effects
Copenhagen Consensus	Development	copenhagenconsensus.com	Development priorities

These databases enable systematic ranking of interventions by cost-effectiveness. For example, deworming programs consistently rank among the most cost-effective health interventions, with costs as low as $30-50 per DALY averted[18].

15.3 US Budget Data

Source	Coverage	URL	Use Case
OMB Historical Tables	1789-present	whitehouse.gov/omb	Federal spending
CBO Budget Analyses	Federal	cbo.gov	Fiscal impact scoring[135]

Source	Coverage	URL	Use Case
USASpending	Federal awards	usaspending.gov	Program-level detail
Census of Governments	State & local	census.gov	Subnational spending

16 Limitations

16.1 Diminishing Returns Uncertainty

- **Functional form**: True relationship may not match assumed function
- **Extrapolation**: Estimating returns outside observed spending range
- **Interaction effects**: Returns may depend on other spending categories

Mitigation: Report confidence intervals, use multiple functional forms, acknowledge extrapolation limits.

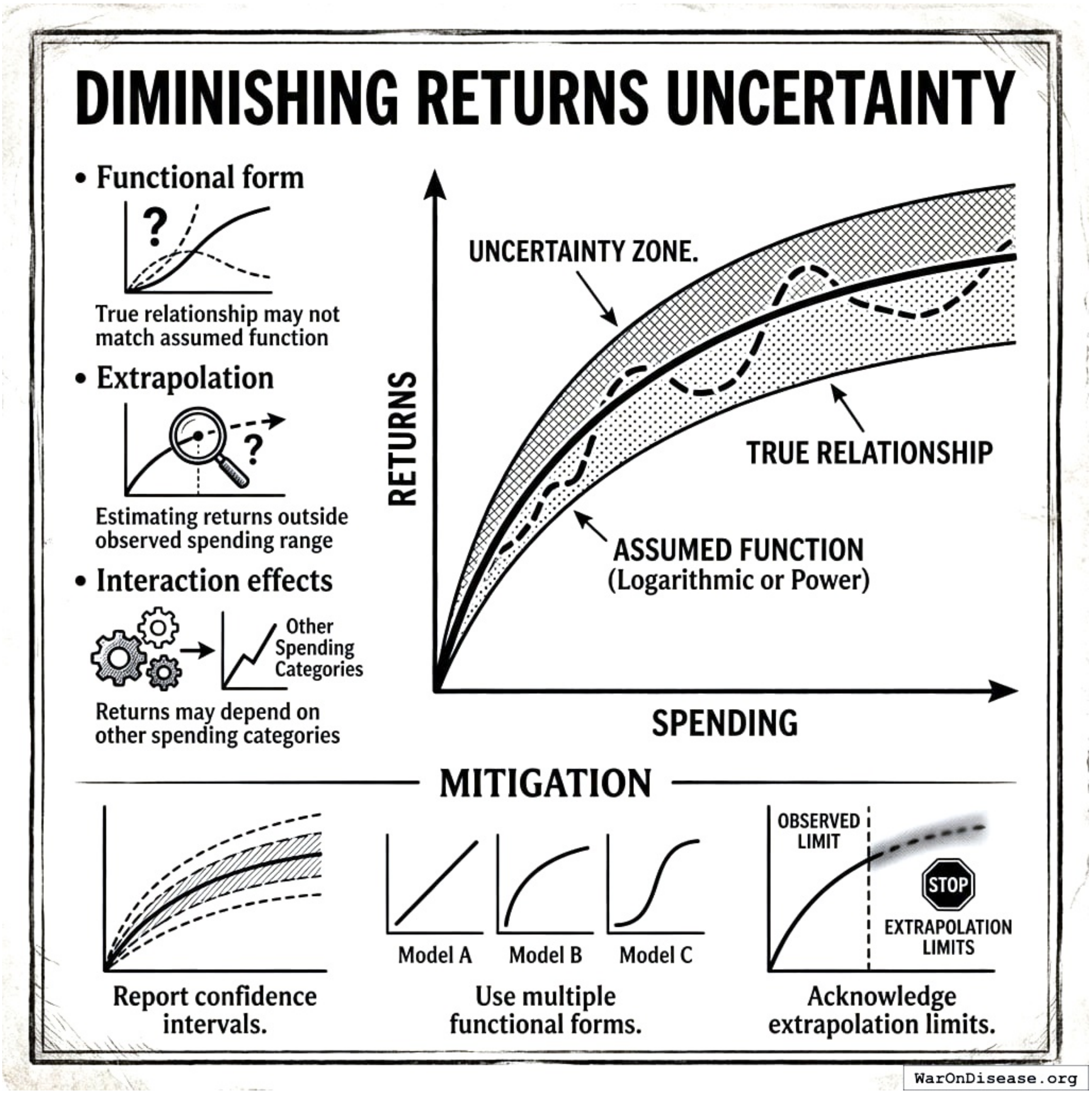

Figure 21: A line graph illustrating diminishing returns with a curve flattening out, featuring shaded confidence intervals and a dashed line representing the risks of extrapolation beyond historical data points.

16.2 Implementation Capacity

Higher spending may not translate to outcomes if implementation capacity is lacking.

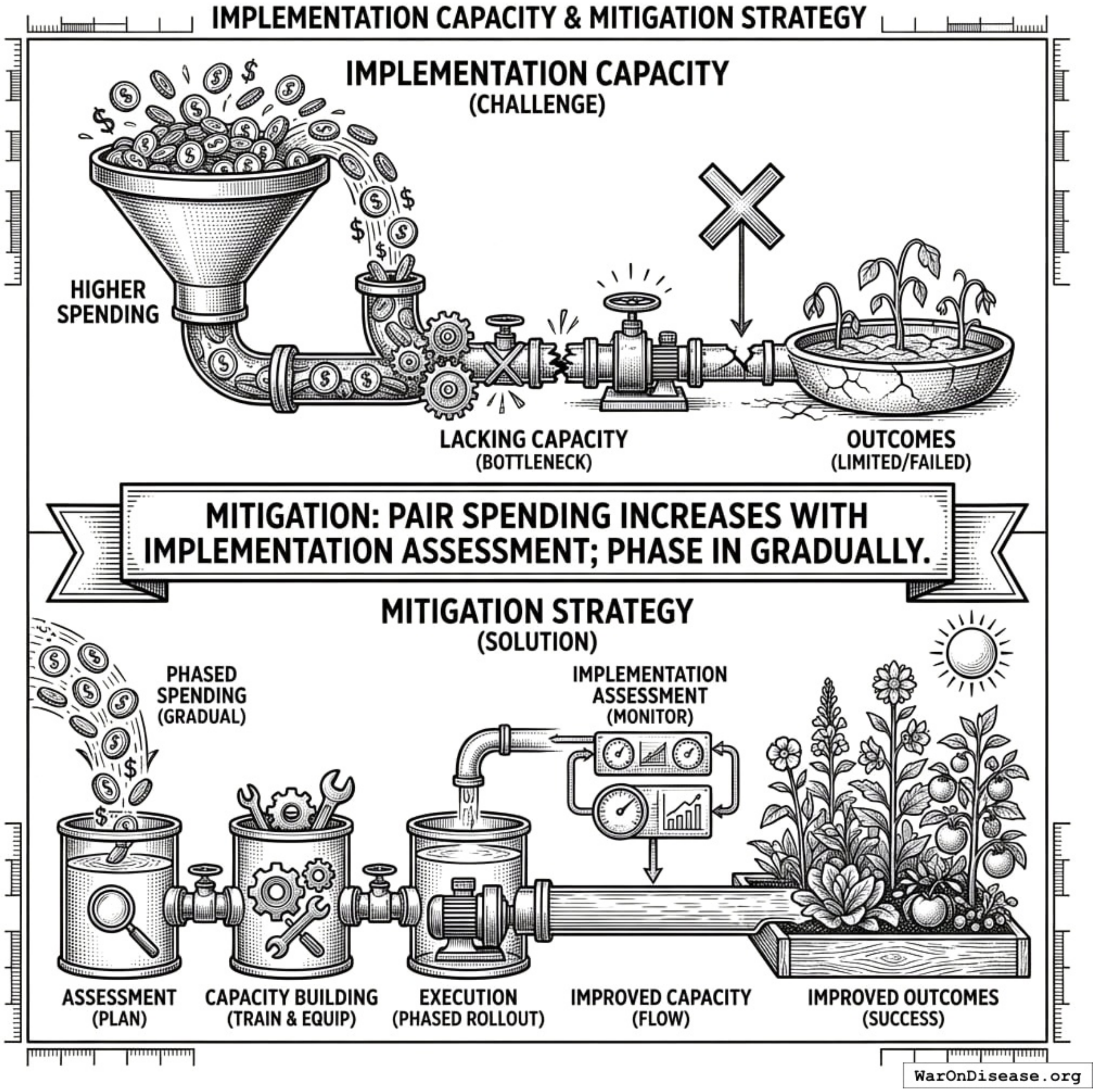

Figure 22: A flow diagram illustrating how spending is successfully converted to outcomes by passing through the filters of implementation assessment and gradual phasing.

Mitigation: Pair spending increases with implementation assessment; phase in gradually.

17 Validation Framework

Rigorous validation is essential for any framework that claims to identify optimal spending levels. This section outlines the validation approach, acknowledging that comprehensive empirical validation remains future work.

17.1 Retrospective Validation

Question: Did jurisdictions that moved toward OSL achieve better outcomes than those that diverged?

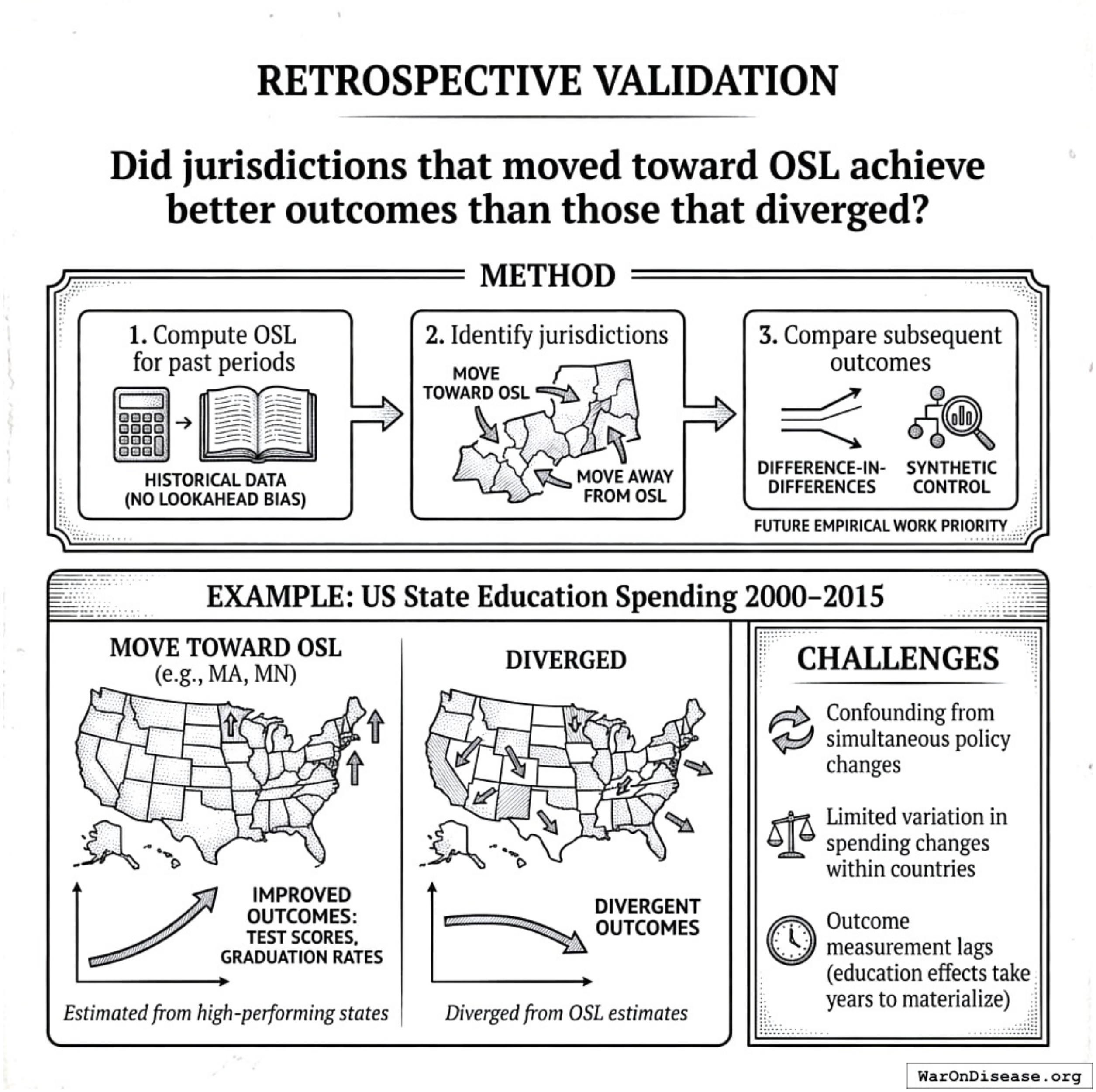

Figure 23: A flowchart outlining the three-step methodology for retrospective validation, showing the sequence from historical OSL calculation to the comparative analysis of jurisdiction outcomes.

Method: 1. Compute OSL for past periods using only data available at that time (to avoid lookahead bias) 2. Identify jurisdictions that moved toward/away from OSL 3. Compare subsequent outcomes using difference-in-differences or synthetic control methods[147]

Example: US State Education Spending 2000-2015

A preliminary retrospective analysis could examine whether states that moved toward education OSL (estimated from high-performing states like Massachusetts and Minnesota) subsequently showed improved test scores and graduation rates relative to states that diverged. This analysis is noted as a priority for future empirical work.

Challenges:

- Confounding from simultaneous policy changes
- Limited variation in spending changes within countries
- Outcome measurement lags (education effects take years to materialize)

17.2 Prospective Validation

Question: Do OBG-guided reallocations improve outcomes going forward?

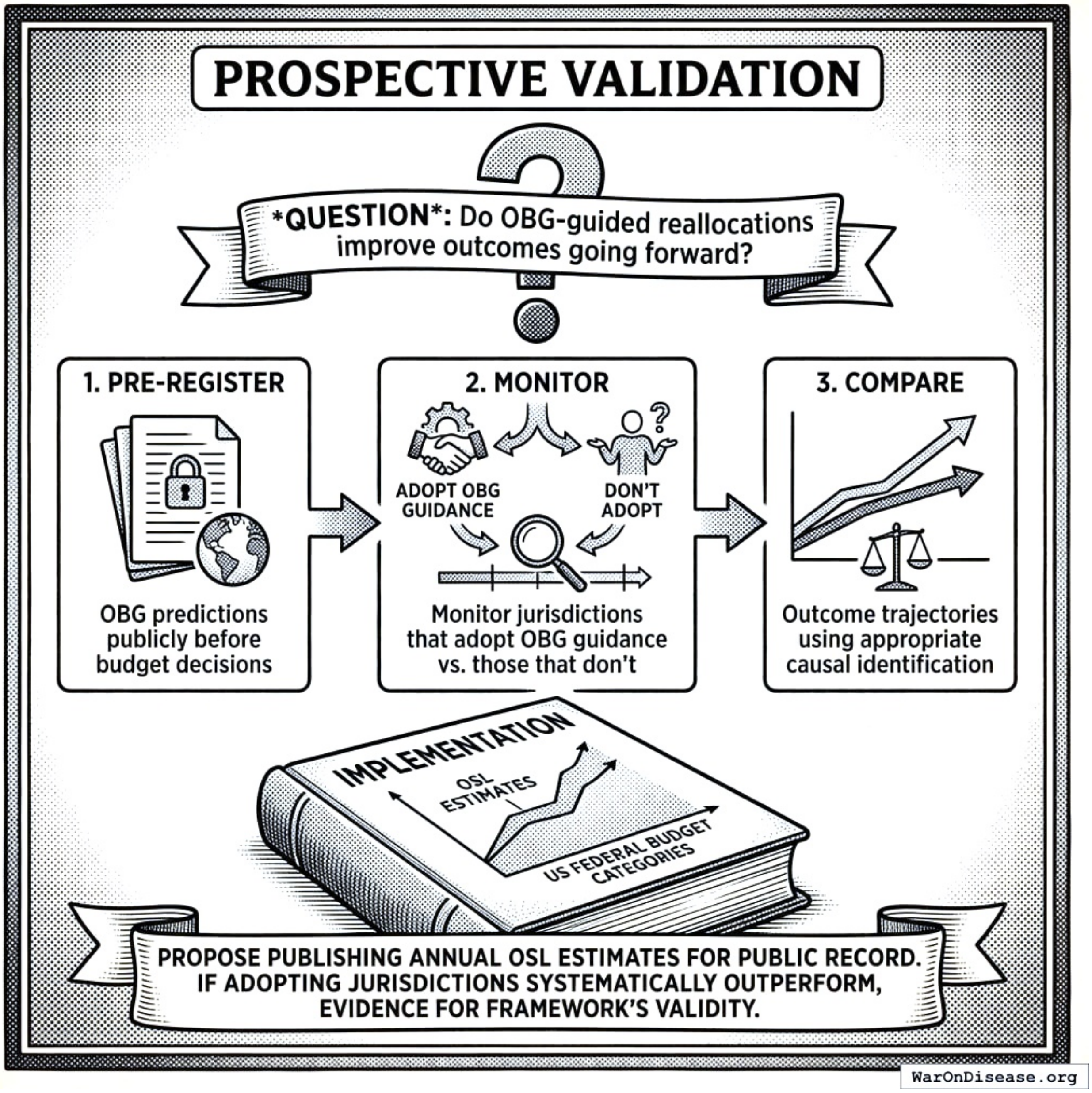

Figure 24: A flowchart illustrating the prospective validation process, from public pre-registration of predictions to the comparative analysis of outcome trajectories between jurisdictions.

Method: 1. Pre-register OBG predictions publicly before budget decisions 2. Monitor jurisdictions that adopt OBG guidance vs. those that don't 3. Compare outcome trajectories using appropriate causal identification

Implementation: We propose publishing annual OSL estimates for US federal budget categories, creating a public record that enables future validation. If jurisdictions that adopt OBG guidance systematically outperform those that don't, this provides evidence for the framework's validity.

17.3 Success Metrics

Metric	Definition	Target	Interpretation
Gap reduction	Did spending move toward OSL?	> 50% of gap closed in 10 years	Tests political feasibility
Outcome improvement	Did welfare metrics improve more in OBG-following jurisdictions?	> 10% relative improvement	Tests welfare prediction accuracy
Prediction accuracy	Did estimated returns match actual returns?	Correlation r > 0.5	Tests underlying model
Cross-method consistency	Do diminishing returns and cost-effectiveness methods converge?	Agreement within 30%	Tests methodological robustness

17.4 Validation Status

This working paper presents the OBG *methodology*. Comprehensive empirical validation is future work requiring:

1. **Data collection**: Longitudinal spending and outcome data across jurisdictions
2. **Historical OSL estimation**: Computing past OSL using only contemporaneously available data
3. **Causal analysis**: Rigorous identification of spending → outcome effects
4. **Publication**: Peer-reviewed validation study with pre-registered analysis plan

The framework's current evidence base consists of the underlying studies cited throughout (e.g.,[140] for education,[144] for vaccinations), not direct validation of OBG itself.

18 Sensitivity Analysis

18.1 Parameter Sensitivity

Parameter	Default	Test Range	Impact on OSL
Country data set	All OECD	OECD + G20, High-income only	±15%
Discount rate	5%	3-7%	±20%
BIS confidence threshold	0.40	0.30-0.60	Category inclusion
Recency decay rate	0.03/year	0.01-0.05	Estimate weights

18.2 Scenario Analysis

Optimistic scenario: All uncertain categories have high returns **Pessimistic scenario**: Uncertain categories have low/zero returns **Base case**: Use point estimates

Report OSL range across scenarios for policy guidance.

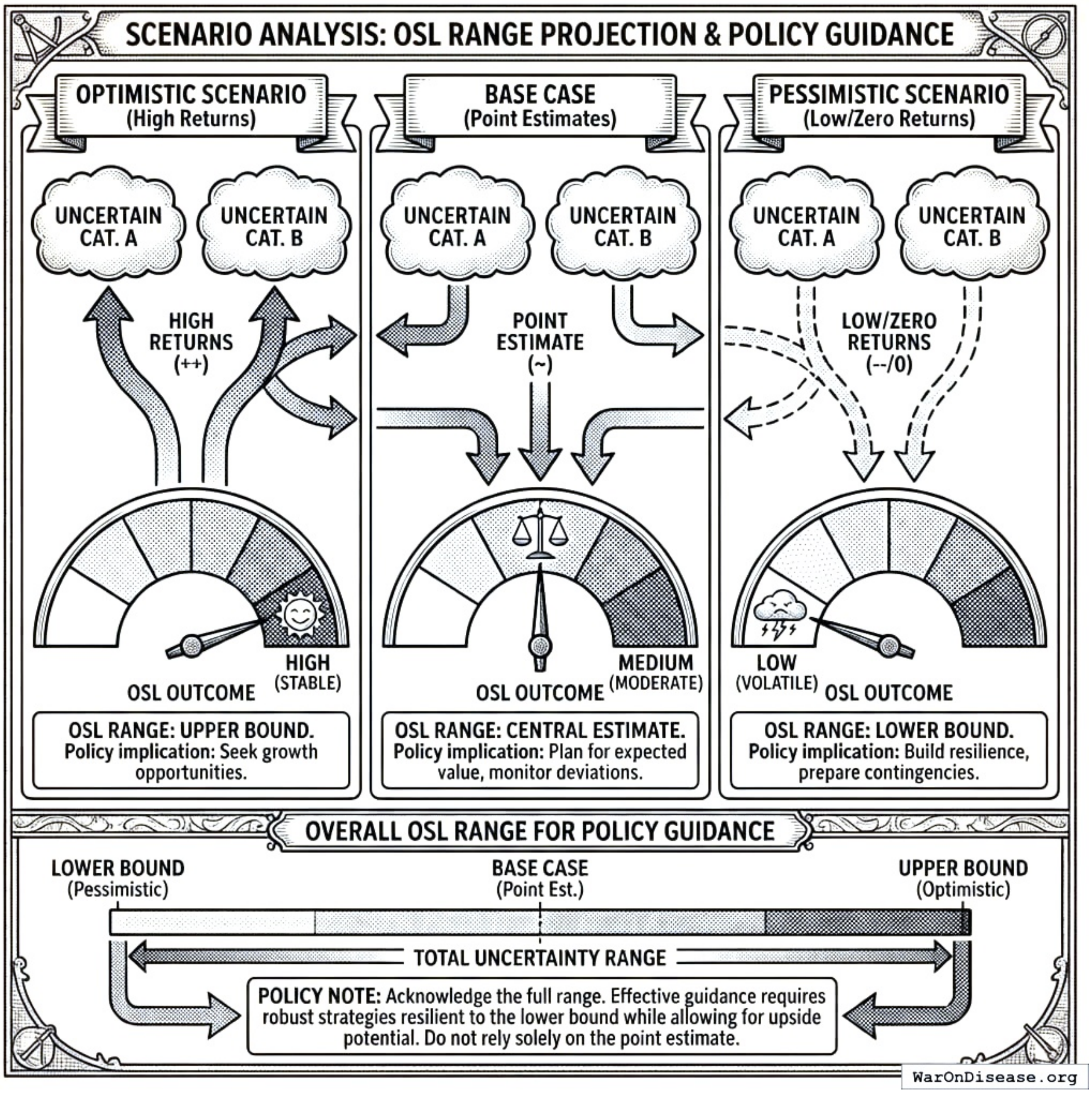

Figure 25: A comparison chart showing the projected OSL range across pessimistic, base case, and optimistic scenarios based on varying return estimates.

19 Conclusion

The Optimal Budget Generator framework provides a systematic, evidence-based approach to budget allocation. Unlike marginal-return frameworks that can justify infinite spending on high-return categories, OBG recognizes that every category has an optimal level - like the Recommended Daily Allowance for nutrients.

The framework answers three questions:

1. **What is the target?** OBG provides evidence-based spending levels for each category

2. **How far are we?** Gap analysis shows where current spending diverges from optimal
3. **How confident are we?** BIS scores evidence quality so policymakers know which OSL estimates are reliable

Even with imperfect evidence, systematically moving from severe misallocation (military 100% above OSL, vaccinations 75% below OSL) toward evidence-based targets should produce substantially larger welfare gains than current lobbying-driven allocation achieves.

Acknowledgments

The author thanks seminar participants and anonymous reviewers for helpful comments and suggestions. All errors remain the author's own.

20 References

1. NIH Common Fund. NIH pragmatic trials: Minimal funding despite 30x cost advantage. *NIH Common Fund: HCS Research Collaboratory* https://commonfund.nih.gov/hcscollaboratory (2025)
The NIH Pragmatic Trials Collaboratory funds trials at $500K for planning phase, $1M/year. for implementation-a tiny fraction of NIH's budget. The ADAPTABLE trial cost $14 million for 15,076 patients (= $929/patient) versus $420 million for a similar traditional RCT (30x cheaper), yet pragmatic trials remain severely underfunded. PCORnet infrastructure enables real-world trials embedded in healthcare systems, but receives minimal support compared to basic research funding. Additional sources: https://commonfund.nih.gov/hcscollaboratory | https://pcornet.org/wp-content/uploads/2025/08/ADAPTABLE_Lay_Summary_21JUL2025.pdf | https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5604499/
2. NIH. Antidepressant clinical trial exclusion rates. *Zimmerman et al.* https://pubmed.ncbi.nlm.nih.gov/26276679/ (2015)
Mean exclusion rate: 86.1% across 158 antidepressant efficacy trials (range: 44.4% to. 99.8%) More than 82% of real-world depression patients would be ineligible for antidepressant registration trials Exclusion rates increased over time: 91.4% (2010-2014) vs. 83.8% (1995-2009) Most common exclusions: comorbid psychiatric disorders, age restrictions, insufficient depression severity, medical conditions Emergency psychiatry patients: only 3.3% eligible (96.7% excluded) when applying 9 common exclusion criteria Only a minority of depressed patients seen in clinical practice are likely to be eligible for most AETs Note: Generalizability of antidepressant trials has decreased over time, with increasingly stringent exclusion criteria eliminating patients who would actually use the drugs in clinical practice Additional sources: https://pubmed.ncbi.nlm.nih.gov/26276679/ | https://pubmed.ncbi.nlm.nih.gov/26164052/ | https://www.wolterskluwer.com/en/news/antidepressant-trials-exclude-most-real-world-patients-with-depression
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Berkshire's compounded annual return from 1965 through 2024 was 19.9%, nearly. double the 10.4% recorded by the S&P 500. Berkshire shares skyrocketed 5,502,284% compared to the S&P 500's 39,054% rise during that period. Additional sources: https://www.cnbc.com/2025/05/05/warren-buffetts-return-tally-after-60-years-5502284percent.html | https://www.slickcharts.com/berkshire-hathaway/returns

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Comprehensive mortality and morbidity data by cause, age, sex, country, and year Global. mortality: 55-60 million deaths annually Lives saved by modern medicine (vaccines, cardiovascular drugs, oncology): 12M annually (conservative aggregate) Leading causes of death: Cardiovascular disease (17.9M), Cancer (10.3M), Respiratory disease (4.0M) Note: Baseline data for regulatory mortality analysis. Conservative estimate of pharmaceutical impact based on WHO immunization data (4.5M/year from vaccines) + cardiovascular interventions (3.3M/year) + oncology (1.5M/year) + other therapies. Additional sources: https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates
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General range: $3,000-$5,500 per life saved (GiveWell top charities) Helen Keller International. (Vitamin A): $3,500 average (2022-2024); varies $1,000-$8,500 by country Against Malaria Foundation: $5,500 per life saved New Incentives (vaccination incentives): $4,500 per life saved Malaria Consortium (seasonal malaria chemoprevention): $3,500 per life saved VAS program details: $2 to provide vitamin A supplements to child for one year Note: Figures accurate for 2024. Helen Keller VAS program has wide country variation ($1K-$8.5K) but $3,500 is accurate average. Among most cost-effective interventions globally Additional sources: https://www.givewell.org/charities/top-charities | https://www.givewell.org/charities/helen-keller-international | https://ourworldindata.org/cost-effectiveness
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Average family caregiver: 25-26 hours per week (100-104 hours per month) 38 million. caregivers providing 36 billion hours of care annually Economic value: $16.59 per hour = $600 billion total annual value (2021) 28% of people provided eldercare on a given day, averaging 3.9 hours when providing care Caregivers living with care recipient: 37.4 hours per week Caregivers not living with recipient: 23.7 hours per week Note: Disease-related caregiving is subset of total; includes elderly care, disability care, and child care Additional sources: https://www.aarp.org/caregiving/financial-legal/info-2023/unpaid-caregivers-provide-billions-in-care.html | https://www.bls.gov/news.release/elcare.nr0.htm | https://www.caregiver.org/resource/caregiver-statistics-demographics/
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Only 3-5% of adult cancer patients in US receive treatment within clinical trials About 5% of. American adults have ever participated in any clinical trial Oncology: 2-3% of all oncology patients participate Contrast: 50-60% enrollment for pediatric cancer trials (<15 years old) Note: 20% of cancer trials fail due to insufficient enrollment; 11% of research sites enroll zero patients Additional sources: https://www.fightcancer.org/policy-resources/barriers-patient-enrollment-therapeutic-clinical-trials-cancer | https://hints.cancer.gov/docs/Briefs/HINTS_Brief_48.pdf
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2.3 billion individuals had more than five ailments (2013) Chronic conditions caused 74%. of all deaths worldwide (2019), up from 67% (2010) Approximately 1 in 3 adults suffer from multiple chronic conditions (MCCs) Risk factor exposures: 2B exposed to biomass fuel, 1B to air pollution, 1B smokers Projected economic cost: $47 trillion by 2030 Note: 2.3B with 5+ ailments is more accurate than "2B with chronic disease." One-third of all adults globally have multiple chronic conditions Additional sources: https://www.sciencedaily.com/releases/2015/06/150608081753.htm | https://pmc.ncbi.nlm.nih.gov/articles/PMC10830426/ | https://pmc.ncbi.nlm.nih.gov/articles/PMC6214883/
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50 new drugs approved annually Additional sources: https://cen.acs.org/pharmaceuticals/50-new-drugs-received-FDA/103/i2 | https://www.fda.gov/drugs/development-approval-process-drugs/novel-drug-approvals-fda
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Historical estimates (1970-1985): USD $226M fully capitalized (2011 prices) 1980s drugs:. $65M after-tax R&D (1990 dollars), $194M compounded to approval (1990 dollars) Modern comparison: $2-3B costs, 7-12 years (dramatic increase from pre-1962) Context: 1962 regulatory clampdown reduced new treatment production by 70%, dramatically increasing development timelines and costs Note: Secondary source; less reliable than Congressional testimony Additional sources: https://thinkbynumbers.org/health/how-many-net-lives-does-the-fda-save/ | https://en.wikipedia.org/wiki/Cost_of_drug_development | https://www.statnews.com/2018/10/01/changing-1962-law-slash-drug-prices/
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Phase I duration: 2.3 years average Total time to market (Phase I-III + approval): 10.5. years average Phase transition success rates: Phase I→II: 63.2%, Phase II→III: 30.7%, Phase III→Approval: 58.1% Overall probability of approval from Phase I: 12% Note: Largest publicly available study of clinical trial success rates. Efficacy lag = 10.5 - 2.3 = 8.2 years post-safety verification. Additional sources: https://go.bio.org/rs/490-EHZ-999/images/ClinicalDevelopmentSuccessRates2011_2020.pdf
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Healthcare fiscal multiplier: 4.3 (95% CI: 2.5-6.1) during pre-recession period (1995-2007) Overall government spending multiplier: 1.61 (95% CI: 1.37-1.86) Why healthcare has high multipliers: No effect on trade deficits (spending stays domestic); improves productivity & competitiveness; enhances long-run potential output Gender-sensitive fiscal spending (health & care economy) produces substantial positive growth impacts Note: "1.8" appears to be conservative estimate; research shows healthcare multipliers of 4.3 Additional sources: https://pmc.ncbi.nlm.nih.gov/articles/PMC5954824/ | https://cepr.org/voxeu/columns/government-investment-and-fiscal-stimulus | https://ncbi.nlm.nih.gov/pmc/articles/PMC3849102/ | https://set.odi.org/wp-content/uploads/2022/01/Fiscal-multipliers-review.pdf

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Infrastructure fiscal multiplier: 1.6 during contractionary phase of economic cycle Average across all economic states: 1.5 (meaning $1 of public investment → $1.50 of economic activity) Time horizon: 0.8 within 1 year, 1.5 within 2-5 years Range of estimates: 1.5-2.0 (following 2008 financial crisis & American Recovery Act) Italian public construction: 1.5-1.9 multiplier US ARRA: 0.4-2.2 range (differential impacts by program type) Economic Policy Institute: Uses 1.6 for infrastructure spending (middle range of estimates) Note: Public investment less likely to crowd out private activity during recessions; particularly effective when monetary policy loose with near-zero rates Additional sources: https://blogs.worldbank.org/en/ppps/effectiveness-infrastructure-investment-fiscal-stimulus-what-weve-learned | https://www.gihub.org/infrastructure-monitor/insights/fiscal-multiplier-effect-of-infrastructure-investment/ | https://cepr.org/voxeu/columns/government-investment-and-fiscal-stimulus | https://www.richmondfed.org/publications/research/economic_brief/2022/eb_22-04

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2024: 233,597 deaths (30% increase from 179,099 in 2023) Deadliest conflicts: Ukraine (67,000), Palestine (35,000) Nearly 200,000 acts of violence (25% higher than 2023, double from 5 years ago) One in six people globally live in conflict-affected areas Additional sources: https://acleddata.com/2024/12/12/data-shows-global-conflict-surged-in-2024-the-washington-post/ | https://acleddata.com/media-citation/data-shows-global-conflict-surged-2024-washington-post | https://acleddata.com/conflict-index/index-january-2024/
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Uppsala Conflict Data Program (UCDP): Tracks one-sided violence (organized actors attacking unarmed civilians) UCDP definition: Conflicts causing at least 25 battle-related deaths in calendar year 2023 total organized violence: 154,000 deaths; Non-state conflicts: 20,900 deaths UCDP collects data on state-based conflicts, non-state conflicts, and one-sided violence Specific "2,700 annually" figure for state violence not found in recent UCDP data; actual figures vary annually Additional sources: https://ucdp.uu.se/ | https://en.wikipedia.org/wiki/Uppsala_Conflict_Data_Program | https://ourworldindata.org/grapher/deaths-in-armed-conflicts-by-region

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In 2021, global DALYs totaled approximately 2.88 billion, comprising 1.75 billion Years of Life. Lost (YLL) and 1.13 billion Years Lived with Disability (YLD). This represents a 13% increase from 2019 (2.55B DALYs), largely attributable to COVID-19 deaths and aging populations. YLD accounts for approximately 39% of total DALYs, reflecting the substantial burden of non-fatal chronic conditions. Additional sources: https://vizhub.healthdata.org/gbd-results/ | https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(24)00757-8/fulltext | https://www.healthdata.org/research-analysis/about-gbd

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War on Terror emissions: 1.2B metric tons GHG (equivalent to 257M cars/year) Military:. 5.5% of global GHG emissions (2X aviation + shipping combined) US DoD: World's single largest institutional oil consumer, 47th largest emitter if nation Cleanup costs: $500B+ for military contaminated sites Gaza war environmental damage: $56.4B; landmine clearance: $34.6B expected Climate finance gap: Rich nations spend 30X more on military than climate finance Note: Military activities cause massive environmental damage through GHG emissions, toxic contamination, and long-term cleanup costs far exceeding current climate finance commitments Additional sources: https://watson.brown.edu/costsofwar/costs/social/environment | https://earth.org/environmental-costs-of-wars/ | https://transformdefence.org/transformdefence/stats/

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Global military spending: $2.7 trillion (2024, SIPRI) Global government medical research: $68 billion (2024) Actual ratio: 39.7:1 in favor of weapons over medical research Military R&D alone: $85B (2004 data, 10% of global R&D) Military spending increases crowd out health: 1% ↑ military = 0.62% ↓ health spending Note: Ratio actually worse than 36:1. Each 1% increase in military spending reduces health spending by 0.62%, with effect more intense in poorer countries (0.962% reduction) Additional sources: https://www.sipri.org/commentary/blog/2016/opportunity-cost-world-military-spending | https://pmc.ncbi.nlm.nih.gov/articles/PMC9174441/ | https://www.congress.gov/crs-product/R45403

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Lost human capital from war: $300B annually (economic impact of losing skilled/productive individuals to conflict) Broader conflict/violence cost: $14T/year globally 1.4M violent deaths/year; conflict holds back economic development, causes instability, widens inequality, erodes human capital 2002: 48.4M DALYs lost from 1.6M violence deaths = $151B economic value (2000 USD) Economic toll includes: commodity prices, inflation, supply chain disruption, declining output, lost human capital Additional sources: https://thinkbynumbers.org/military/war/the-economic-case-for-peace-a-comprehensive-financial-analysis/ | https://www.weforum.org/stories/2021/02/war-violence-costs-each-human-5-a-day/ | https://pubmed.ncbi.nlm.nih.gov/19115548/

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Global days of therapy reached 1.8 trillion in 2019 (234 defined daily doses per person). Diabetes, respiratory, CVD, and cancer account for 71 percent of medicine use. Projected to reach 3.8 trillion DDDs by 2028.
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Estimated private pharmaceutical and biotech clinical trial spending is approximately $75-90 billion annually, representing roughly 90% of global clinical trial spending.
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Estimates social returns to R&D of 20-60% through technology spillovers, substantially exceeding private returns. Provides empirical evidence for the positive externalities of research investment, supporting public funding of basic research.

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The synthetic control method provides a systematic way to choose comparison units in comparative case studies. A combination of comparison units often provides a better comparison for the unit affected by the policy intervention than any single comparison unit alone.

21 Appendix A: Analysis Workflow

21.1 Complete OBG Analysis Pipeline

```
+--------------------------------------------------------------+
|                     OBG ANALYSIS WORKFLOW                      |
+--------------------------------------------------------------+

Phase 1: DATA COLLECTION
-------------------------
1. Budget data ingestion
   +-- Pull current spending by category (OMB, USASpending)

   +-- Normalize categories to standard taxonomy
   +-- Identify subcategories for detailed analysis
   +-- Flag data quality issues

2. Cross-country spending data
```

```
   +-- Pull spending data from OECD, World Bank
   +-- Include all comparable countries
   +-- Normalize to per-capita and % GDP
   +-- Prepare for regression analysis

3. Effect estimate data
   +-- Search systematic reviews and meta-analyses
   +-- Extract effect sizes with standard errors
   +-- Code study quality (RCT, natural experiment, etc.)
   +-- Build literature database by category

Phase 2: OSL ESTIMATION
-----------------------
4. Diminishing returns modeling
   +-- Fit nonlinear spending-outcome functions
   +-- Identify "knee" of curve
   +-- Calculate marginal returns at current spending
   +-- Estimate optimal level

5. Cost-effectiveness analysis (health/life-saving)
   +-- Identify interventions below CE threshold
   +-- Calculate scale-up costs
   +-- Sum to category OSL
   +-- Document assumptions

6. Method reconciliation
   +-- Compare OSL estimates across methods
   +-- Weight by method reliability
   +-- Produce consensus OSL estimate
   +-- Flag discrepancies

Phase 3: EVIDENCE QUALITY
-------------------------
7. BIS calculation
   +-- Compute quality weights per study
   +-- Compute precision weights
   +-- Compute recency weights
   +-- Aggregate to category BIS

8. Evidence grading
   +-- Assign A-F grade based on BIS
   +-- Document key evidence
   +-- Identify research gaps
   +-- Flag high-uncertainty categories

Phase 4: GAP ANALYSIS
---------------------
9. Compute gaps
```

```
    +-- Gap = OSL - Current
    +-- Calculate % gap
    +-- Classify as under/over/optimal
    +-- Apply BIS weighting

10. Priority ranking
    +-- Priority = |Gap| × BIS
    +-- Rank categories
    +-- Identify reallocation pairs
    +-- Estimate welfare gains

Phase 5: OUTPUT GENERATION
--------------------------
11. Multi-unit reporting
    +-- Natural units ($/capita, % GDP)
    +-- Monetized (ROI, opportunity cost)
    +-- Health units (QALYs where applicable)
    +-- Composite (BIS, evidence grade)

12. Sensitivity analysis
    +-- Vary key parameters
    +-- Test country data subsets
    +-- Report OSL ranges
    +-- Identify robust conclusions

13. Documentation
    +-- Generate category reports
    +-- Create methodology audit trail
    +-- Version control estimates
    +-- Publish to dashboard/API
```

22 Appendix B: Glossary

22.1 Core Concepts

- **Optimal Budget Generator (OBG)**: The framework/methodology for generating integrated budget recommendations based on evidence of spending-outcome relationships. OBG accounts for the zero-sum nature of budget allocation and produces Optimal Spending Level (OSL) estimates for each category.

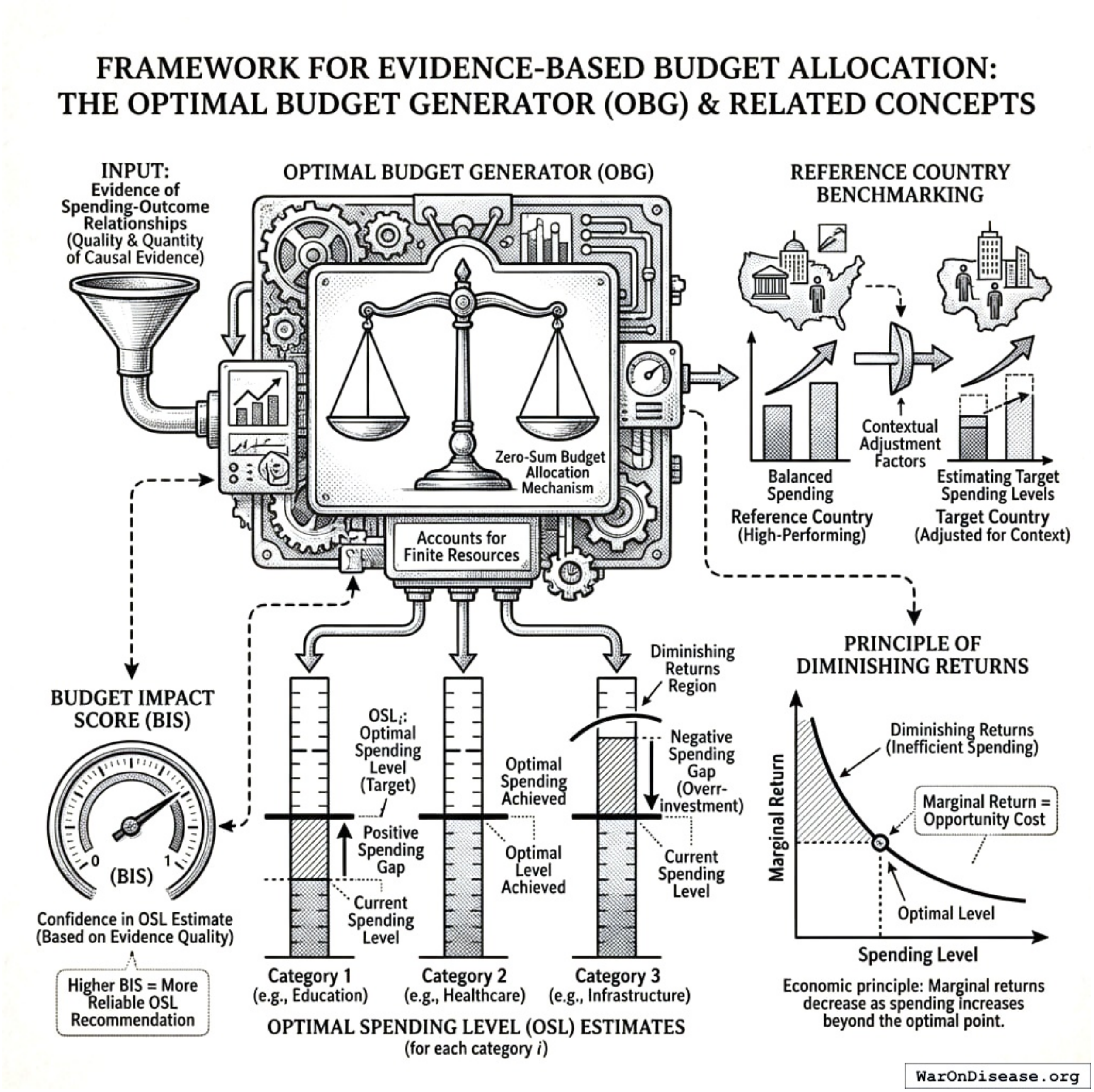

Figure 26: A conceptual framework illustrating the Optimal Budget Generator process, showing how evidence and benchmarking result in OSL and BIS outputs to identify spending gaps.

- **Optimal Spending Level (OSL)**: The evidence-based target spending level for each category, produced by the OBG framework. OSL_i represents the optimal spending level for category i. Below OSL indicates underinvestment; above OSL indicates diminishing returns.
- **Budget Impact Score (BIS)**: A 0-1 score measuring confidence in each category's OSL estimate based on the quality and quantity of causal evidence. Higher BIS indicates more reliable OSL recommendations.
- **Spending Gap**: The difference between current spending and the evidence-based target for each category. Positive gaps indicate underinvestment; negative gaps indicate overinvestment.

- **Diminishing Returns**: The economic principle that marginal returns to spending decrease as spending increases. The optimal level is where marginal return equals opportunity cost.

22.2 Estimation Methods

- **Cost-Effectiveness Threshold**: The maximum acceptable cost per QALY (or other health outcome) for including an intervention in target calculations. Typically $50K-$150K per QALY.
- **Dose-Response Curve**: The relationship between spending level (dose) and outcome (response). Used to identify diminishing returns and estimate optimal spending levels.

22.3 Evidence Quality

- **Quality Weight (w^Q)**: Weight assigned to a study based on identification strategy. RCTs receive 1.0; cross-sectional studies receive 0.25.
- **Precision Weight (w^P)**: Weight assigned based on standard error. More precise estimates receive higher weight.
- **Recency Weight (w^R)**: Weight assigned based on publication date. More recent studies receive higher weight via exponential decay.
- **Evidence Grade**: Letter grade (A-F) summarizing confidence in each category's target estimate. A = strong evidence; F = insufficient evidence.

22.4 Output Concepts

- **Priority Score**: Product of gap magnitude and BIS. Used to rank categories for reallocation priority.
- **Value of Information (VOI)**: Expected benefit of additional research on uncertain categories. High-VOI categories warrant pilot funding.
- **Multi-Unit Reporting**: Presenting results in natural units, monetized equivalents, health units, and composite scores for interpretability.

23 Appendix C: Illustrative Comparison to US Budget

This appendix applies the OBG methodology to the US discretionary budget as an illustrative exercise. "Current" figures reflect approximate FY2024 budget authority. OSL estimates for pragmatic trials, vaccinations, and K-12 education are derived from the worked examples in Sections 5-7. Other OSL values are preliminary estimates based on cross-country benchmarking and published cost-effectiveness evidence; they have not undergone the full OBG estimation pipeline and should be treated as order-of-magnitude approximations pending rigorous analysis. BIS scores reflect the author's qualitative assessment of causal evidence quality.

23.1 Illustrative US Discretionary Budget vs. OSL Targets

Category	Current $(B)|OSL$(B)	Gap ($B)	Gap %	BIS	Inc	Hlth	Priority	
Military (discretionary)	850	459	-391	-46%	0.50	–	–	195
Non-military discretionary	915	1,350	+435	+48%	0.65	++	++	283
- Pragmatic clinical trials	0.5	50	**+49.5**	**+9,900%**	0.90	++	+++	**44.6**
- Education	80	120	+40	+50%	0.75	+++	+	30
- Health (research)	50	100	+50	+100%	0.80	+	+++	40
- Vaccinations	8	35	+27	+338%	0.95	+	+++	26
- Basic research	45	90	+45	+100%	0.70	++	++	32
- Infrastructure	100	150	+50	+50%	0.60	++	+	30
- Early childhood	50	70	+20	+40%	0.85	+++	+	17
Agricultural subsidies	25	0	-25	-100%	0.90	–	–	23

Inc = effect on real after-tax median income growth. Hlth = effect on median healthy life years. Scale: +++ strong positive, ++ moderate, + weak, – negative.

Illustrative findings (subject to the caveats above):

1. **Extreme underinvestment in pragmatic trials**: At 9,900% below OSL with 637:1 (95% CI: 569:1-790:1) BCR, this appears to be the single largest misallocation in the federal budget (see Section 6 for full derivation)
2. **Apparent overinvestment**: Military spending is ~$391B (46%) above preliminary OSL estimates based on cross-country benchmarking
3. **Apparent underinvestment**: Vaccinations, basic research, and health research appear far below evidence-optimal levels
4. **Negative-return spending**: Agricultural subsidies produce negative welfare effects per the cost-effectiveness literature
5. **Reallocation potential**: The direction of reallocation (from military and subsidies toward research, health, and education) is robust even if precise OSL magnitudes shift with better data

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Data Availability: All data sources referenced in this paper are publicly available: OECD iLibrary (education, health spending), World Bank WDI (cross-country indicators), SIPRI Military Expenditure Database (defense spending), and CDC vaccination cost data. URLs are provided in the Data Sources section. A complete replication package including analysis code, data extraction scripts, and worked example calculations will be deposited in a public repository (GitHub/Zenodo) upon publication.

Ethics Statement: This is a methodological specification. No human subjects research was conducted.

Preprint: This working paper has not undergone peer review.