Microeconomic Concepts for Conservation Planning

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SMEA 536: Applied Micro for Marine Affairs – Winter 2021

Today's Outline

Motivation: Defining the conservation planning problem

Case Study: Fish passage prioritization in Western Washington

Conceptual Model: Evaluating targeting tools

Practical Considerations: How do we define costs and benefits?

Prioritization in Practice: Common tools applied in fish passage settings

Motivation:
Why use economics in conservation planning?

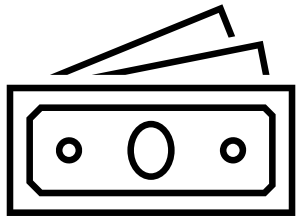
Key problem in conservation is often scarcity…

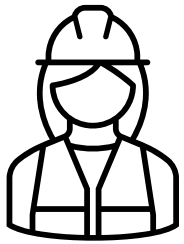
- Which land to purchase for set-aside with limited budget?
- Where to plant native plants from this year's nursery production?
- Where to establish Marine Protected Area while minimizing cost to local fisheries?

What do we do first with limited resources?

Motivation:
What doe we mean by “resources”?

1. **Financial**
   - Budget (funding)
2. **Physical & Human**
   - Labor
   - Equipment
   - Land
3. **Social**
   - Cooperation: where to coordinate?
   - Goodwill: what are costs for partners?





Goal is often: most bang for your buck

(Benefits) ***(Costs)***

Applied Example:
Fish Passage in Western Washington

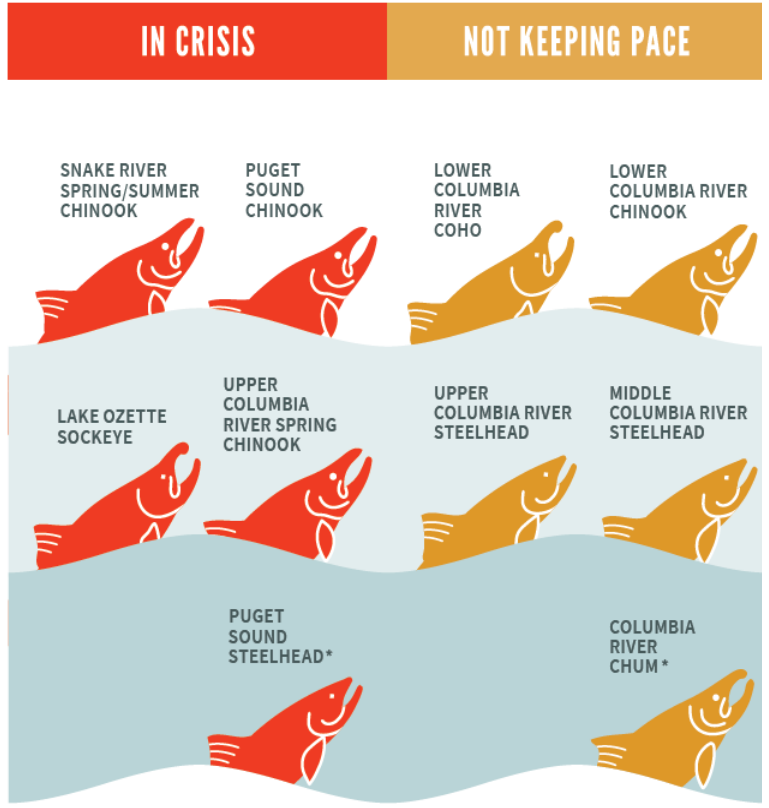
Salmon Populations in Decline

- 14 Evolutionarily Significant Units (ESUs) listed under the Endangered Species Act (ESA) in Washington
- Culturally important, especially for Indian tribes:

"The right of taking fish at usual and accustomed grounds and stations is further secured to said Indians in common with all citizens of the Territory..."

– Treaty of Point Elliot, 1855

- Many limiting factors
  - *Urbanization:* stormwater runoff, shoreline modification
  - *Climate:* steam conditions, ocean conditions
  - *Predation:* mammals, birds
  - *Hatcheries:* genetics, competition
  - *Fish passage:* culverts, dams ←



* Lacks complete data
Data Source: Washington Department of Fish and Wildlife
Figure Source: Governor's Salmon Recovery Office

Applied Example:
Fish Passage in Western Washington

Road Crossing Restrict Habitat Access

- Over **20,000** known artificial barriers blocking salmon from spawning grounds
- Majority are **culverts**: pipes or other structures that carry water under roads
- Culvert improvement can be expensive: **$3.6bill** for state culverts alone

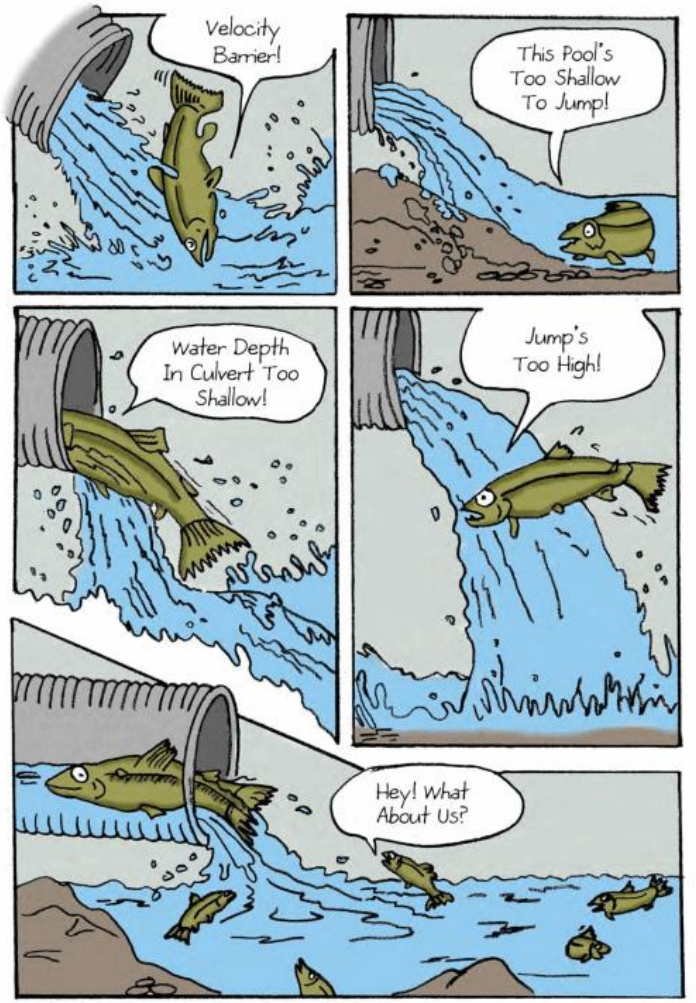


Figure Source: Washington State Department of Transportation

Applied Example:
Fish Passage in Western Washington

US v. WA Timeline

2001: 21 Western Washington tribes sue claiming **state-owned barrier culverts** violate treaty rights

2007: Federal district court agrees with tribes, convenes trial to determine remedy

2013: Federal injunction requires state to improve culverts blocking 90% of habitat by 2030

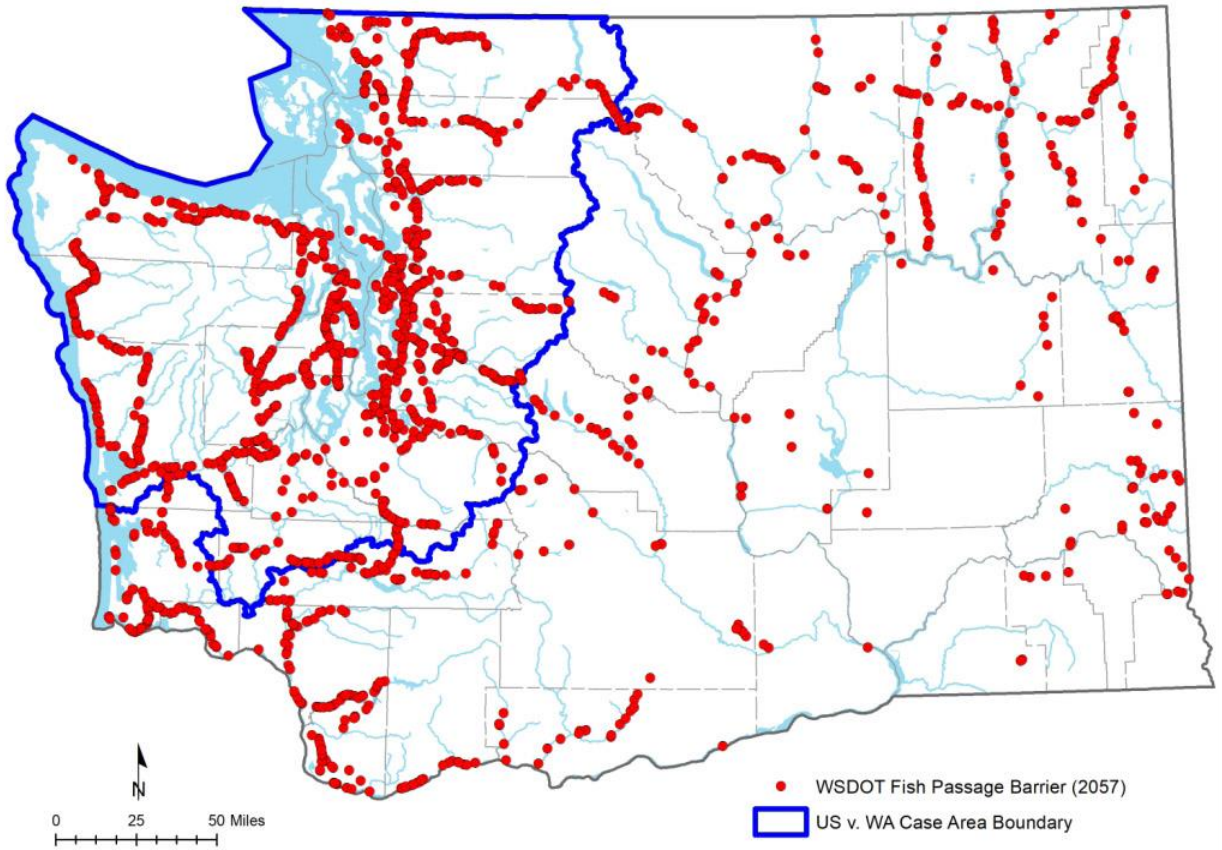
2018: US Supreme Court declines to hear appeal, <u>injunction stands</u>

Applied Example:
Fish Passage in Western Washington

- WSDOT owns over 2,000 barriers, nearly 1,000 within the Case Area
- Each costs **between $1mill-$2mill**
- Annual budget enough than **$150mill**

The Culvert Planning Problem:

With limited appropriations, which barriers to fix first?



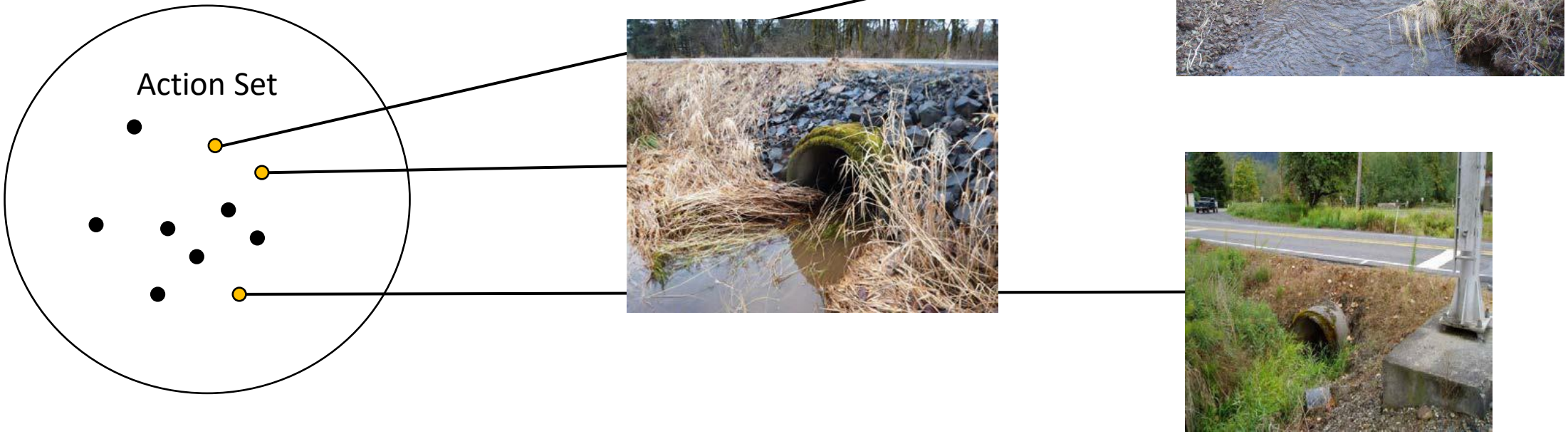
Conceptual Model: Evaluating Targeting Tools

1. Define set of potential actions
2. Define cost and benefit measures for each
3. Plot in cost and benefit space
4. Evaluate targeting criteria
   - Efficiency-targeting
   - Benefit-targeting
   - Cost-targeting

Based on Babcock et al. (1997), Newbold & Siikamäki (2015)

Conceptual Model: Evaluating Targeting Tools

1. Define set of potential actions
   - Can be sites for set aside, restoration activities, etc.
   - Assume no interdependencies
   - Seems restrictive, but a decent starting point



Conceptual Model: Evaluating Targeting Tools

2. Define cost and benefit measures
   - Can be tricky! We will revisit
   - Cost: estimated dollar amount to replace
   - Benefit: total lineal distance upstream

   → Assumption is that all barriers will eventually be repaired

$80,000

$200,000

$1,300,000

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$80,000 3.5mi

$200,000 8mi

$1,300,000 1mi

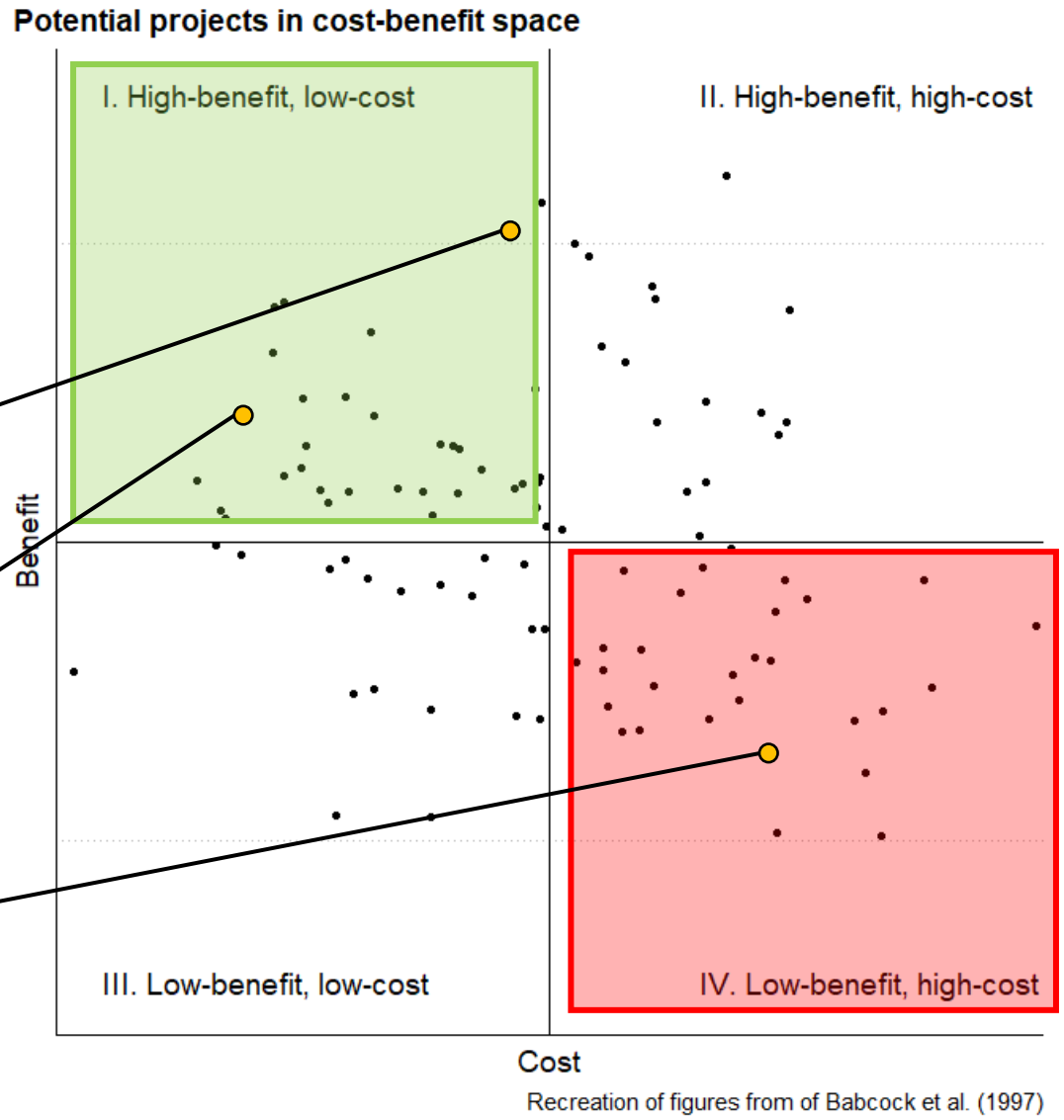
Conceptual Model: Evaluating Targeting Tools

3. Plot in cost and benefit space
   - Highest ROI is in upper-right
   - Lowest ROI is in lower-left

$450,000 8mi

$80,000 3.5mi

$1,300,000 1mi



Recreation of figures from of Babcock et al. (1997)

Conceptual Model: Evaluating Targeting Tools

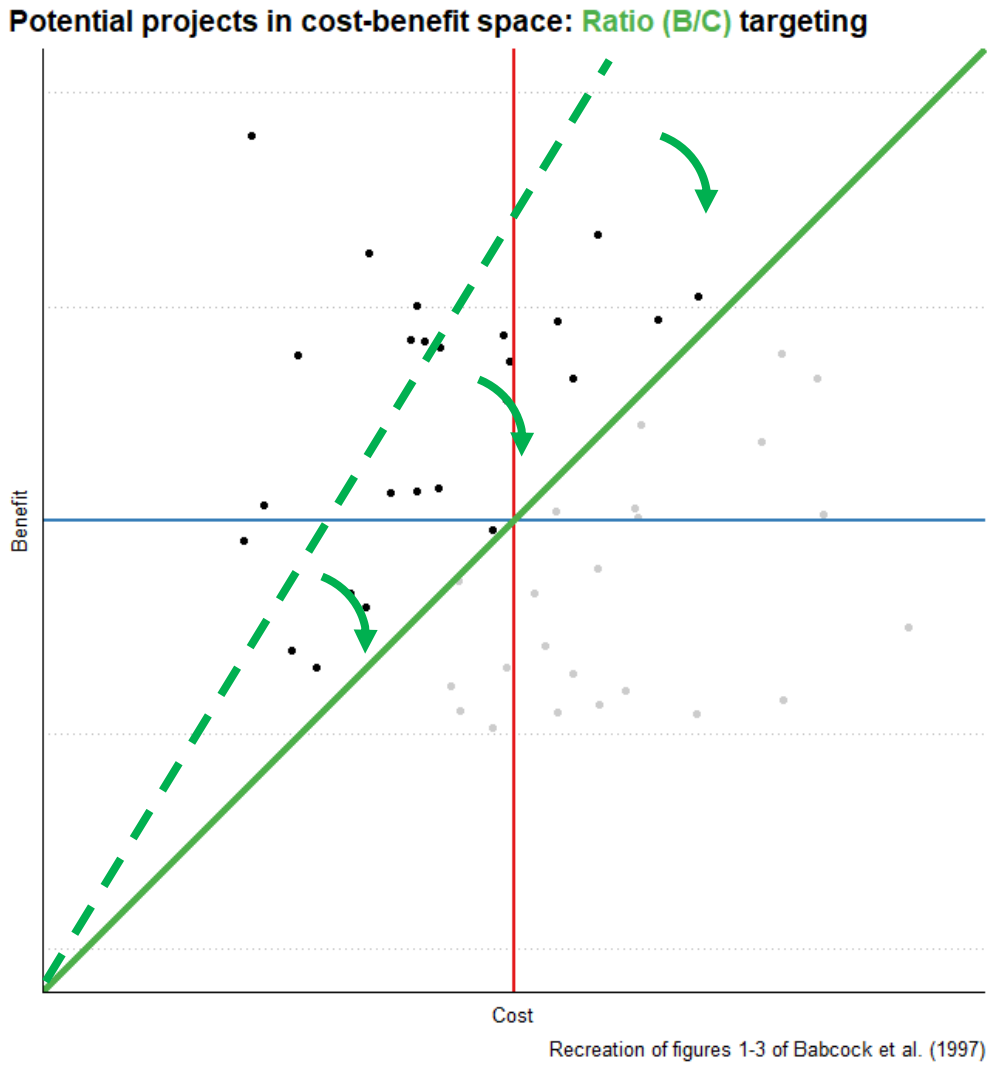
4. Evaluate targeting criteria
   - Efficiency-targeting ←
   - Benefit-targeting
   - Cost-targeting

Picks the projects with **highest ratio** of B/C first

Represented as a ray sweeping **clockwise**

Represents the full information case

Will always be "efficient" in sense of most benefit for a given budget



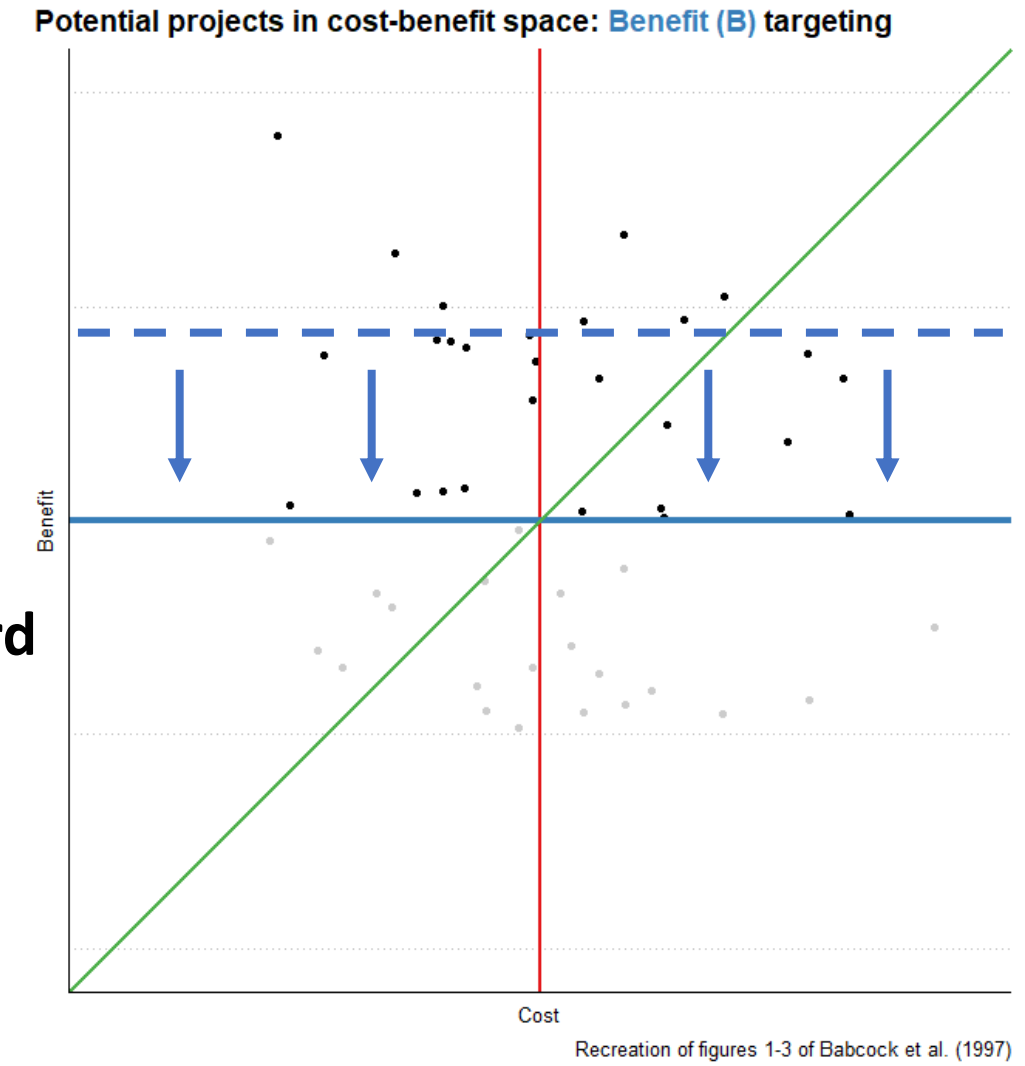
Recreation of figures 1-3 of Babcock et al. (1997)

Conceptual Model: Evaluating Targeting Tools

4. Evaluate targeting criteria
   - Efficiency-targeting
   - Benefit-targeting ←
   - Cost-targeting

Picks the projects with **highest Benefit** first

Represented as a horizontal line falling **downward**

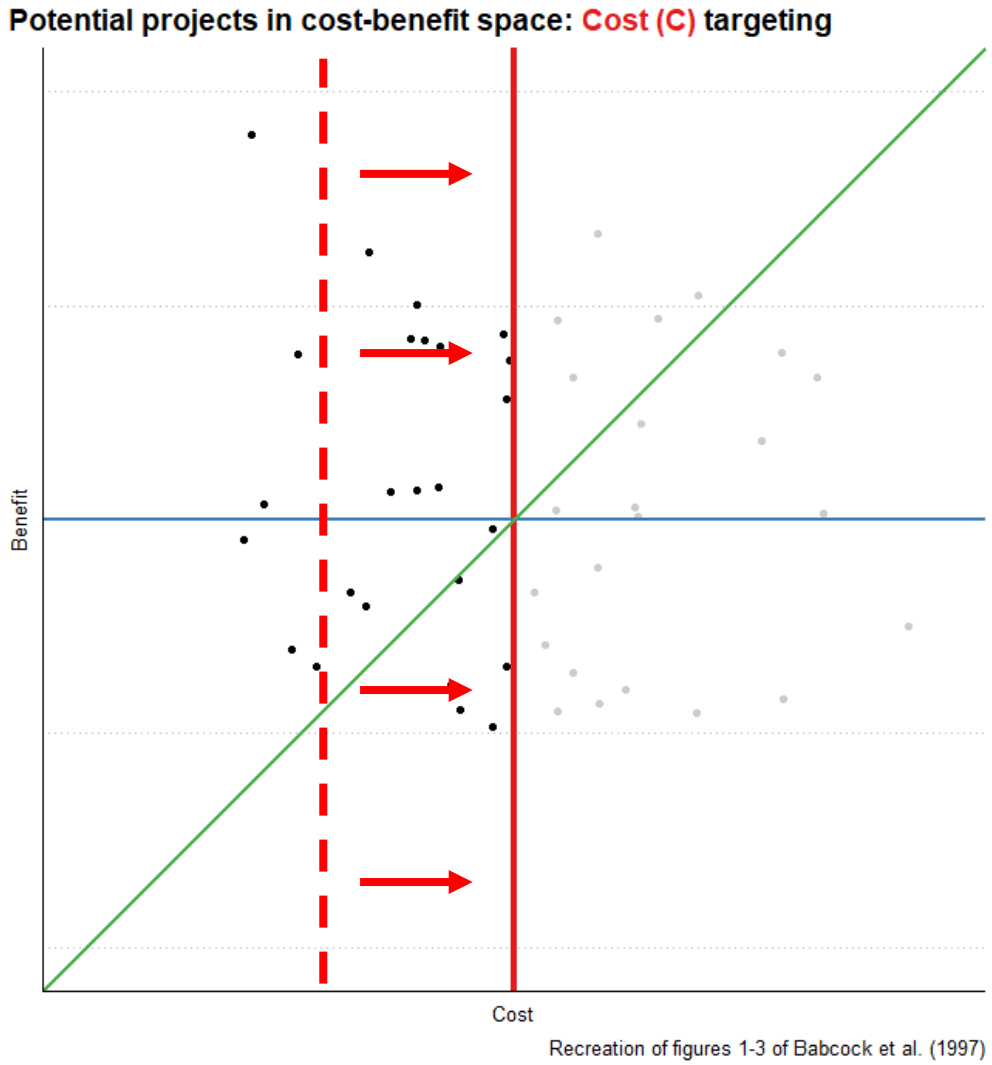


Conceptual Model: Evaluating Targeting Tools

4. Evaluate targeting criteria
   - Efficiency-targeting
   - Benefit-targeting
   - Cost-targeting ←

Picks the projects with **lowest Cost** first

Represented as a vertical line shifting **rightward**

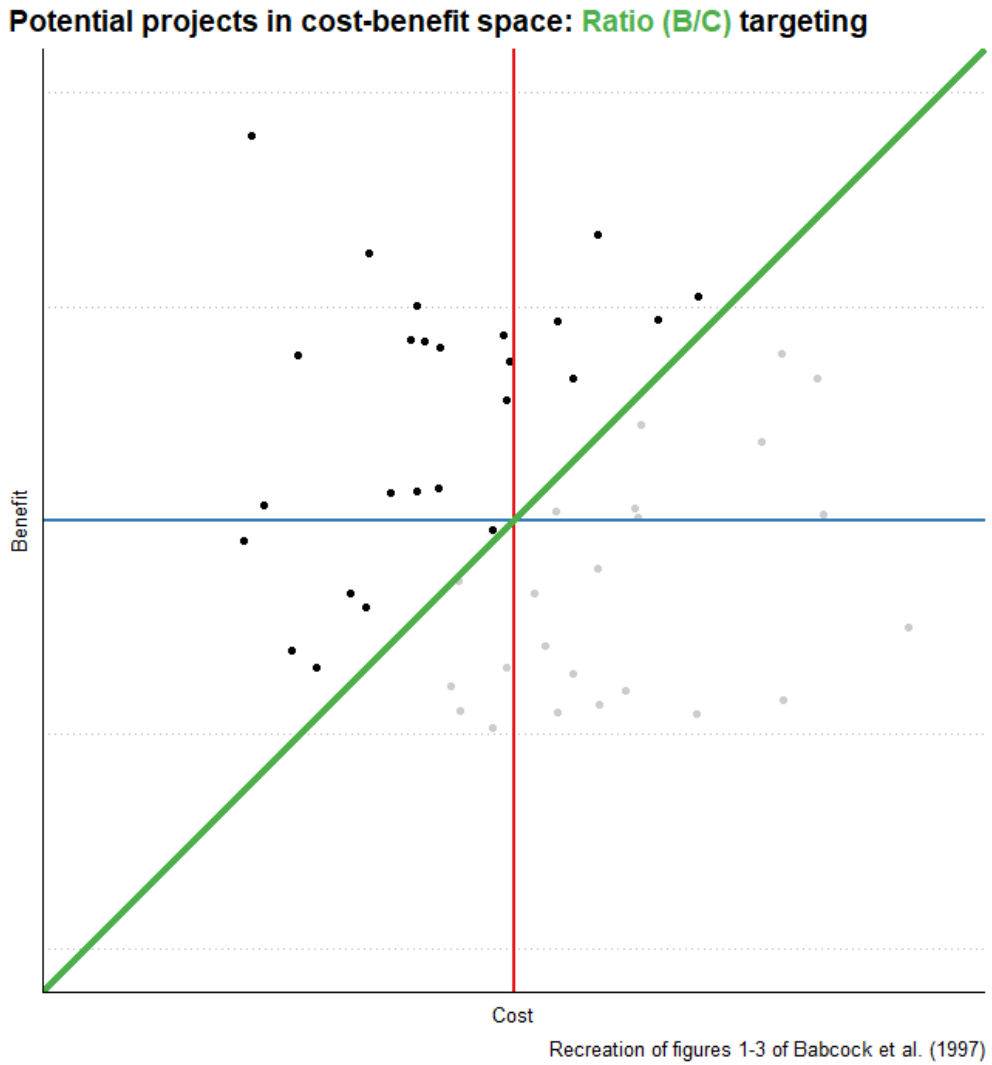


Conceptual Model: Evaluating Targeting Tools

4. Evaluate targeting criteria

If Efficiency-targeting is always most effective, why consider Benefit- or Cost-targeting?

- Information often limited on either costs or benefits
- Gathering information itself is costly



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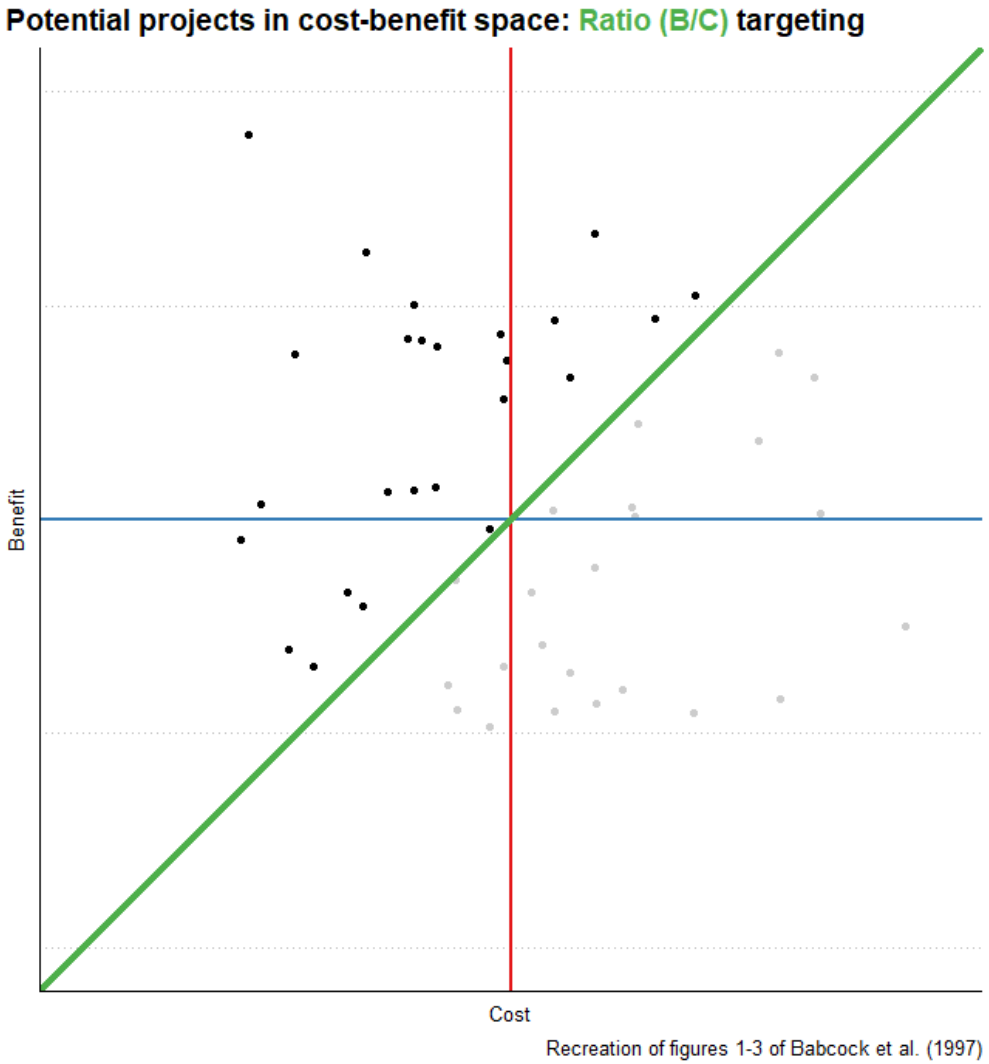
What if you had to choose which to target?



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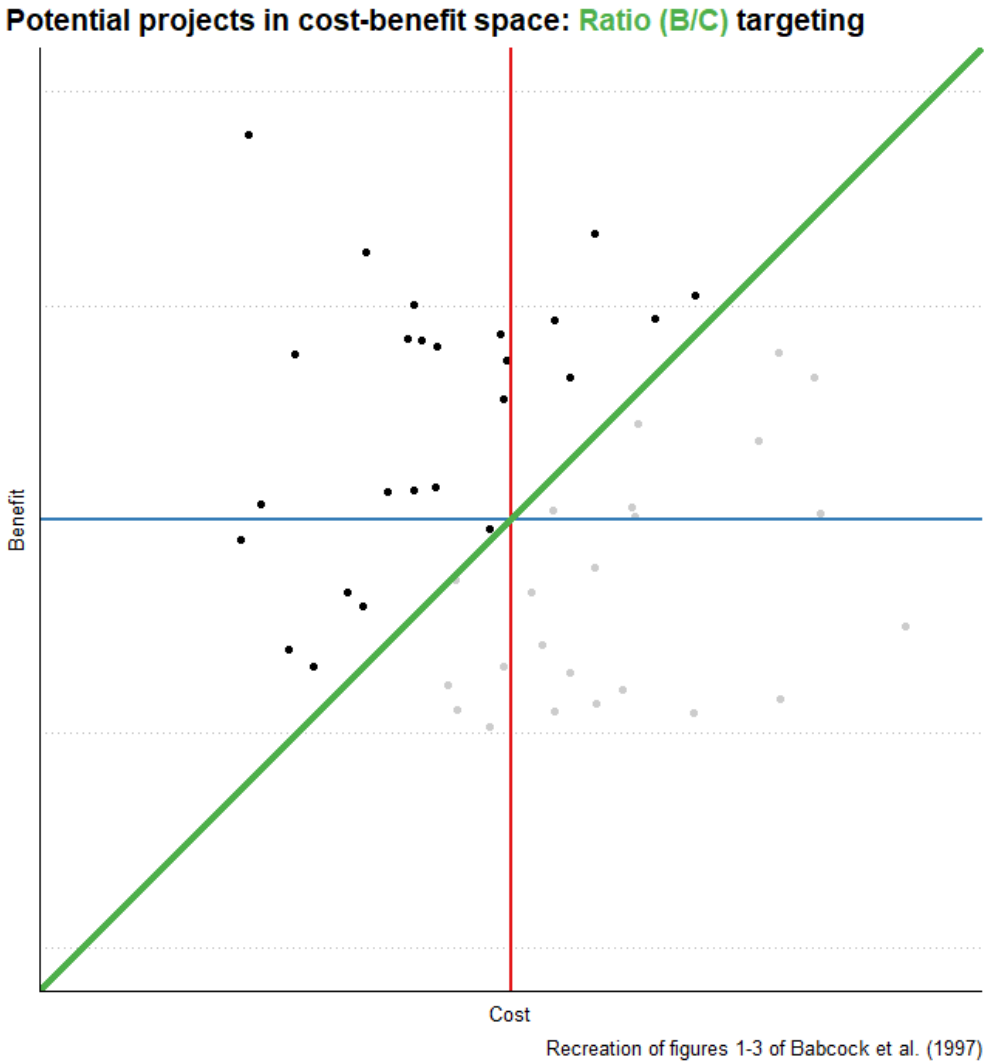
What if you had to choose which to target?

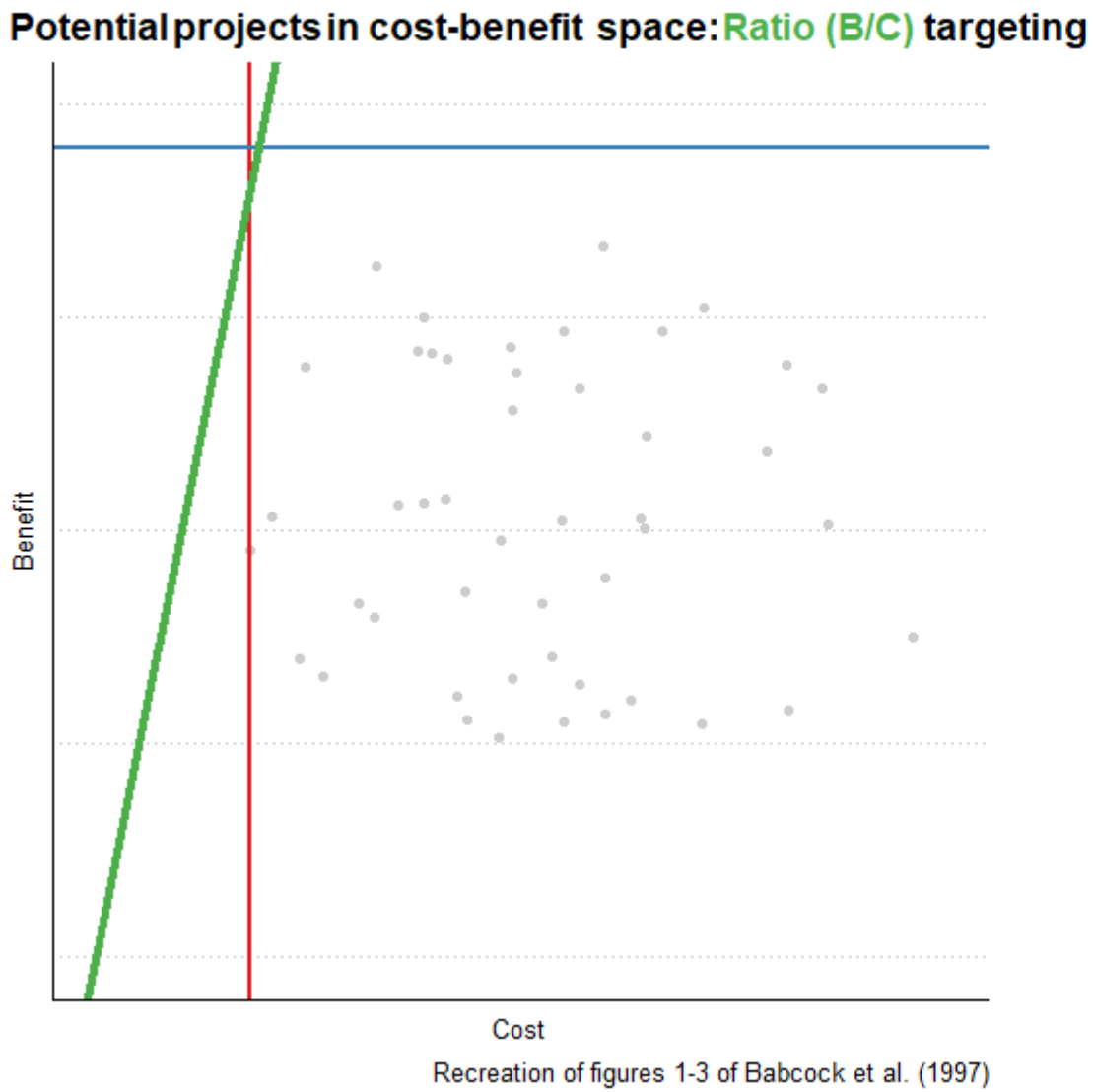
→ It depends!

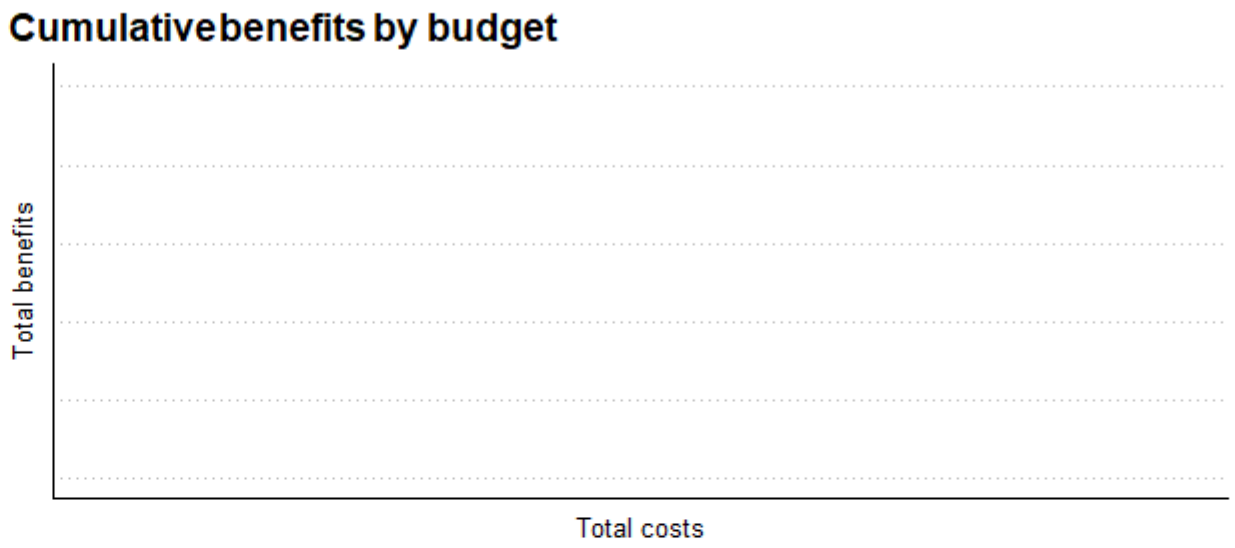


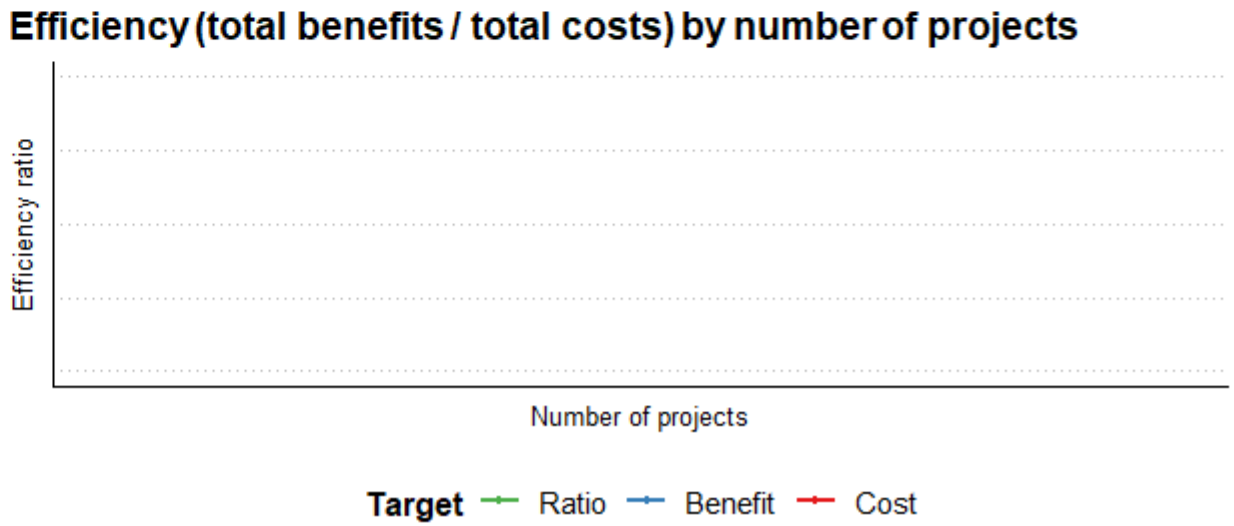
Recreation of figures 1-3 of Babcock et al. (1997)

Conceptual Model: Evaluating Targeting Tools

Equal variation, no correlation







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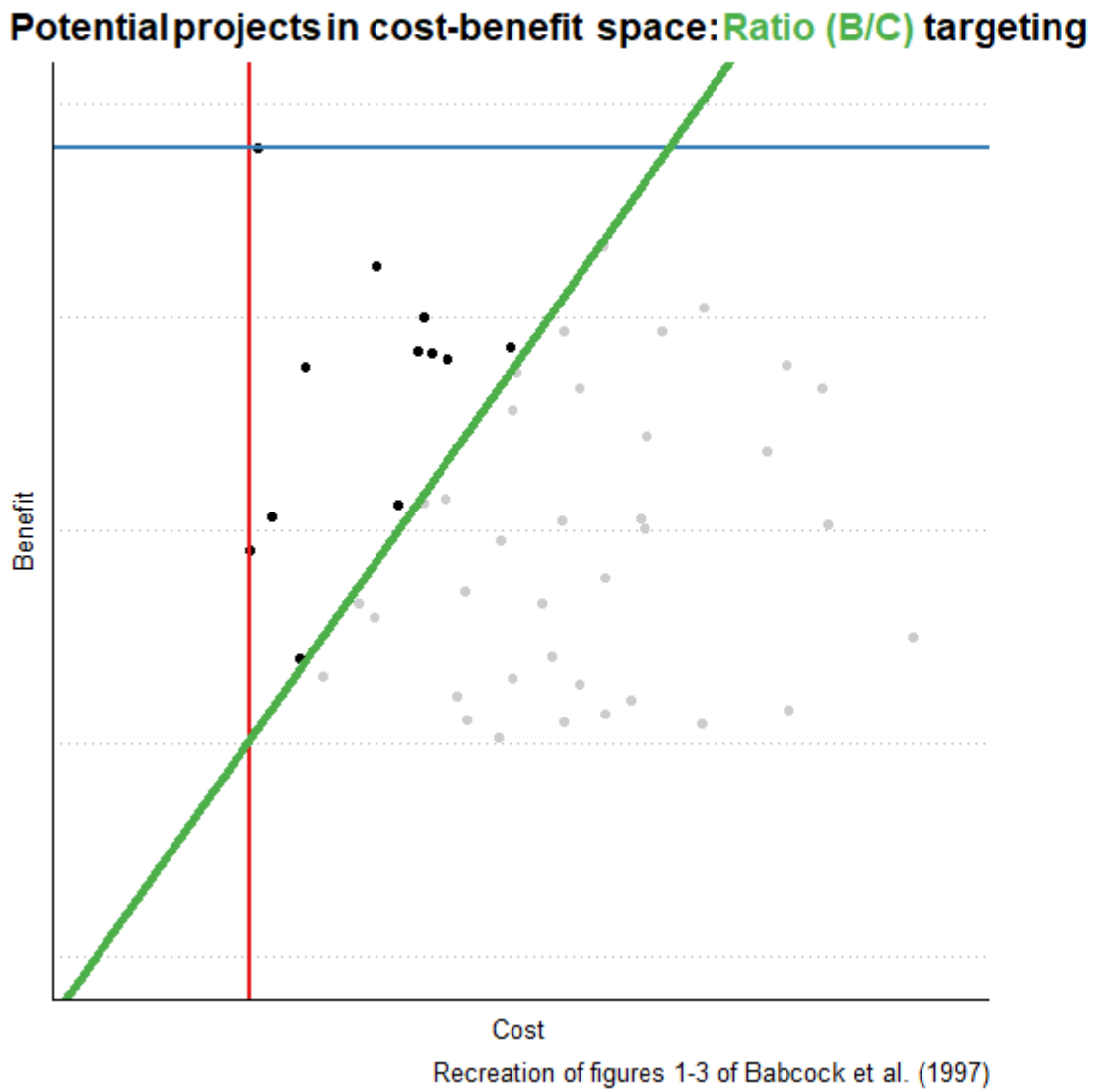

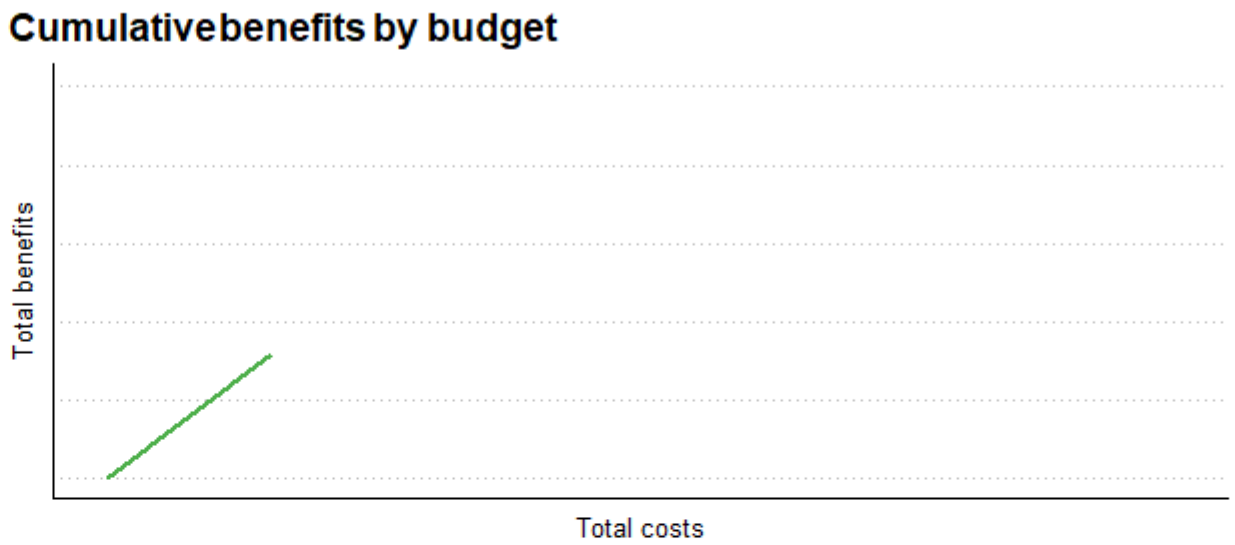

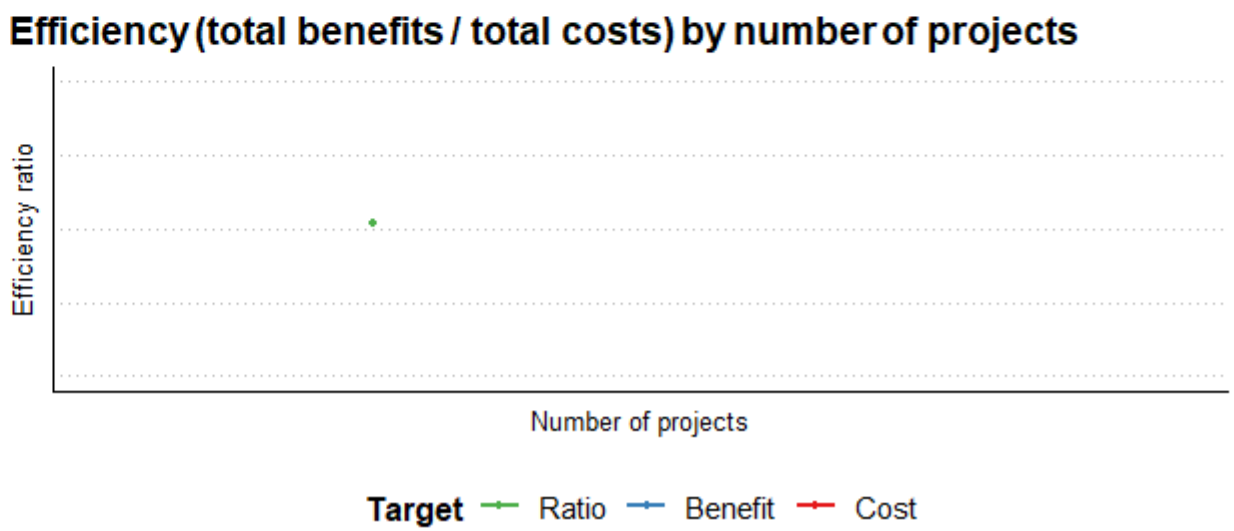

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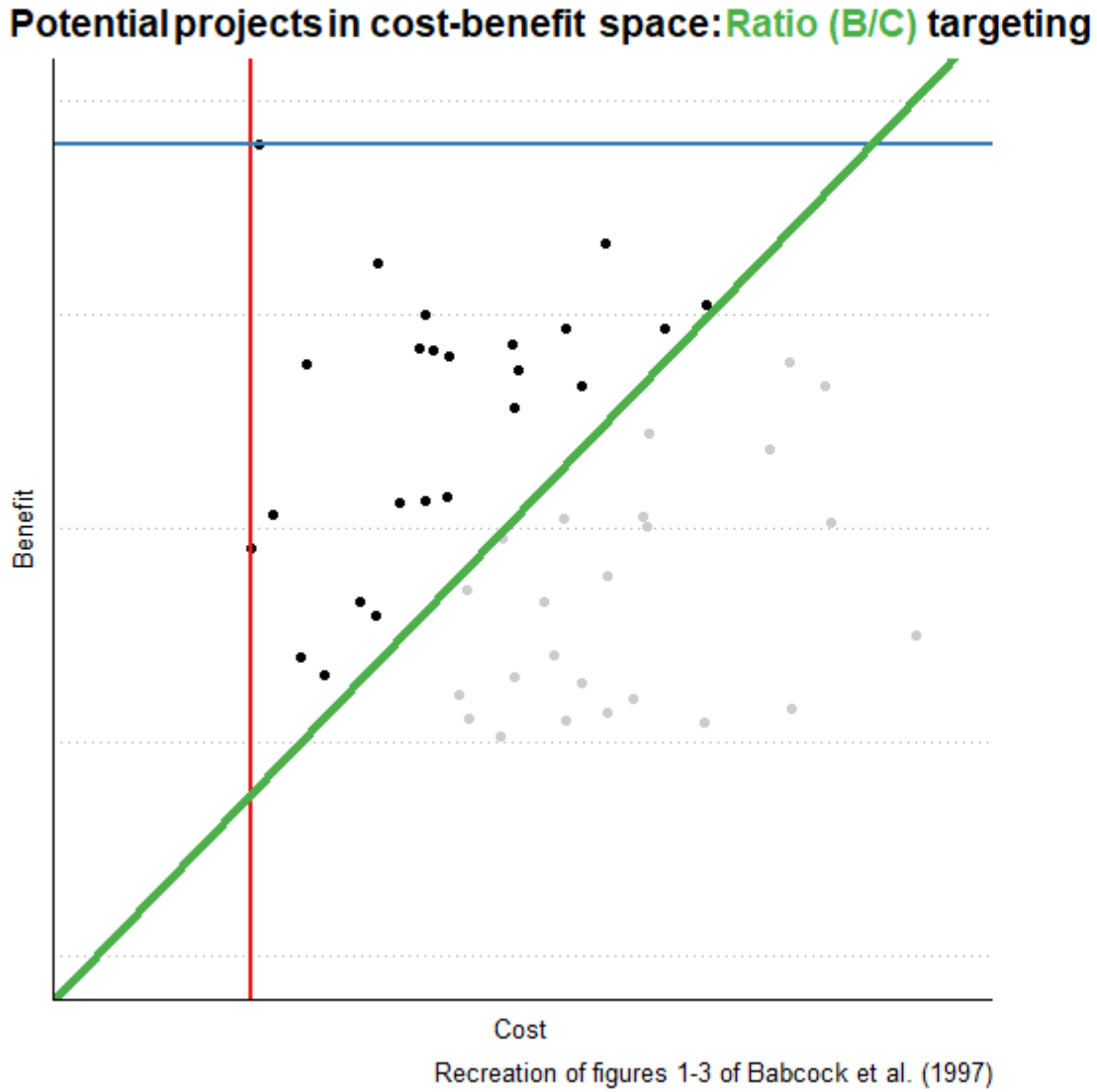
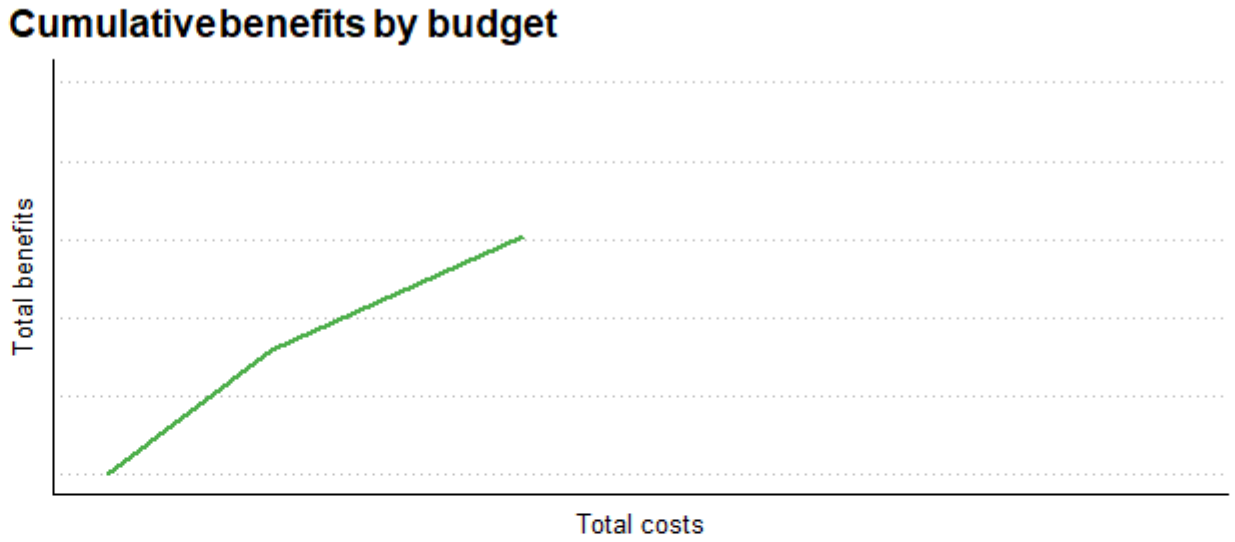
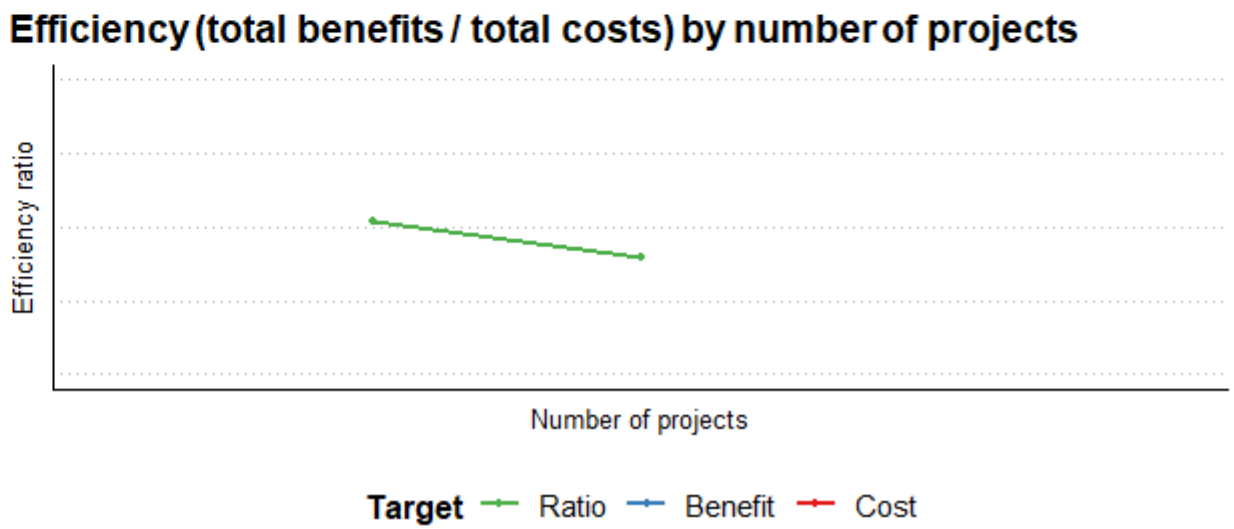




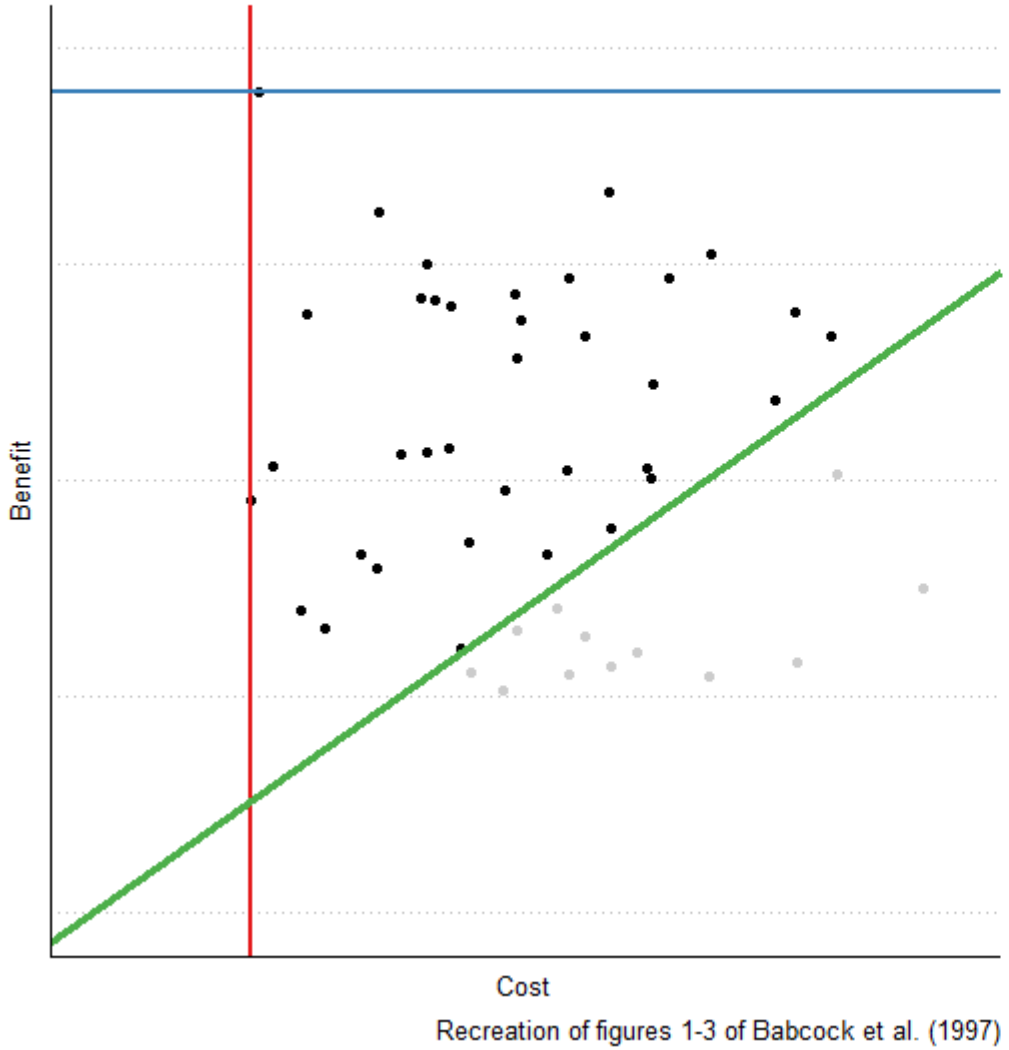


Recreation of figures 1-3 of Babcock et al. (1997)

Conceptual Model: Evaluating Targeting Tools

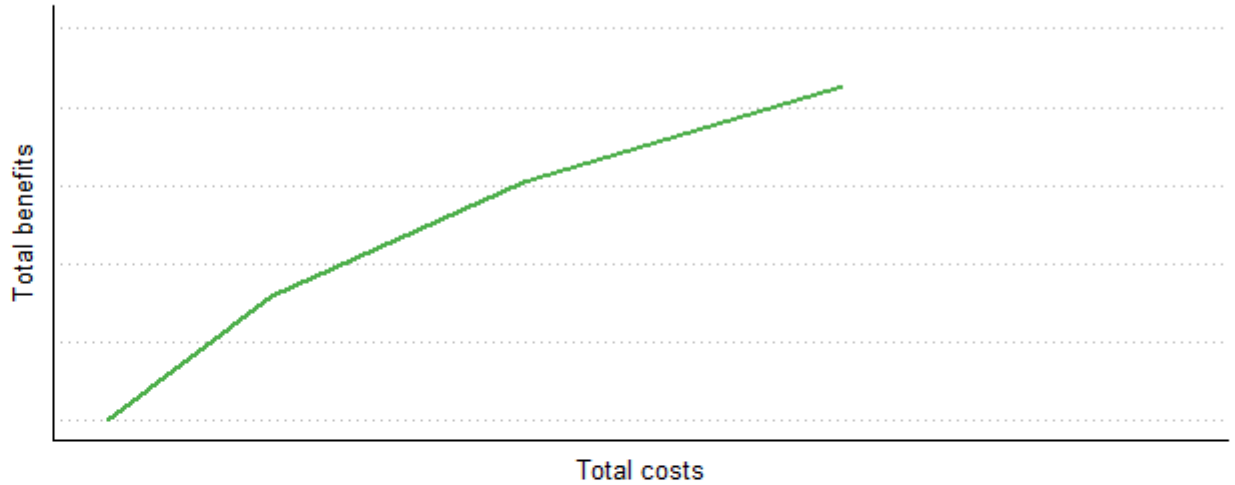
Equal variation, no correlation

Potential projects in cost-benefit space: Ratio (B/C) targeting



Recreation of figures 1-3 of Babcock et al. (1997)

Cumulative benefits by budget

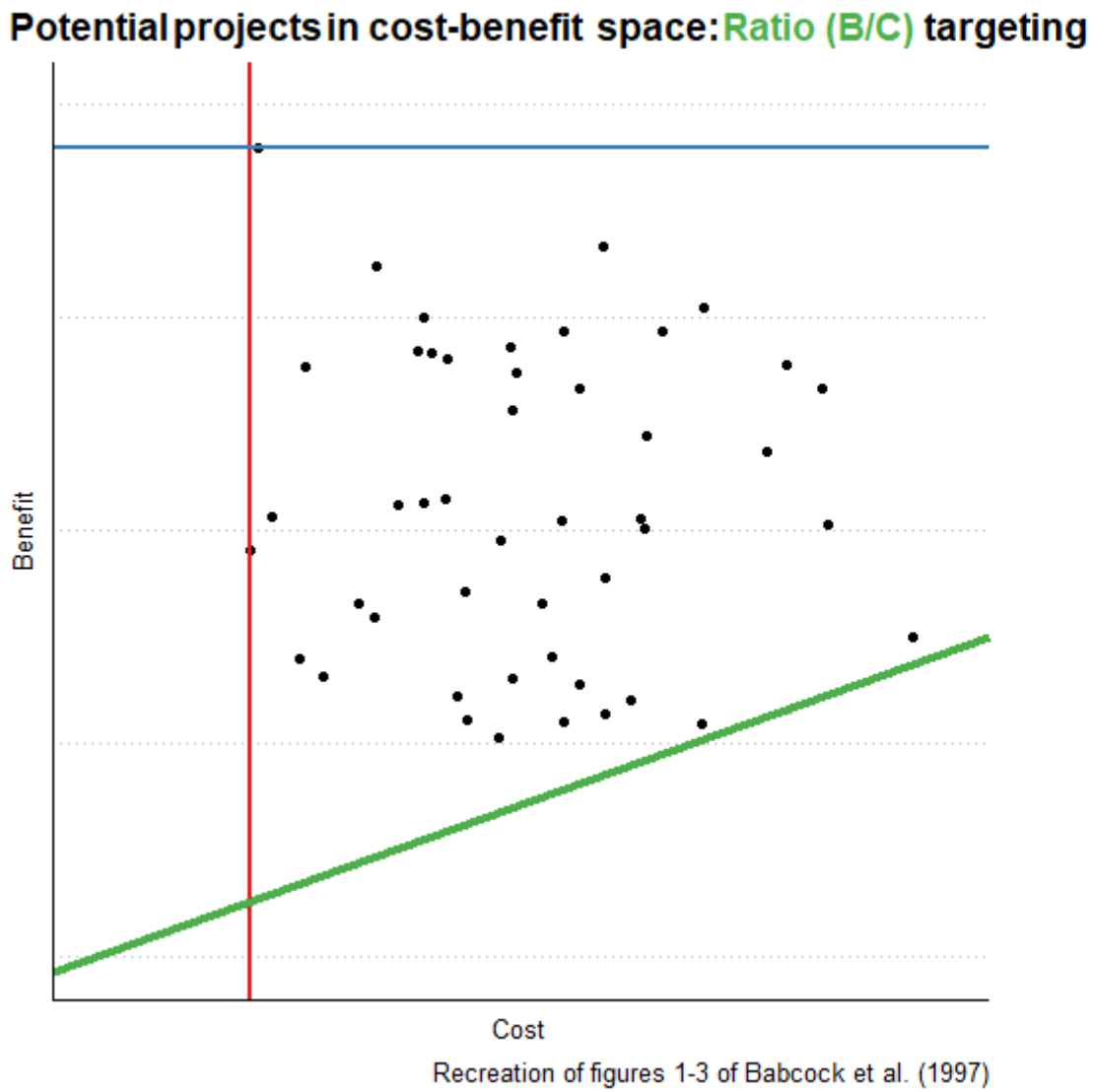


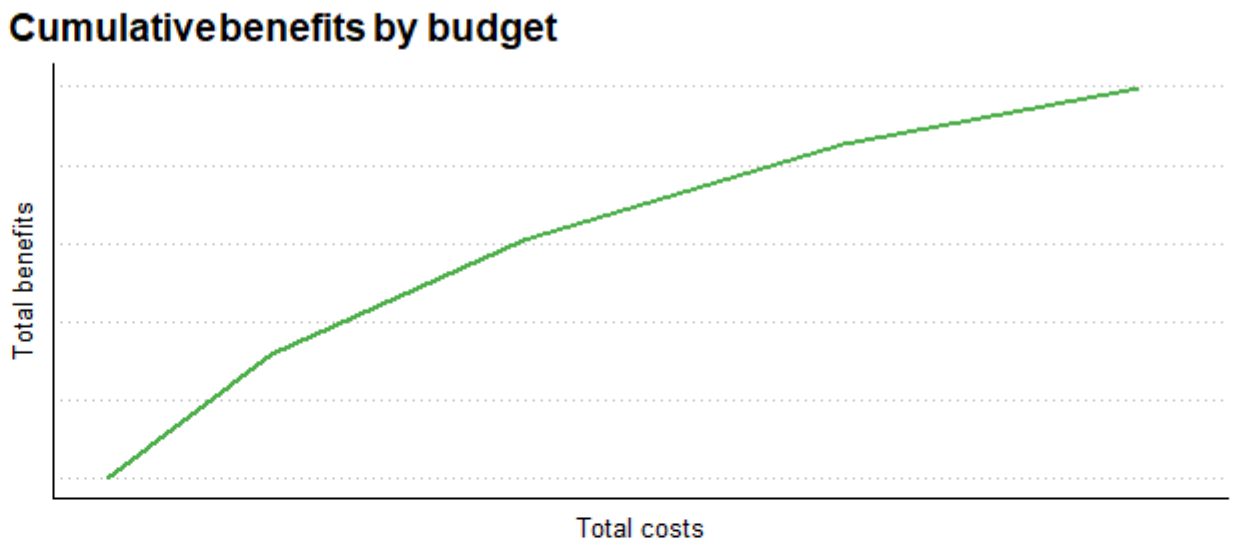
Efficiency (total benefits / total costs) by number of projects

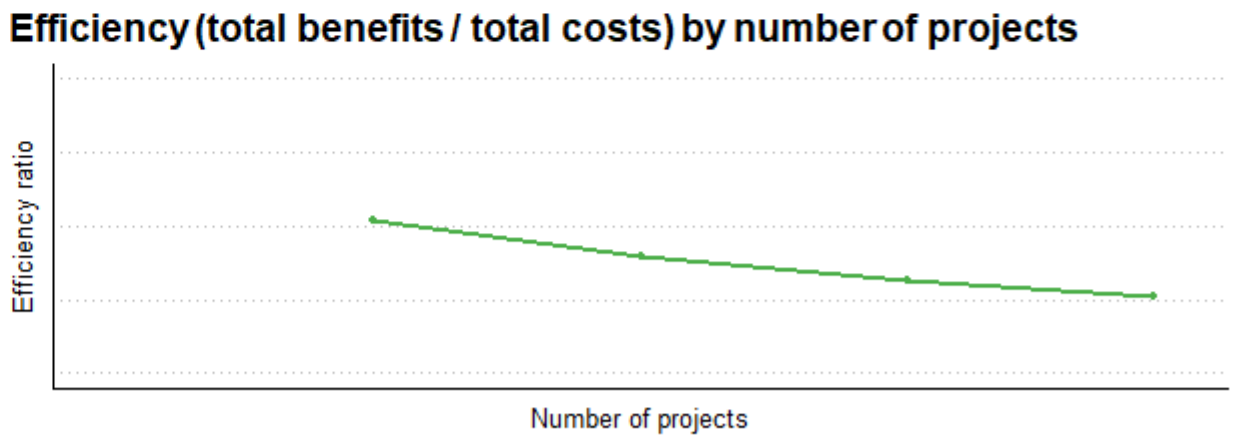
Target Ratio Benefit Cost

Conceptual Model: Evaluating Targeting Tools

Equal variation, no correlation





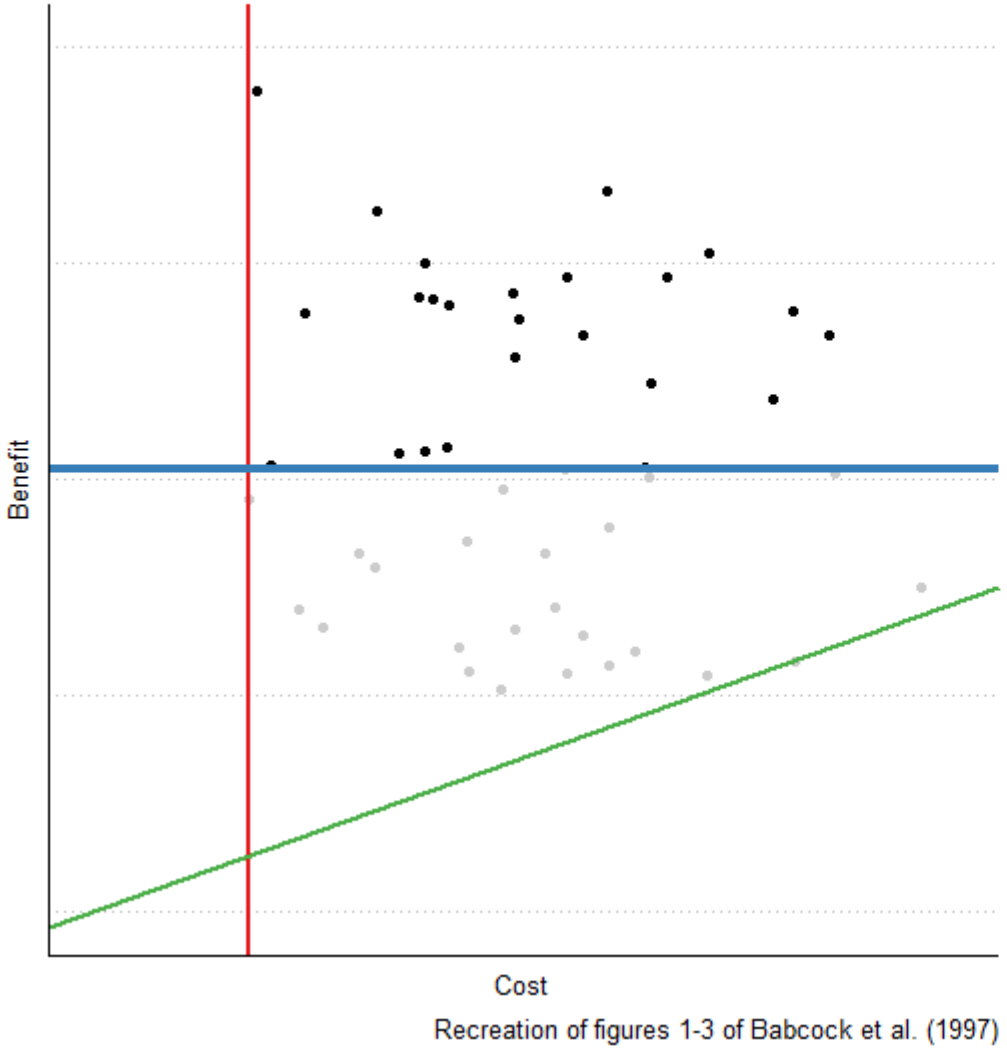


Recreation of figures 1-3 of Babcock et al. (1997)

Conceptual Model: Evaluating Targeting Tools

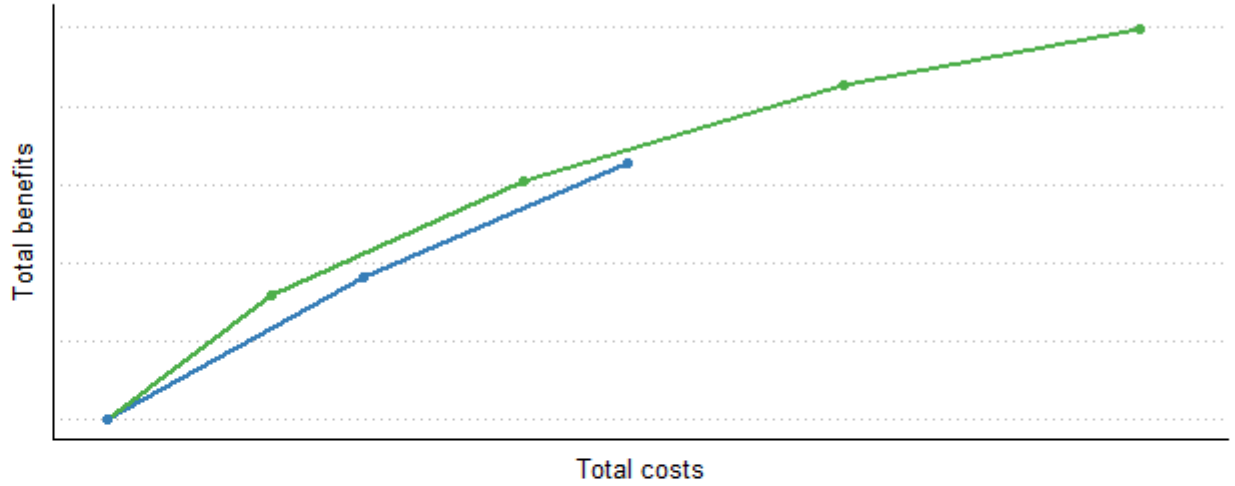
Equal variation, no correlation

Potential projects in cost-benefit space: Benefit (B) targeting



Recreation of figures 1-3 of Babcock et al. (1997)

Cumulative benefits by budget



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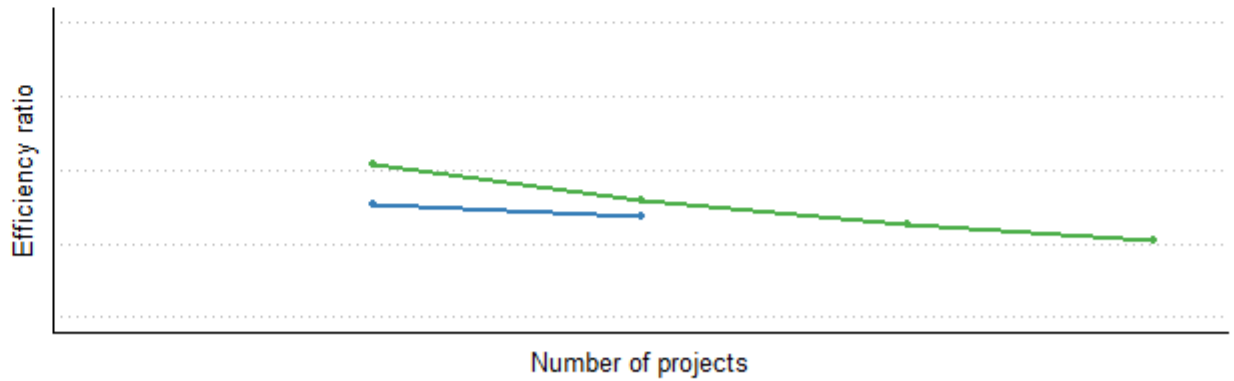
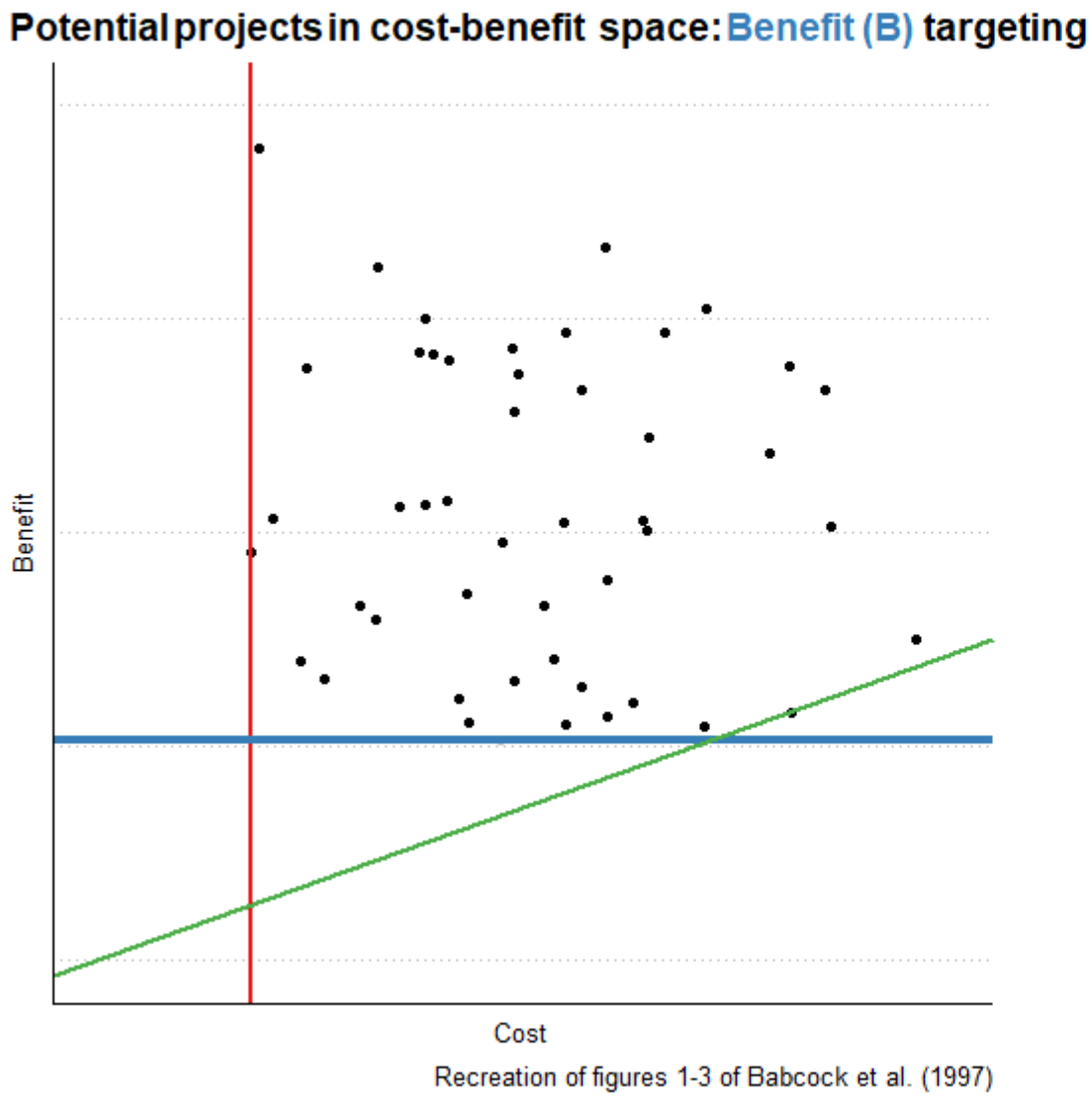
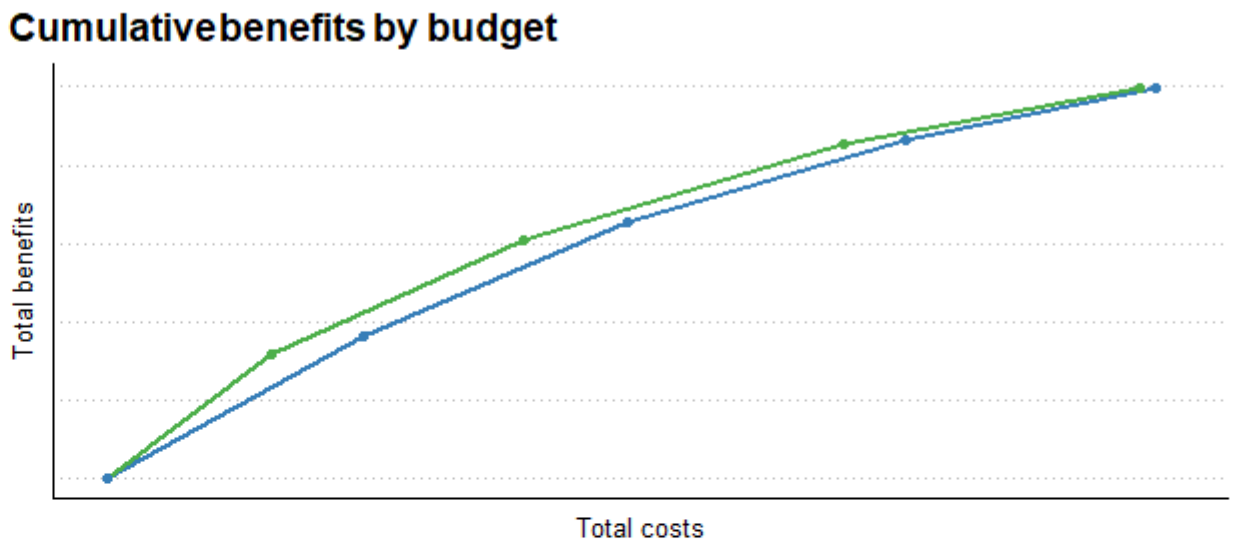


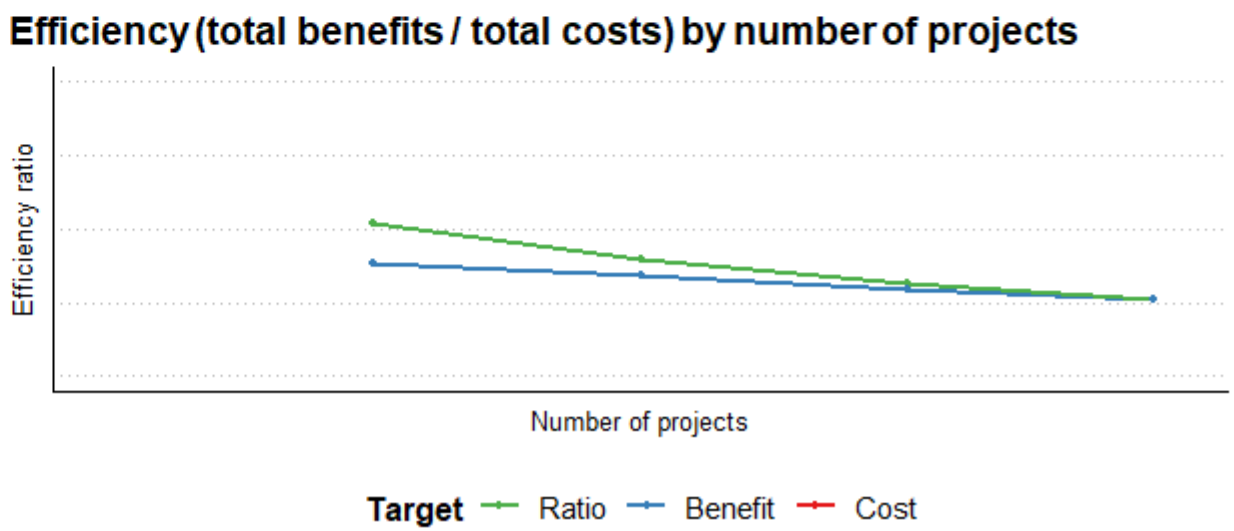
Target Ratio Benefit Cost

Conceptual Model: Evaluating Targeting Tools

Equal variation, no correlation



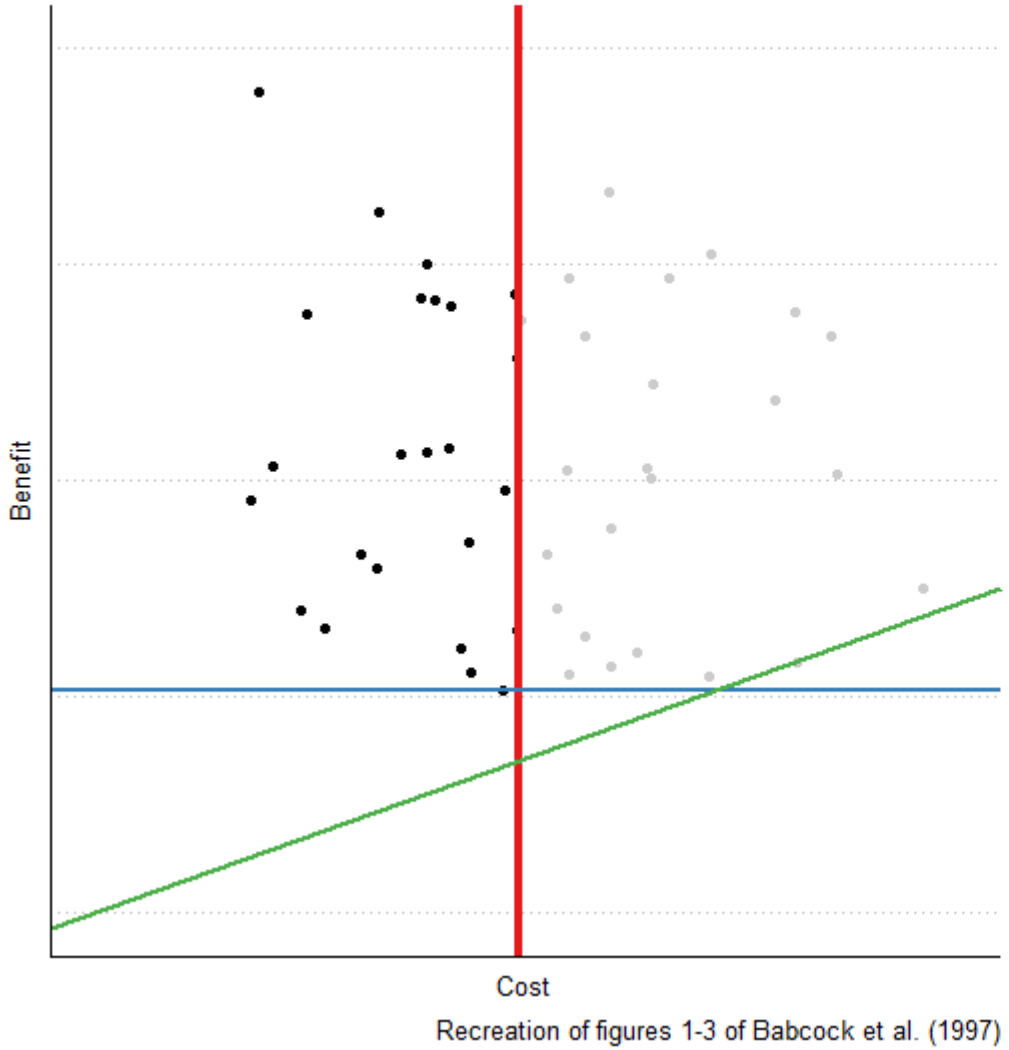




Conceptual Model: Evaluating Targeting Tools

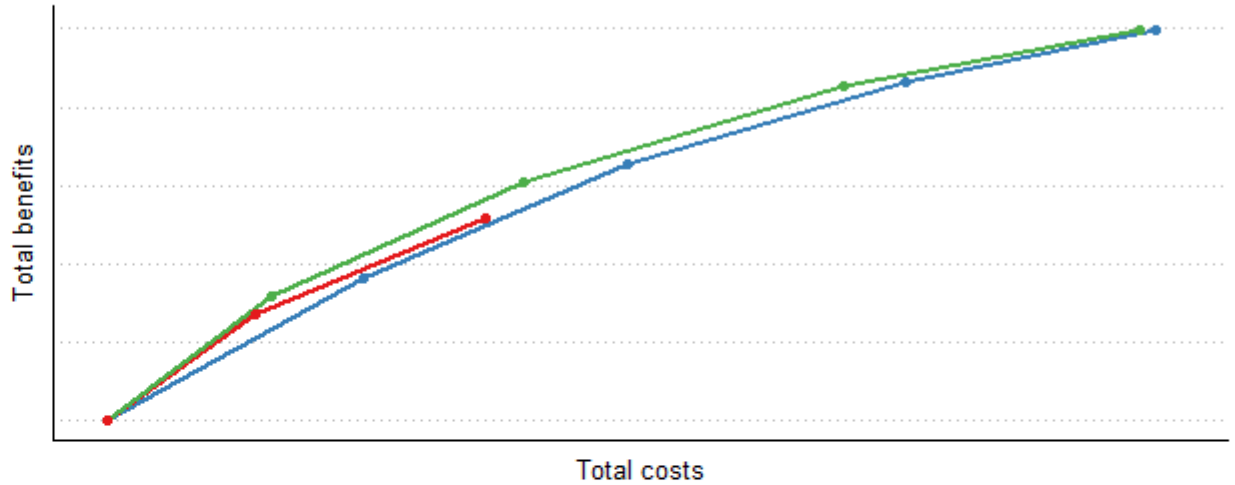
Equal variation, no correlation

Potential projects in cost-benefit space: Cost (C) targeting

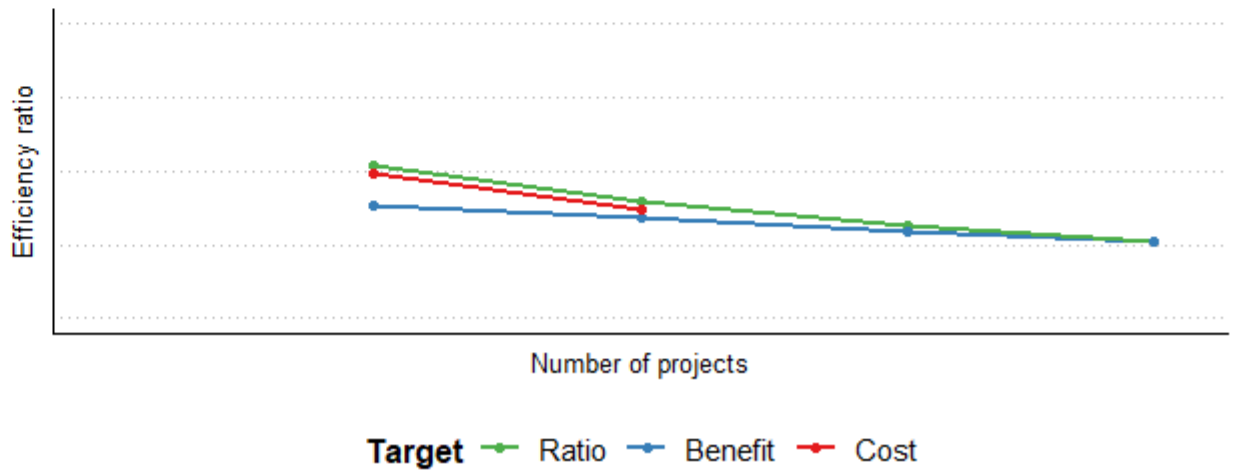


Recreation of figures 1-3 of Babcock et al. (1997)

Cumulative benefits by budget

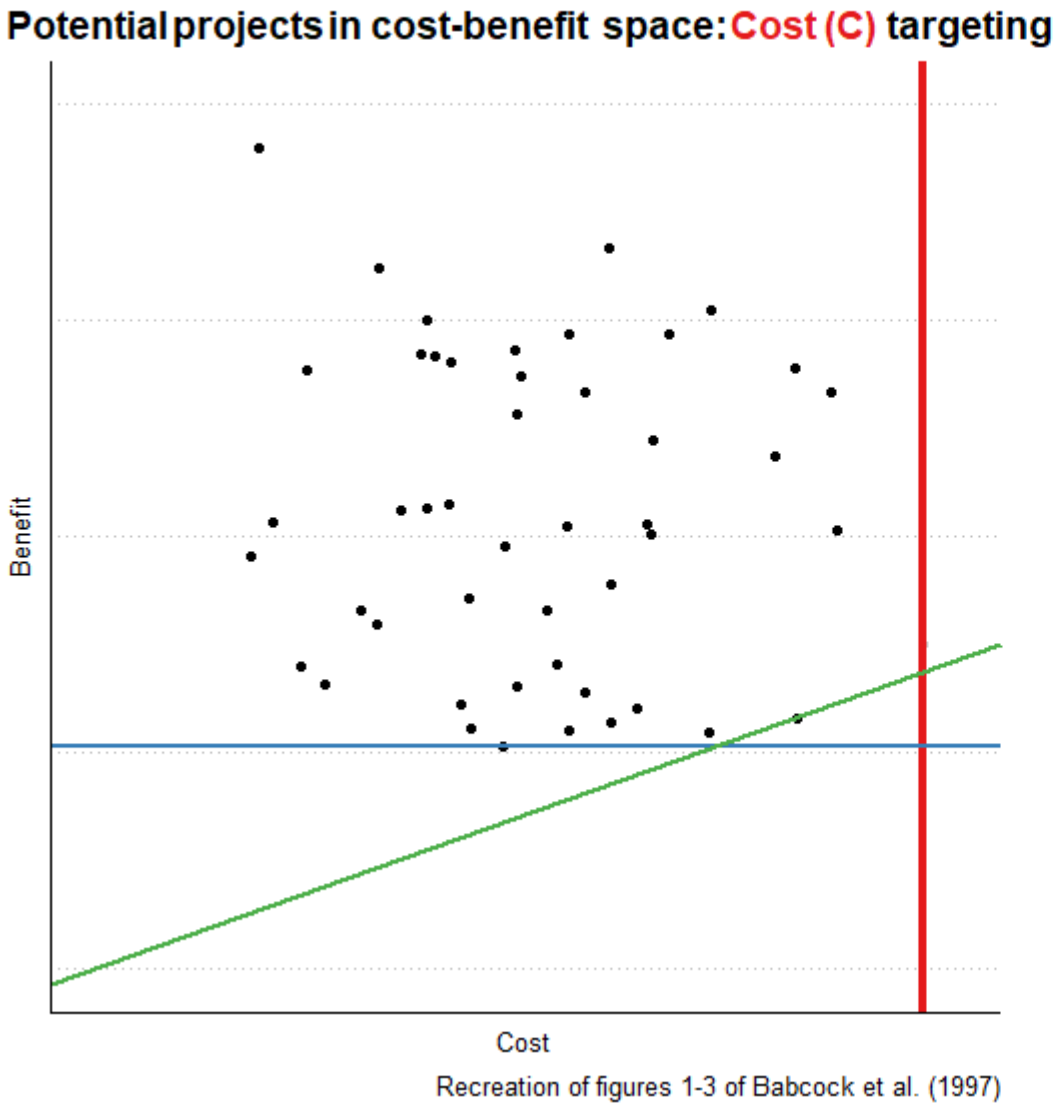


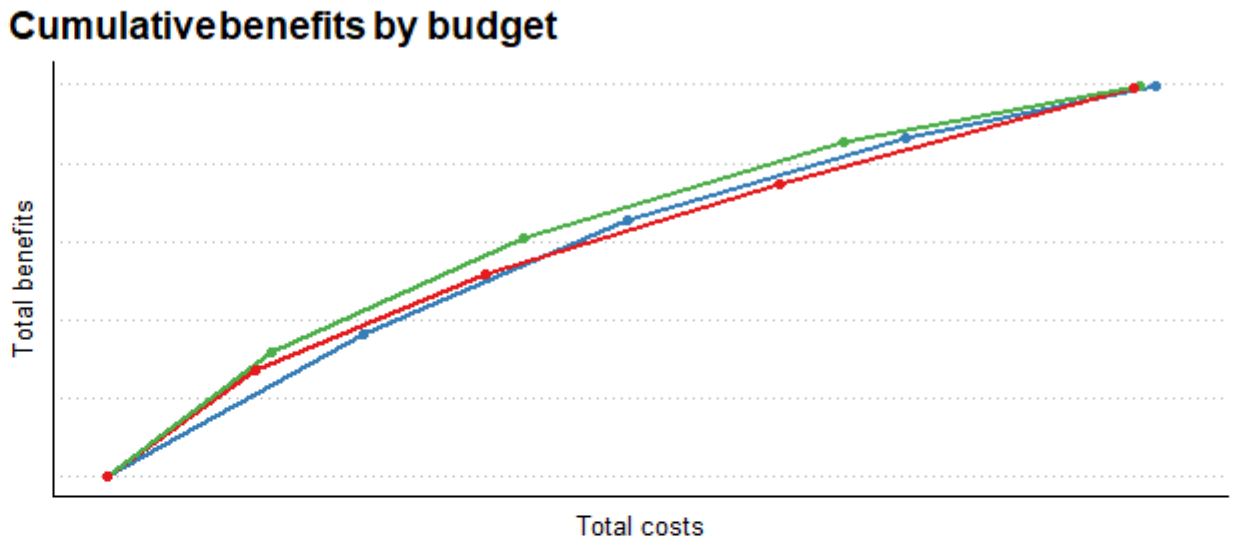
Efficiency (total benefits / total costs) by number of projects

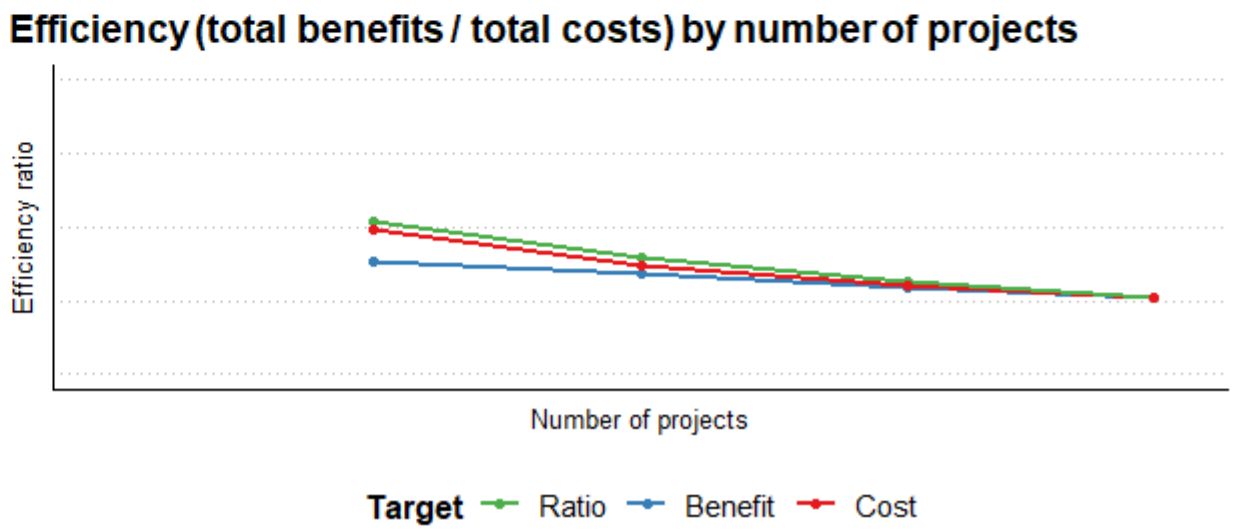


Conceptual Model: Evaluating Targeting Tools

Equal variation, no correlation



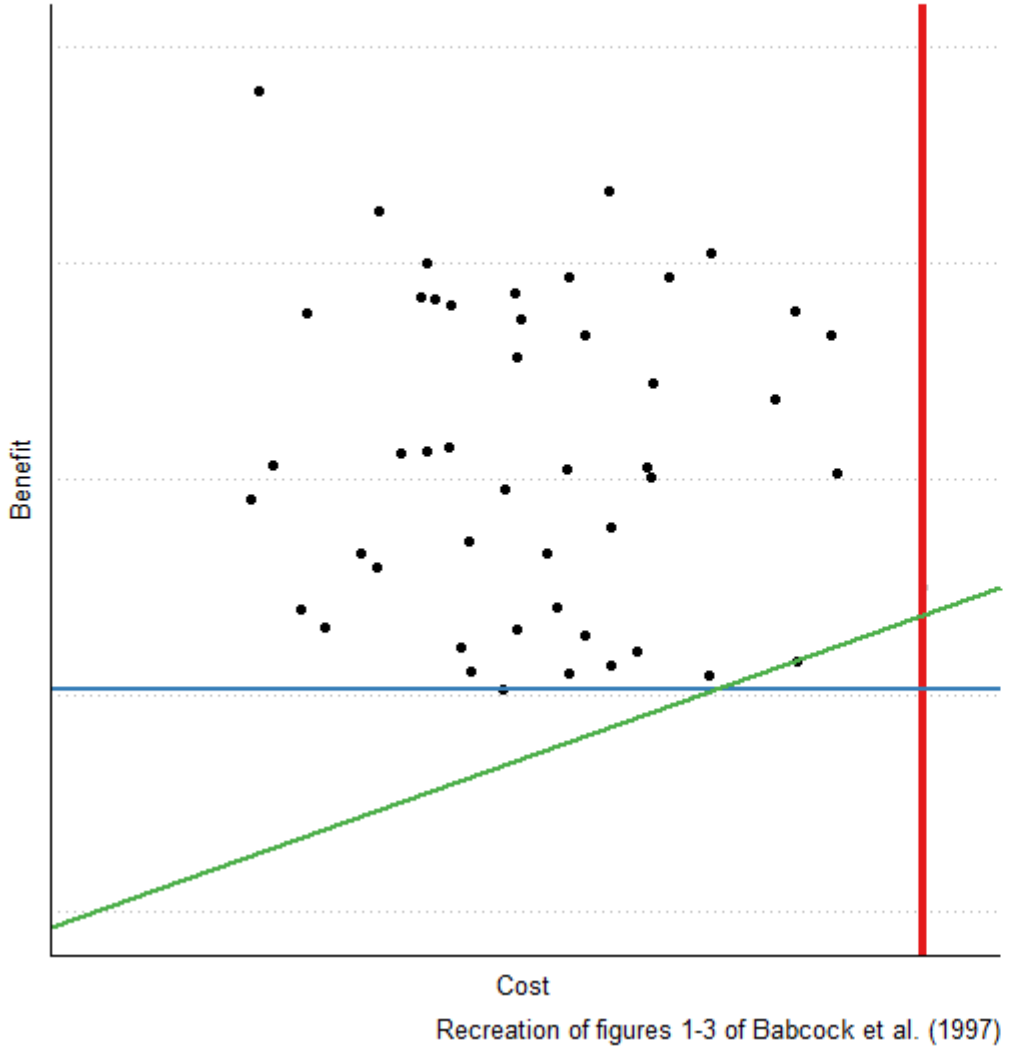




Conceptual Model: Evaluating Targeting Tools

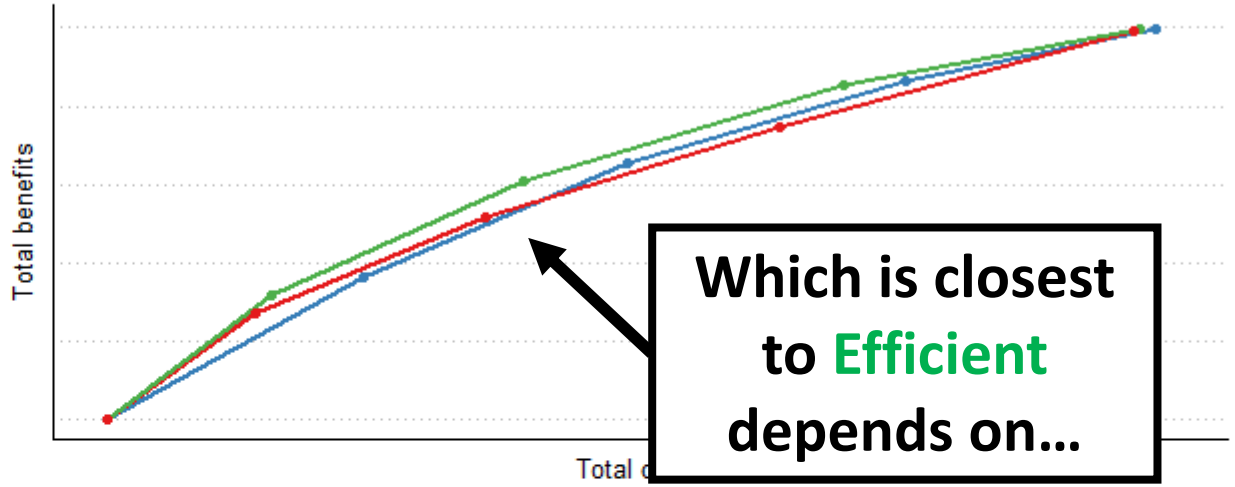
Equal variation, no correlation

Potential projects in cost-benefit space: Cost (C) targeting

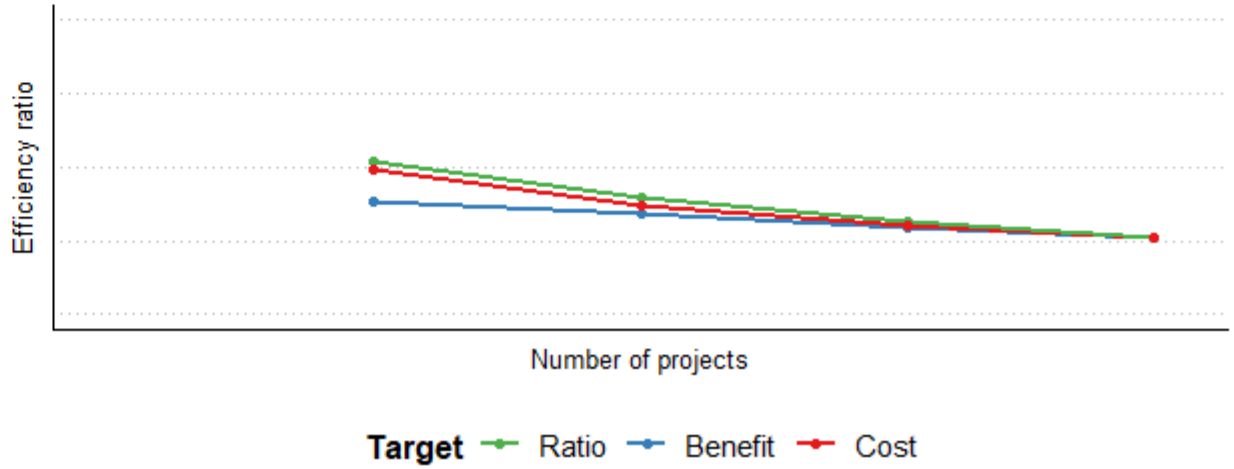


Recreation of figures 1-3 of Babcock et al. (1997)

Cumulative benefits by budget



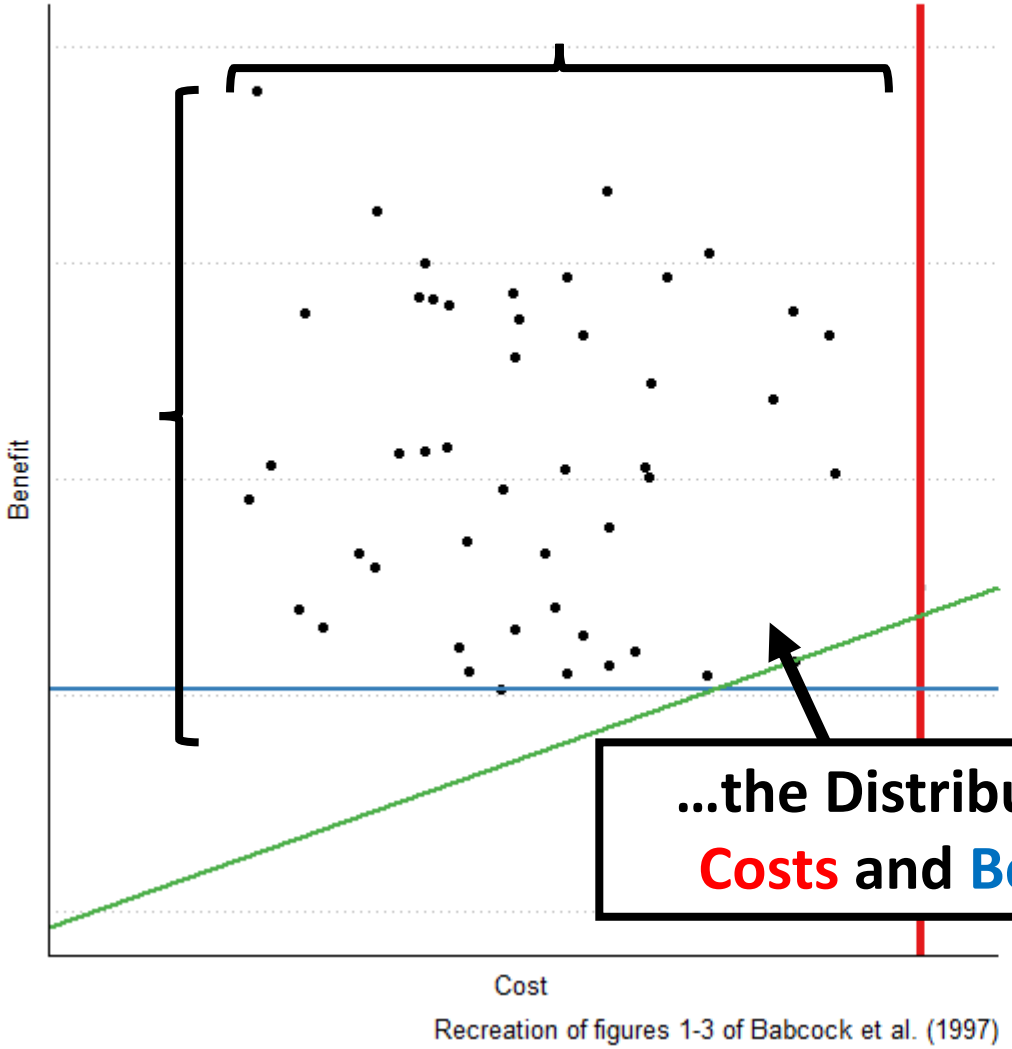
Efficiency (total benefits / total costs) by number of projects



Conceptual Model: Evaluating Targeting Tools

Equal variation, no correlation

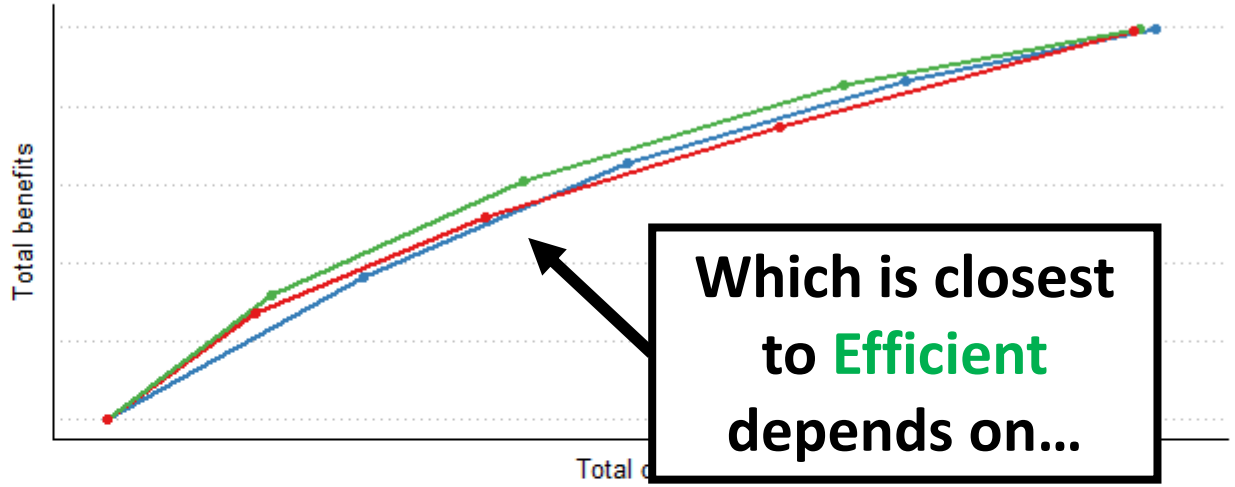
Potential projects in cost-benefit space: Cost (C) targeting



Recreation of figures 1-3 of Babcock et al. (1997)

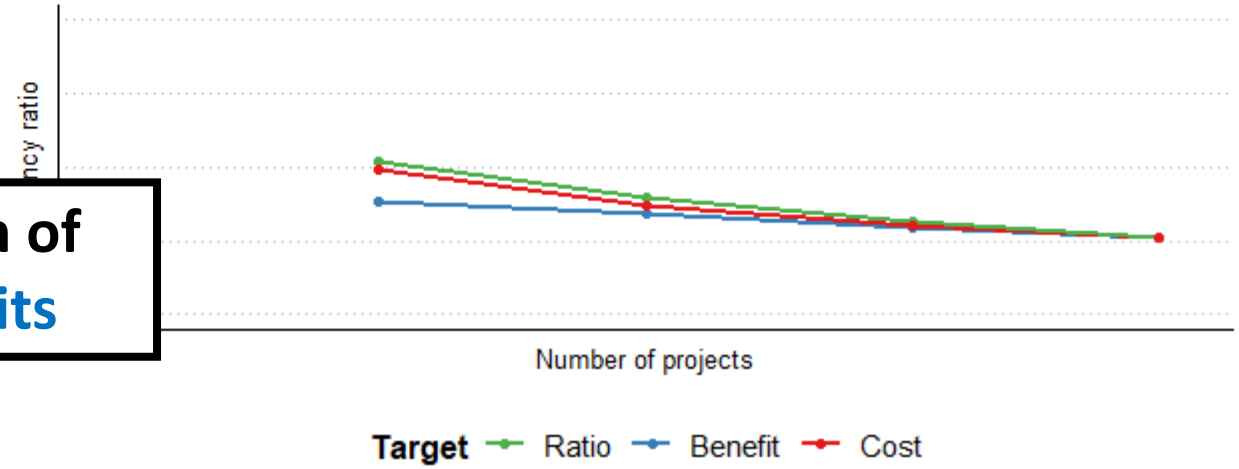
…the Distribution of Costs and Benefits

Cumulative benefits by budget



Which is closest to Efficient depends on…

Efficiency (total benefits / total costs) by number of projects



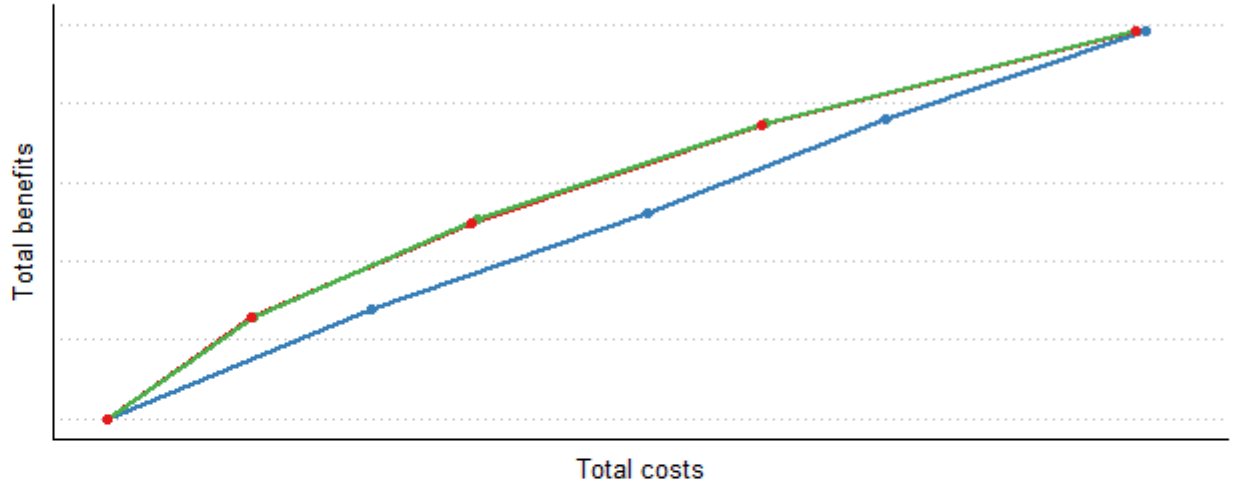
Conceptual Model: Evaluating Targeting Tools

Low benefits variation, no correlation

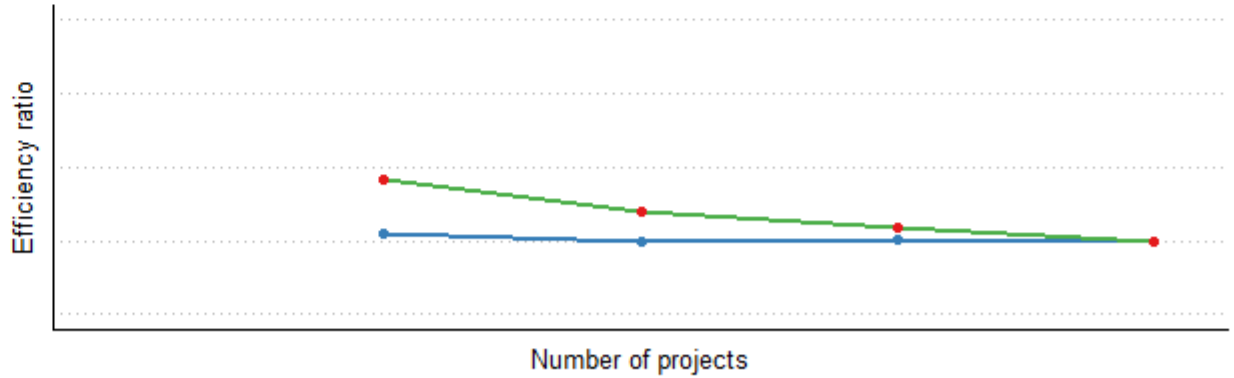
Potential projects in cost-benefit space: Cost (C) targeting

Recreation of figures 1-3 of Babcock et al. (1997)

Cumulative benefits by budget

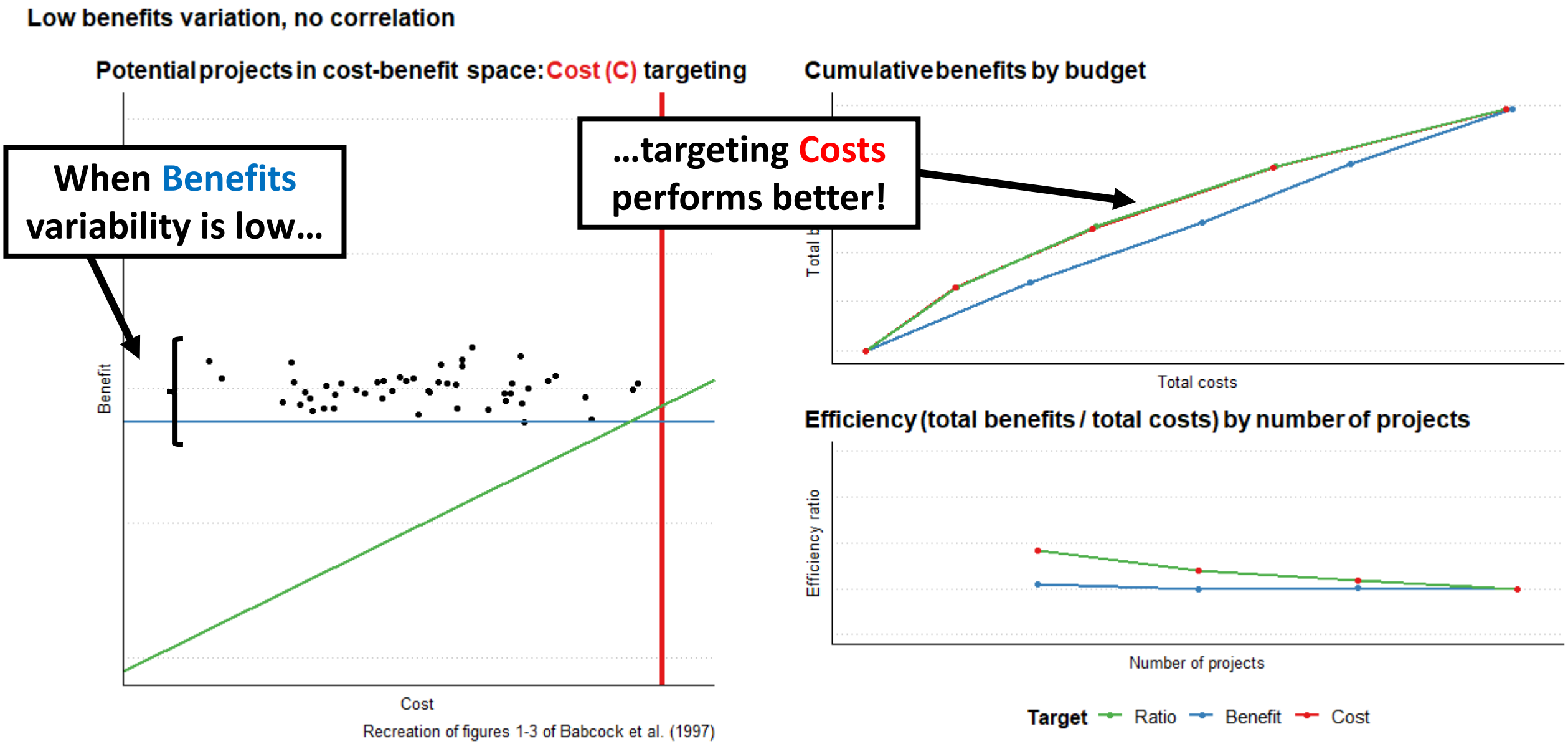


Efficiency (total benefits / total costs) by number of projects

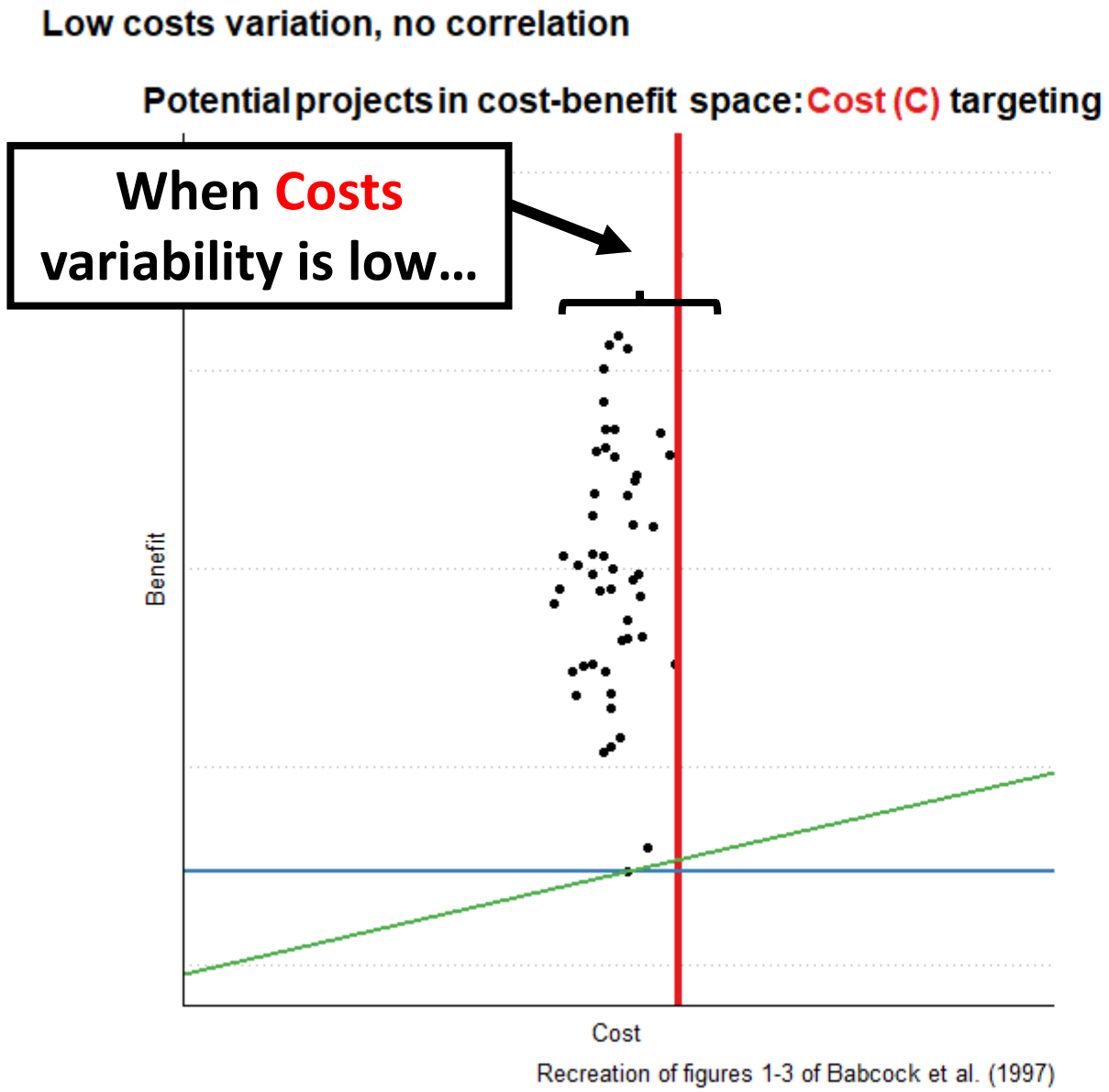


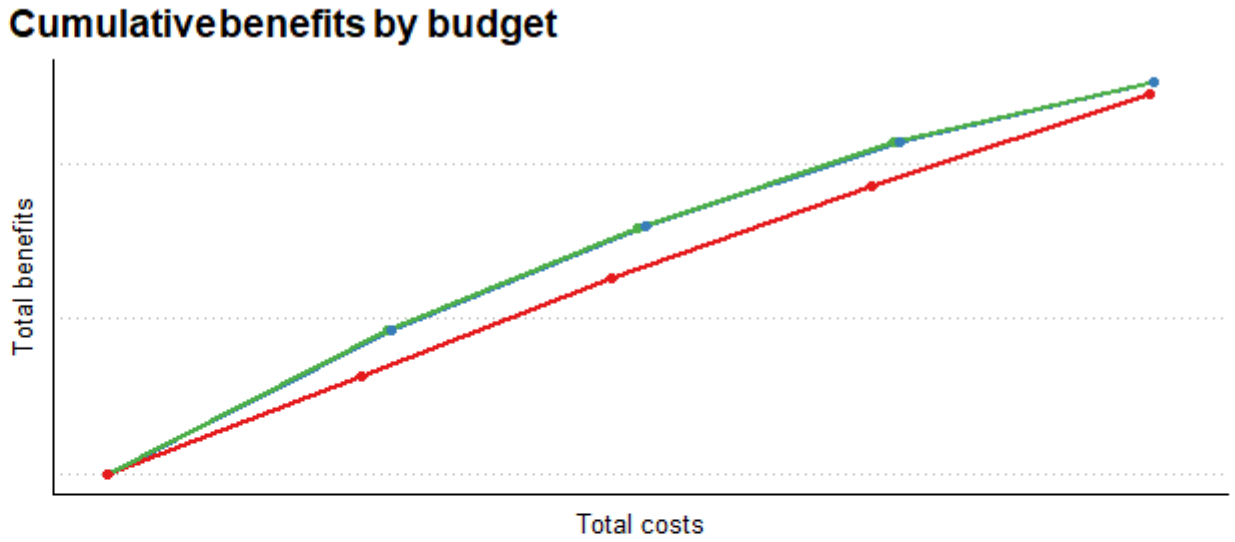
Target Ratio Benefit Cost

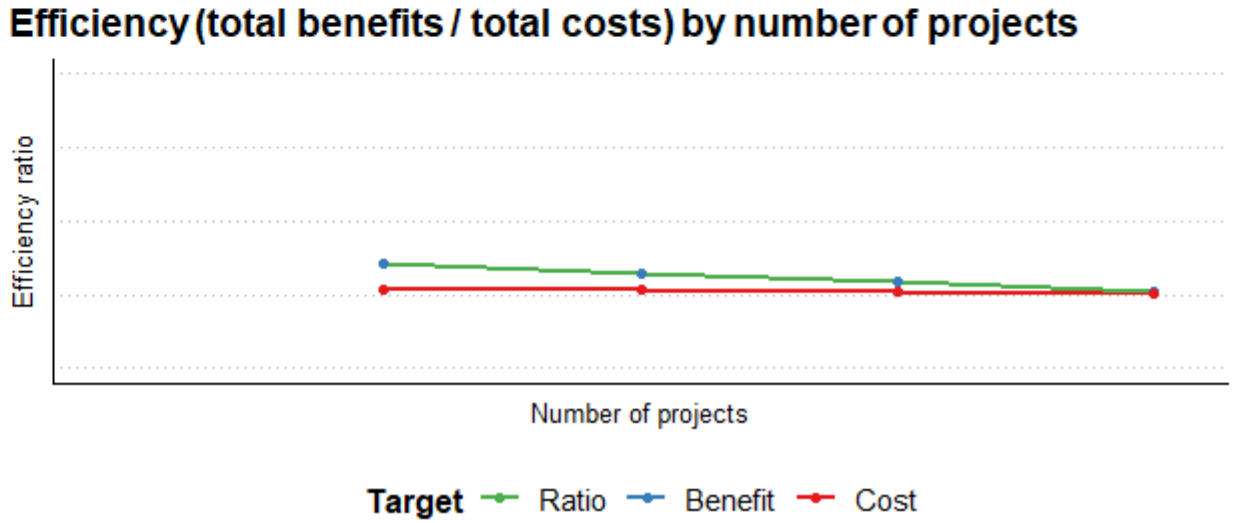
Conceptual Model: Evaluating Targeting Tools



Conceptual Model: Evaluating Targeting Tools







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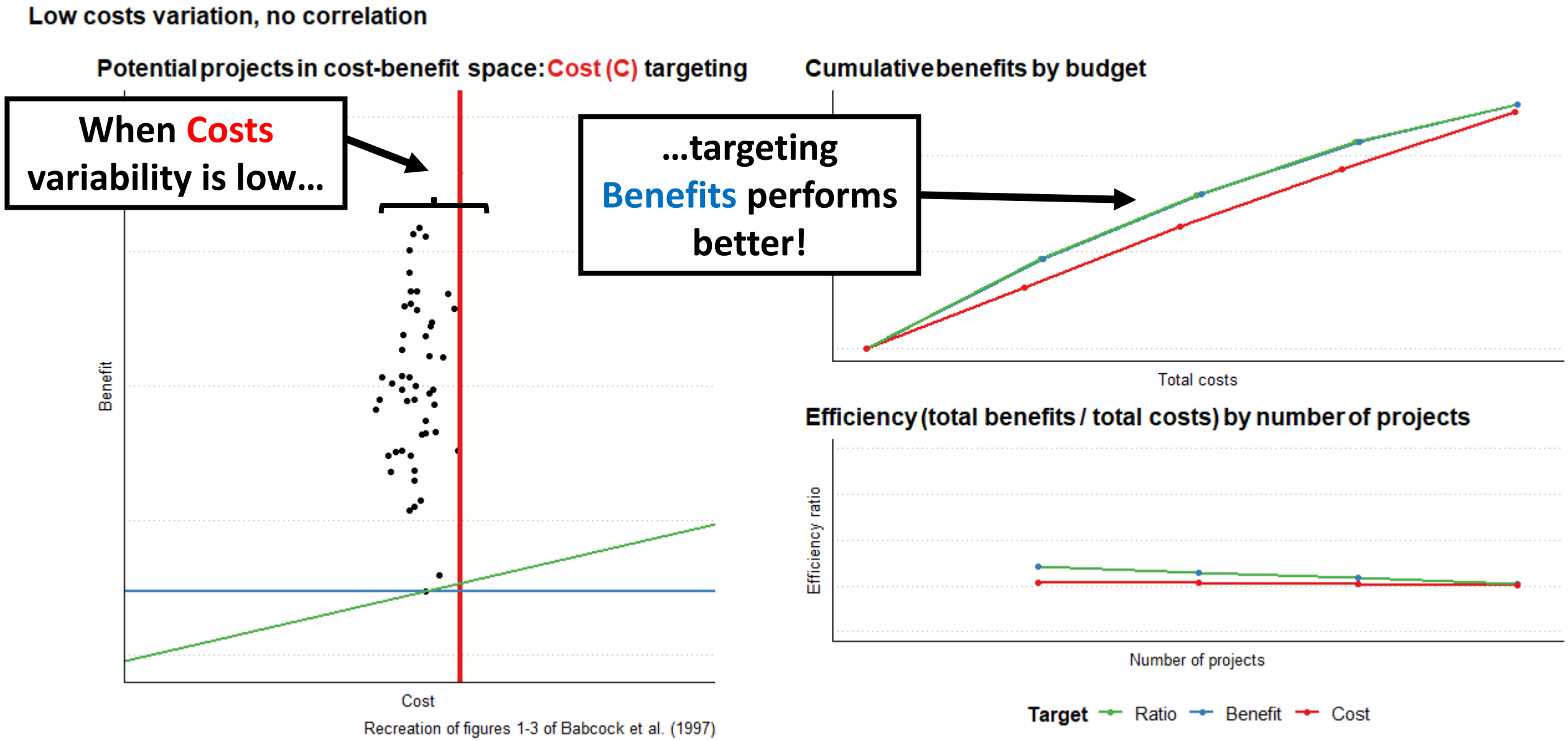
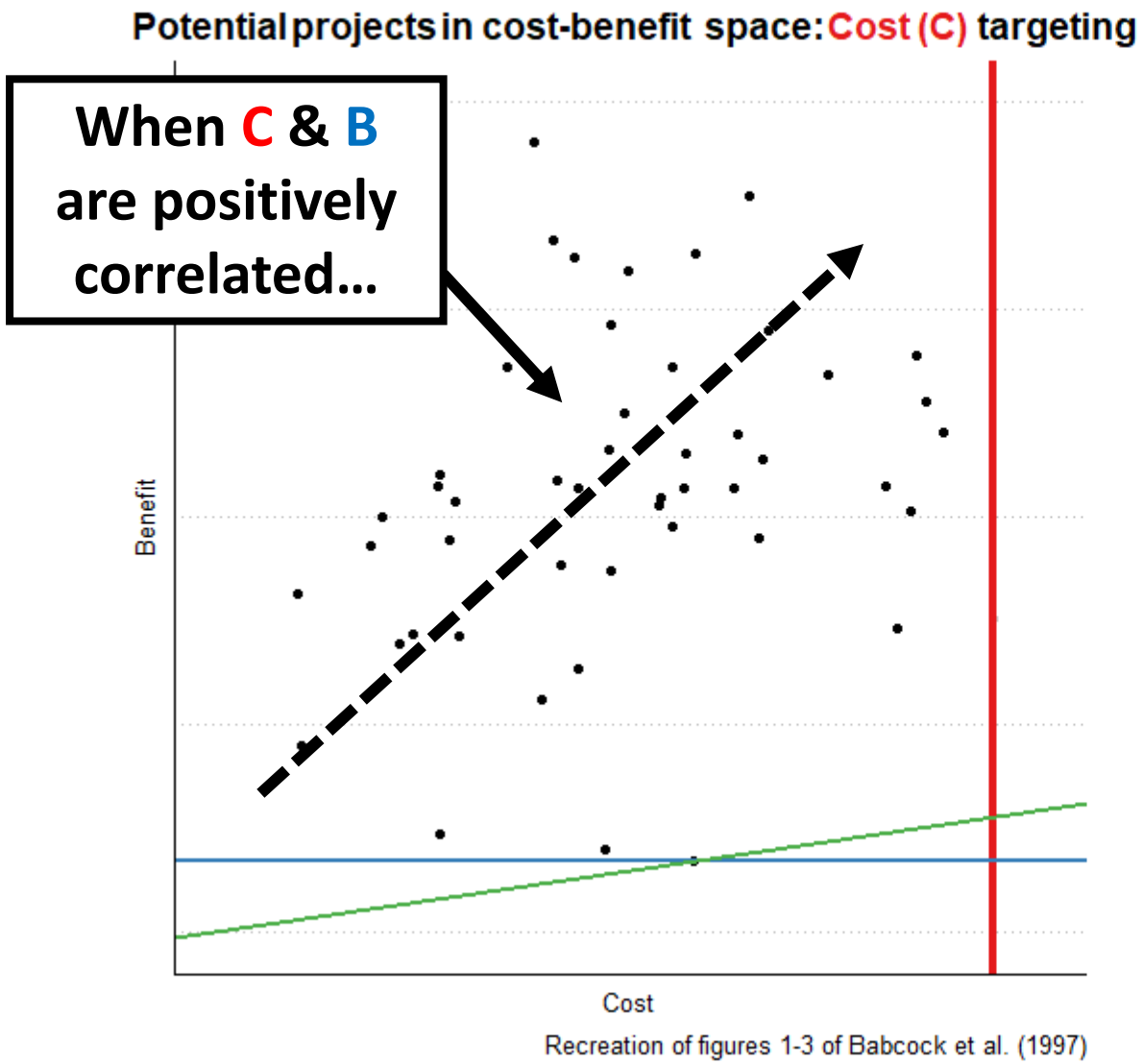
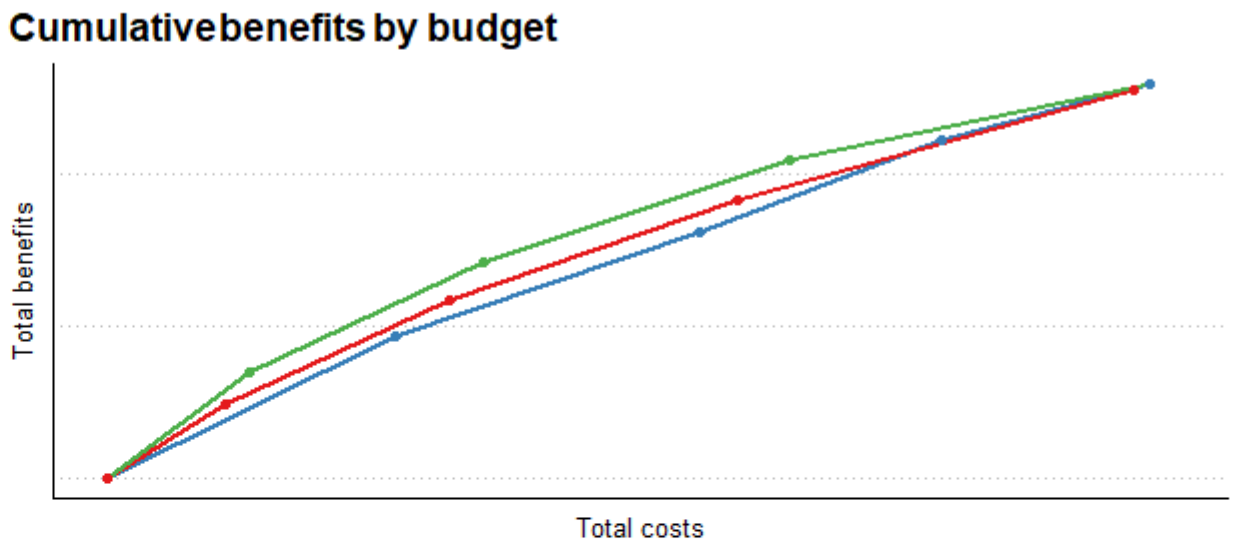
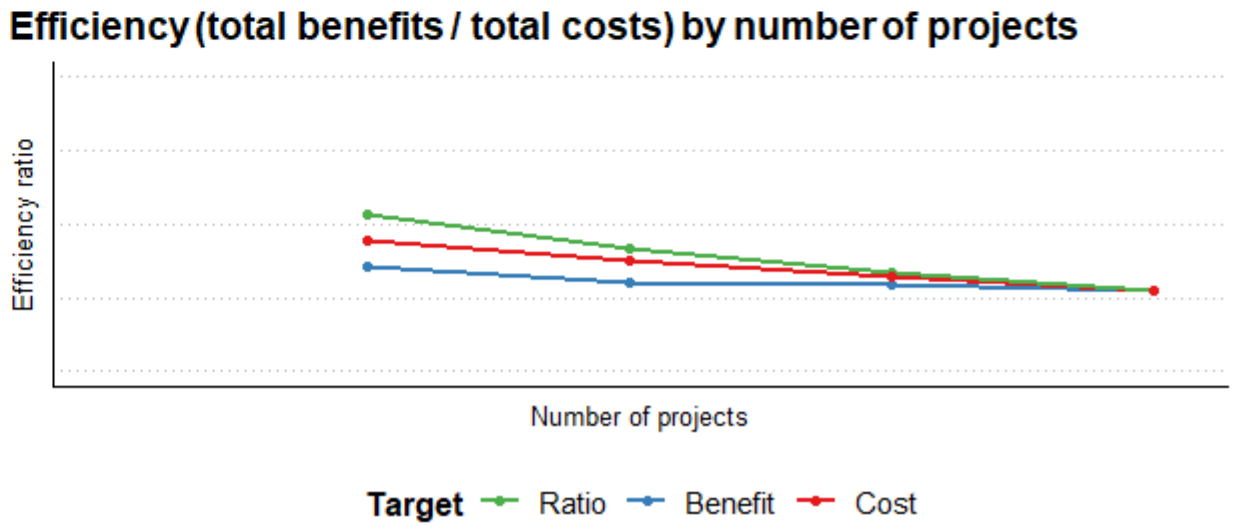


Conceptual Model: Evaluating Targeting Tools

Equal variation, positive correlation







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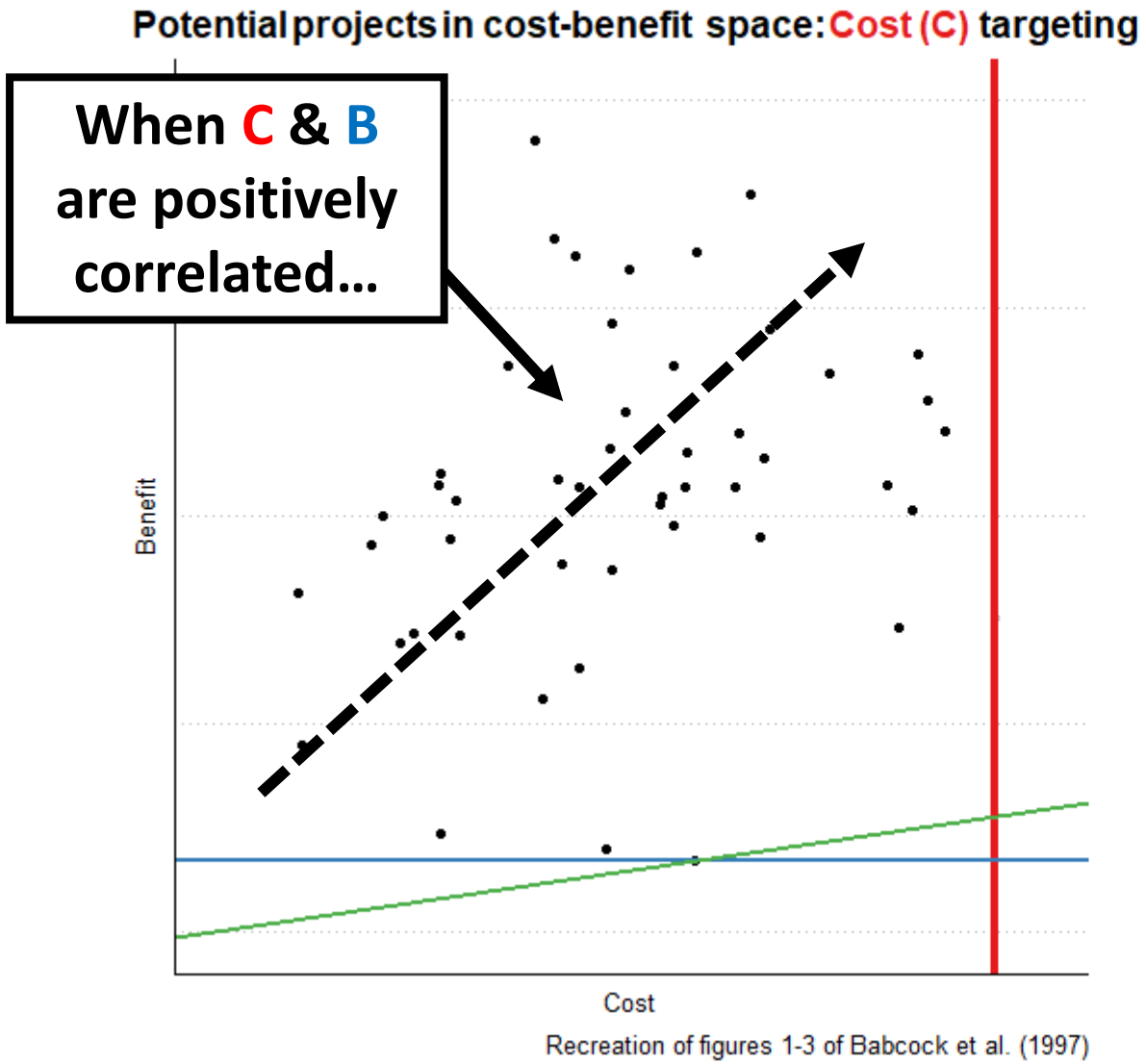
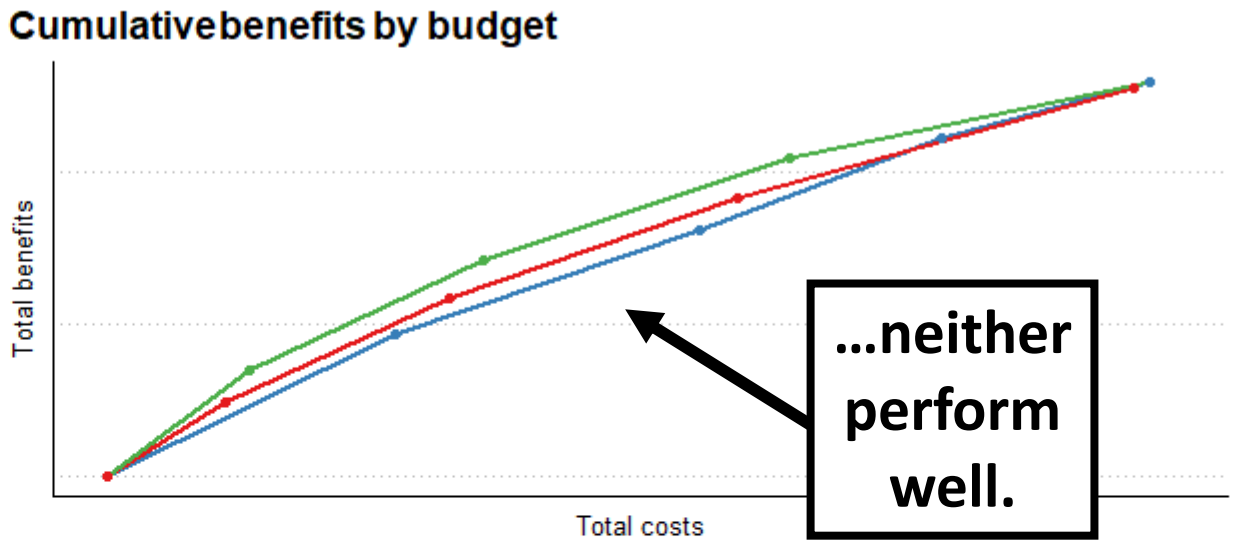
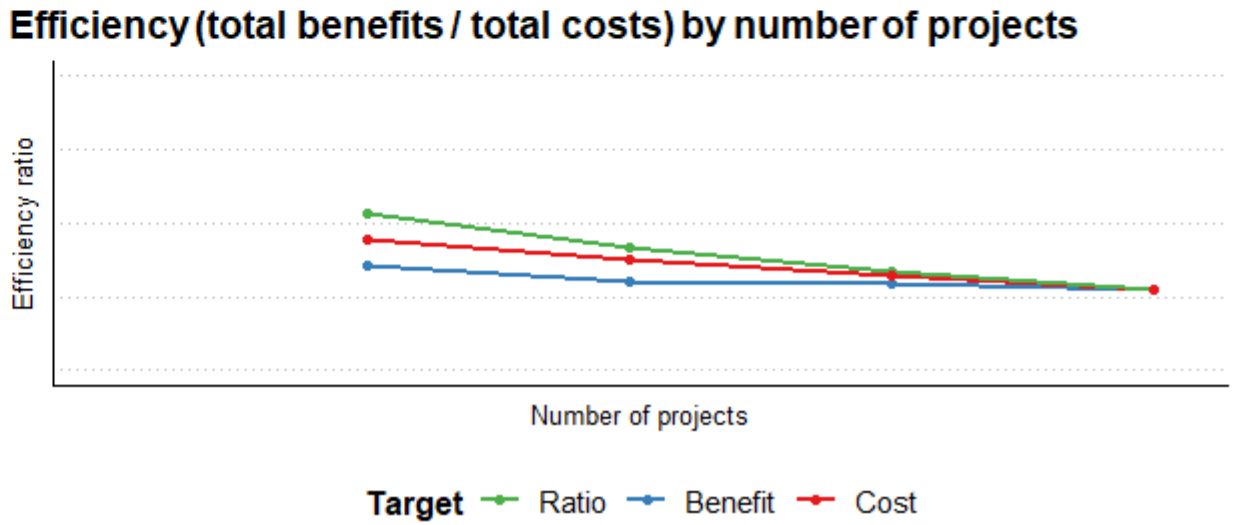
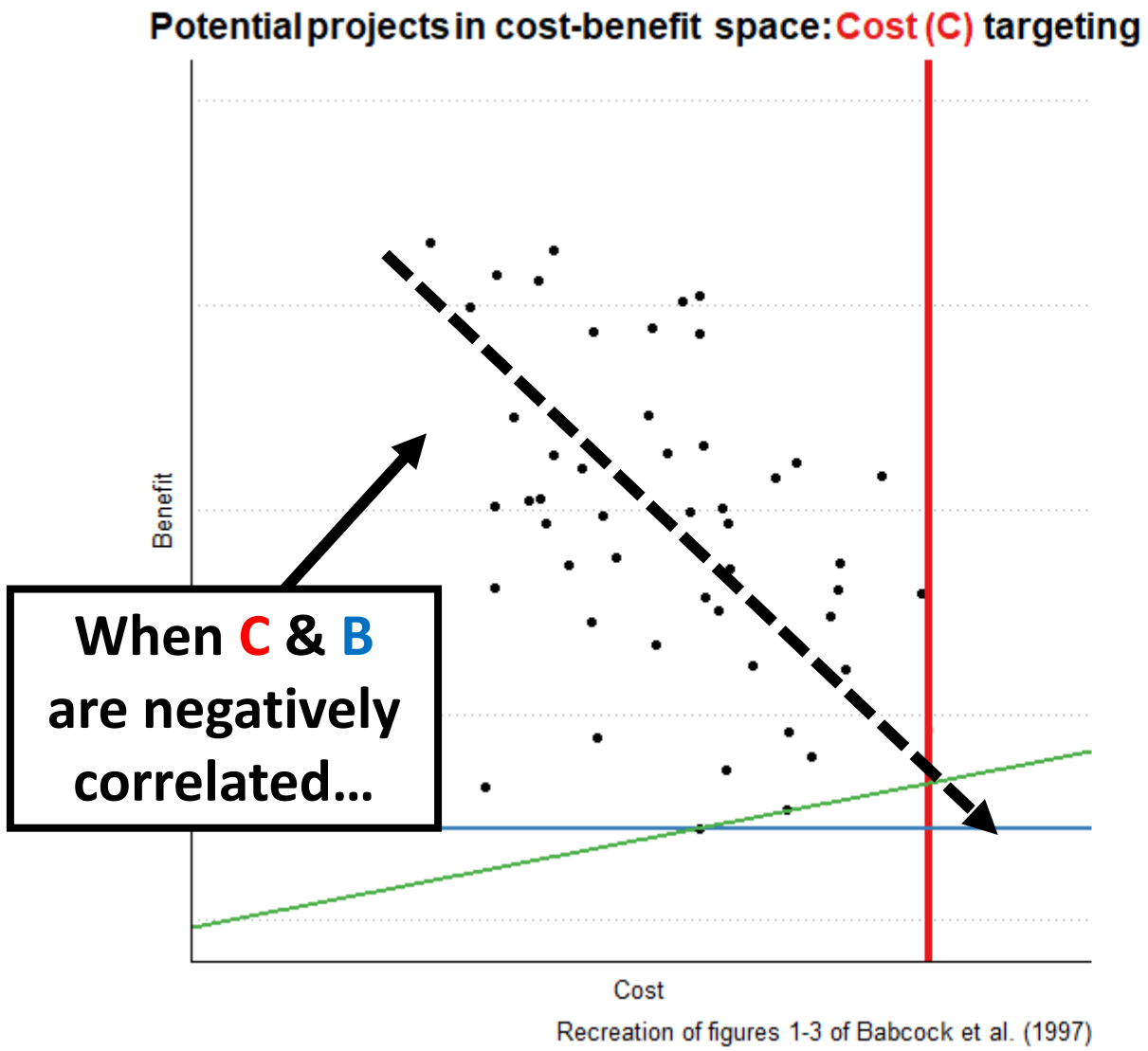


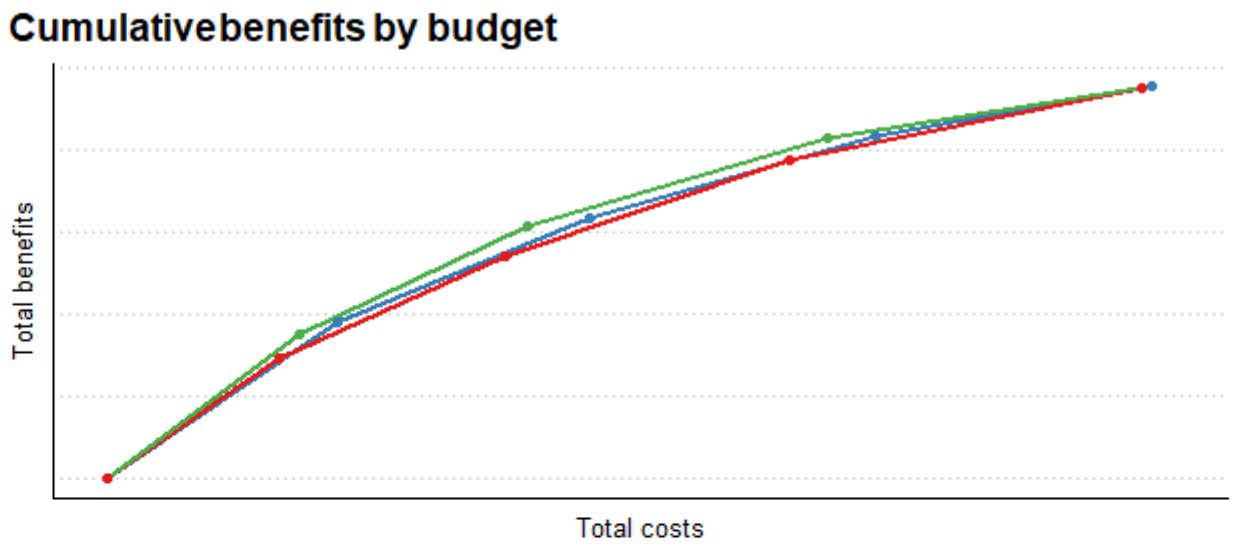


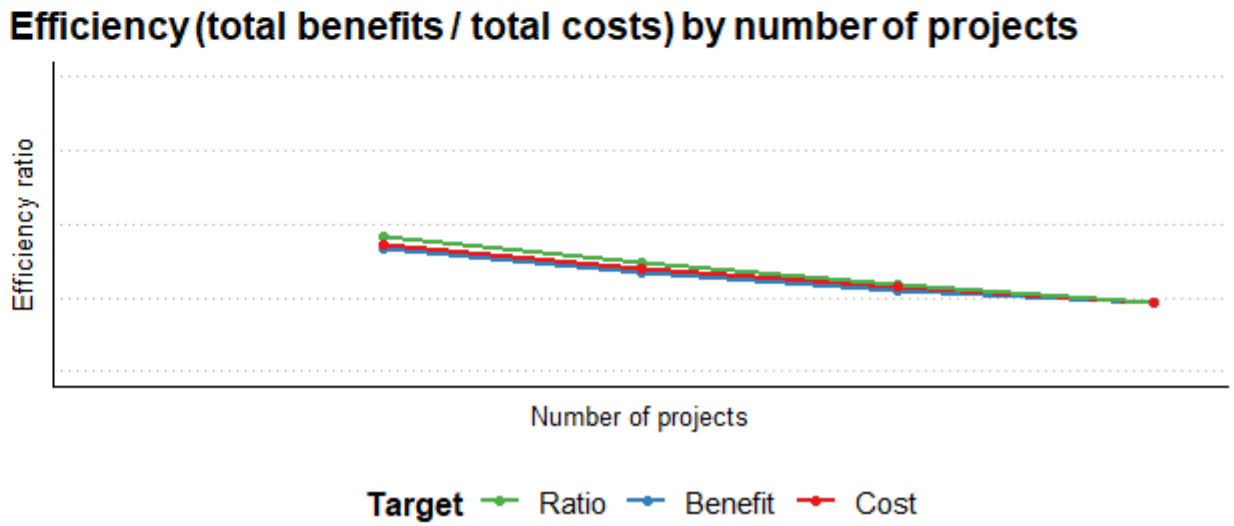


Conceptual Model: Evaluating Targeting Tools

Equal variation, negative correlation







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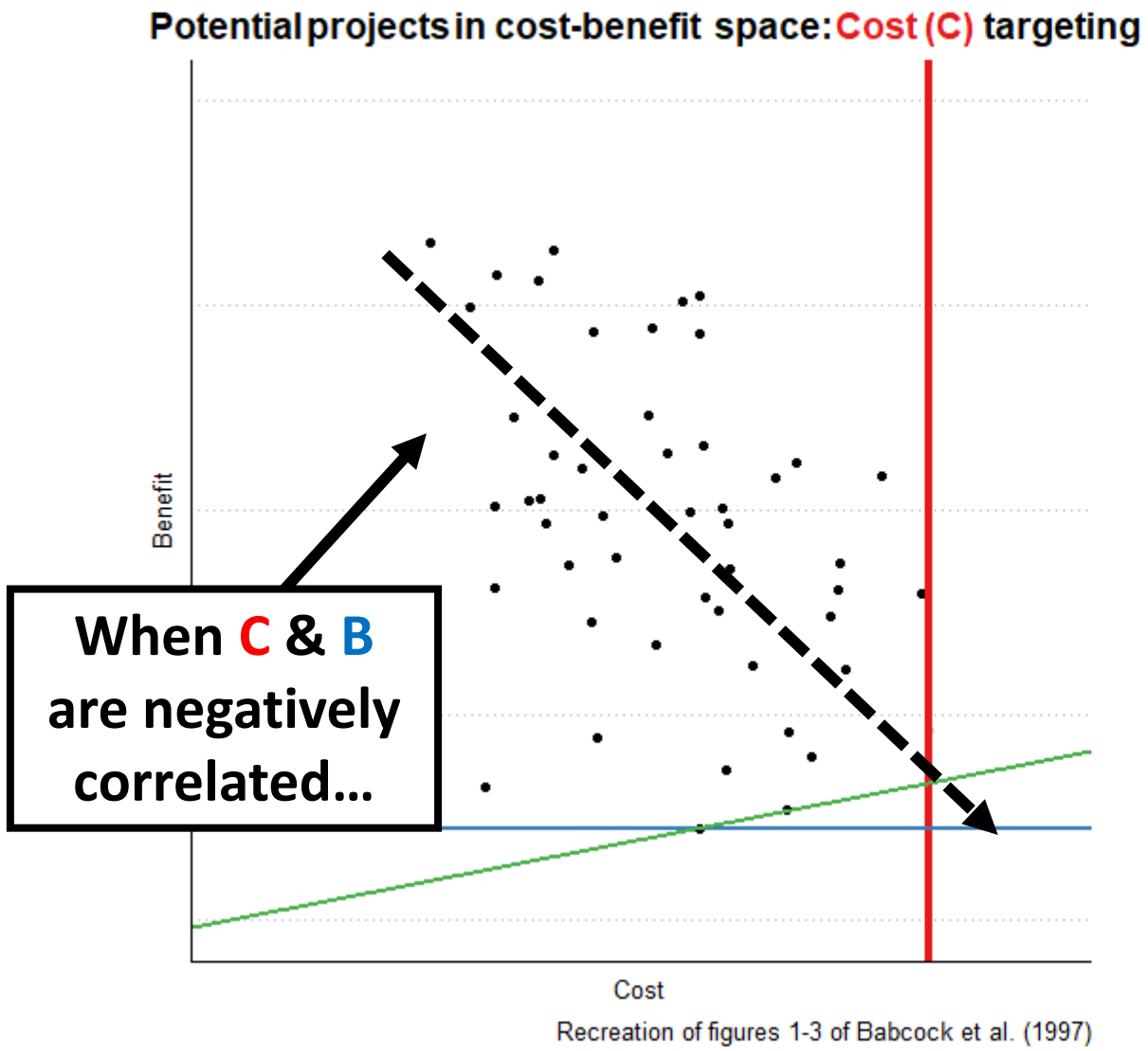

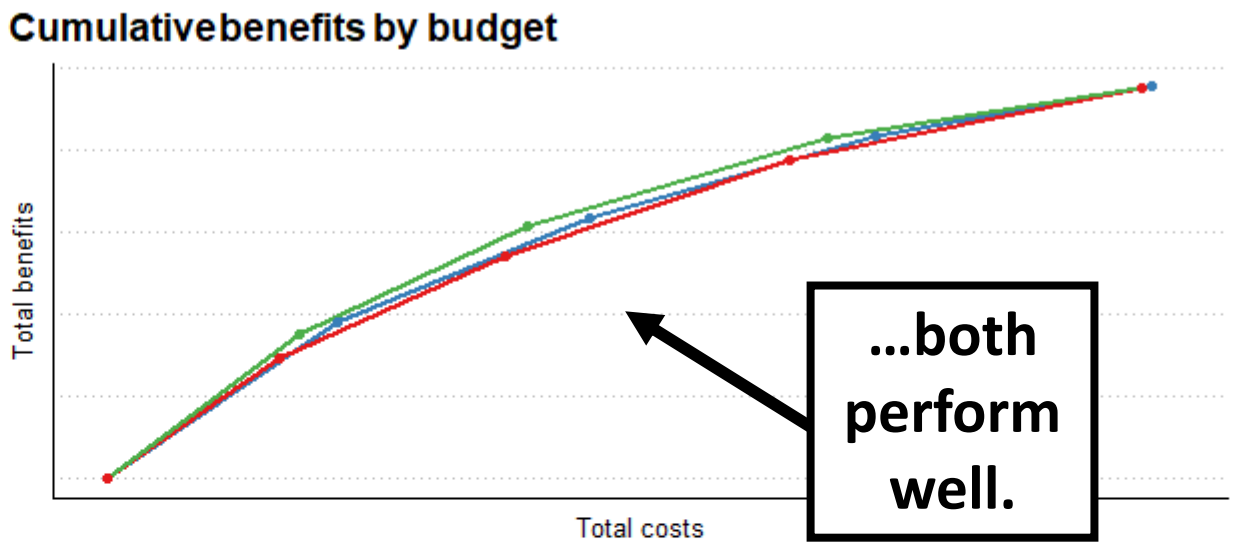

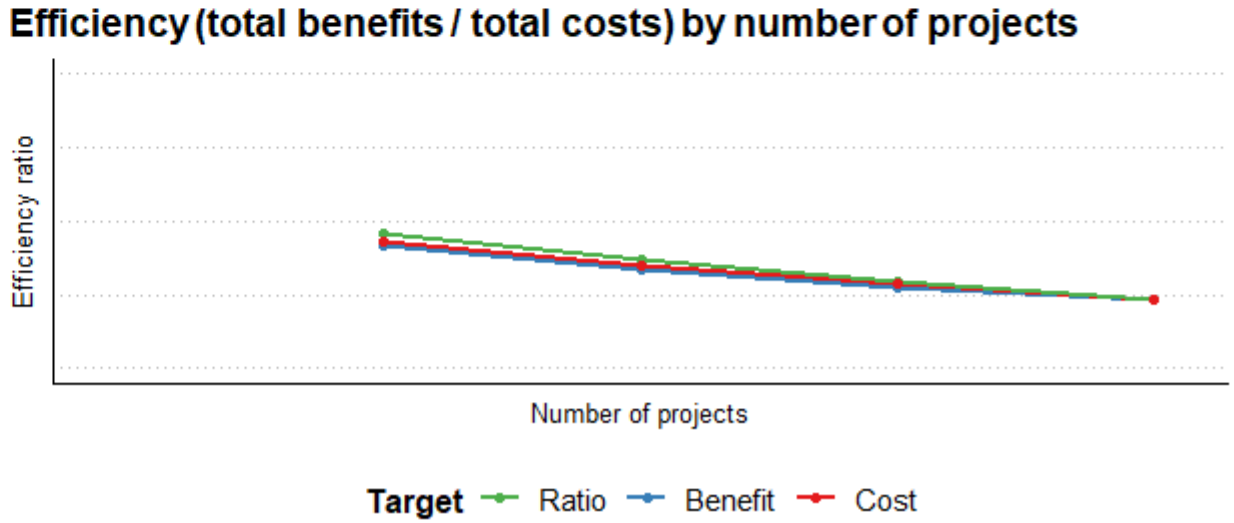

Conceptual Model: Evaluating Targeting Tools

1. Define set of potential actions
2. Define cost and benefit measures for each
3. Plot in cost and benefit space
4. Evaluate targeting criteria
   - Efficiency-targeting
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   - Cost-targeting

Relative efficiency depends on…

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But how to define costs and benefits in practice?
What goes on the axes?

Practical Considerations: Defining Benefits

Gold-Standard Economic Objectives

- Often requires application of non-market valuation
- Useful because it is a single consistent unit capturing value across communities, sectors, time
- Studies are expensive or data for benefit transfer not available

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- *Court Rulings:* Federal injunction requiring restored access to set amount of habitat by a set date

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Other Non-Monetary objectives

- *Population objectives:* reach stable long-term abundance
- *Habitat objectives:* area set-aside, acres revegetated, culverts removed
- *Diversity objectives:* reach level of genetic diversity within (meta-)population, desirable community structure
- *Social objectives:* "fair" or equitable distribution of funds, projects, or benefits across constituencies

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Multiple Objectives

- Weighting or establishing minimum constraints
- Examining trade-offs between multiple objectives is often useful in reaching consensus policy

Practical Considerations: Defining Costs

Types of Economic Costs

- Upfront costs: materials, labor, design, equipment, land acquisition
- Continuous costs: monitoring, management, maintenance
- Opportunity cost: value of next best use?
- Transaction costs: contracting, negotiating, searching

Based loosely on Armsworth (2014), Naidoo et al. (2006)

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For restoration:

Land value not an obvious choice

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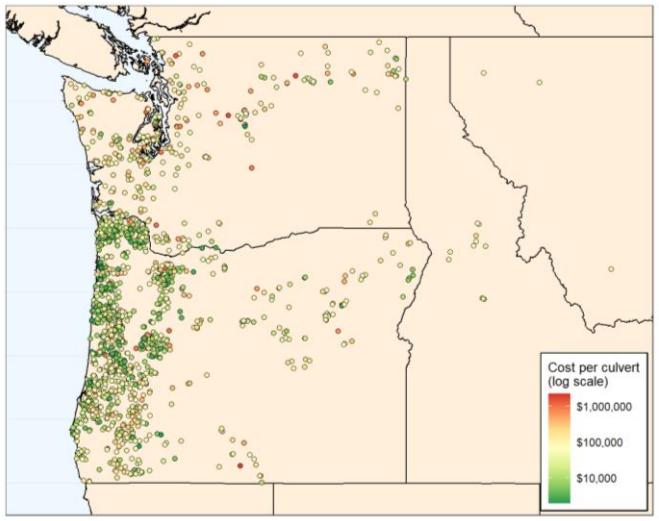
What costs to consider and metrics to use are highly context dependent

- For set aside: Land value
- For gear restrictions: Opportunity cost of catch
- For restoration:
  - Land value not an obvious choice
  - Engineering estimates: survey every possible project ← expensive
  - Management heuristic: cost-out a representative project ← distorts potential variability
  - **Statistical model:** past project records and estimate conditional means with regressions

Based loosely on Armsworth (2014), Naidoo et al. (2006)

Practical Considerations: Modeling Culvert Costs



1. DATA – Worksite Cost Records

Project records for over 1,200 culvert worksites with cost records

→ Use GIS tools to link worksites with landscape features, socioeconomic data

→ E.g., road size, stream slope, stream width, distance to population center

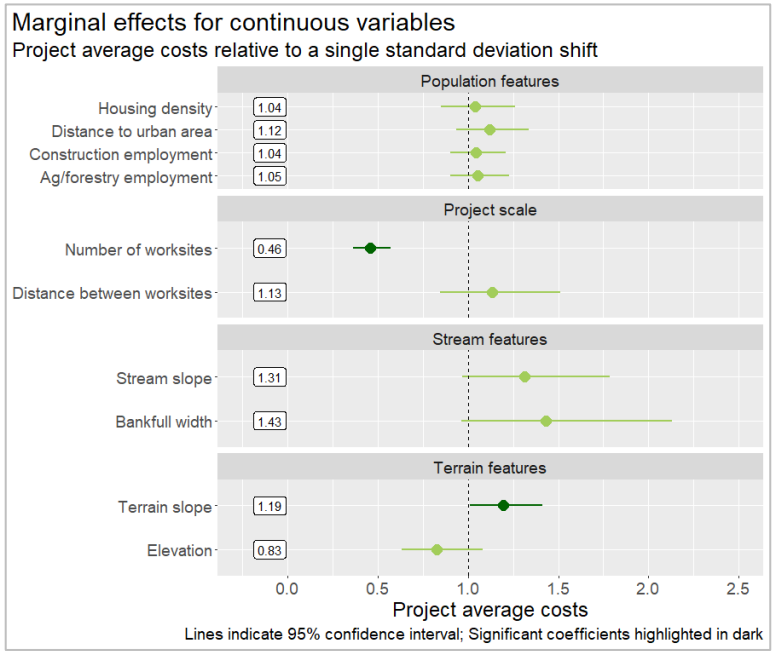
2. MODEL – Econometrics

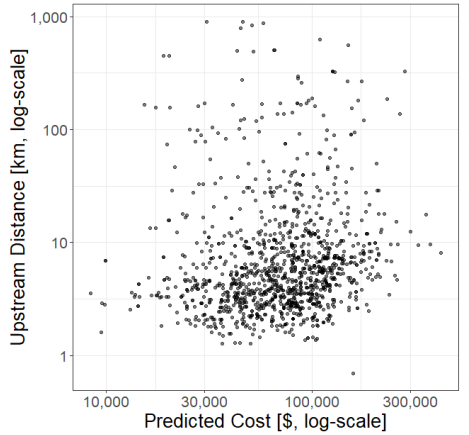
Model worksite costs as a function of observable features

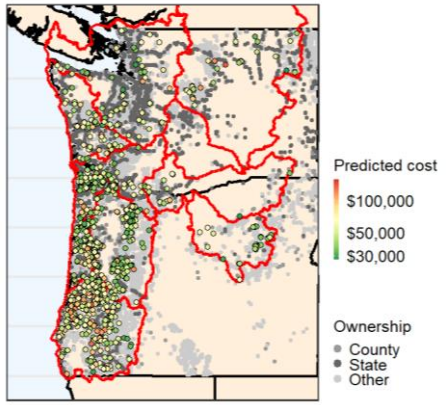
→ OLS, spatial weights, boosted regression trees

→ Inference on cost drivers

→ Predictions for planning-level costs for future projects







3. APPLICATION – Distribution of Costs

Use model predictions to assess variation in costs

→ Assess distribution of costs for…
1) Observed completed projects
2) Known barriers

→ Assess suitability of targeting heuristics (cost vs. benefit)

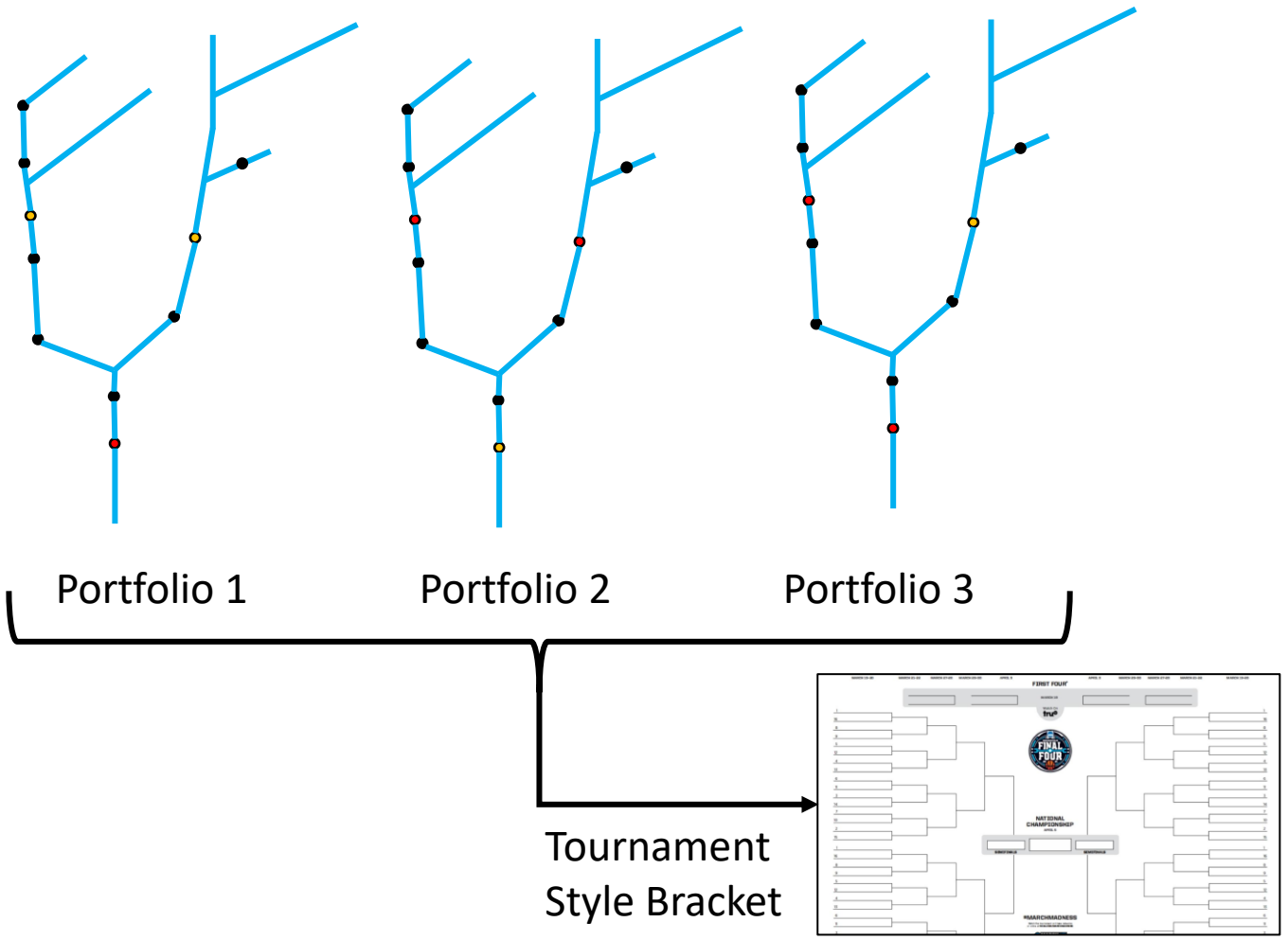
→ Compare across…
1) Watersheds
2) Species
3) Barrier ownership

Van Deynze et al. (In prep)

Prioritization in Practice: Other Targeting Tools

Optimization:

- Searches through space of combinations of potential actions for optimal
- Discards “dominated” portfolios to find “best” outcome under given budget
- Can account for interdependencies
- Can account for multiple objectives (with weights or constraints)



Prioritization in Practice: Other Targeting Tools

Scoring & Ranking:

- "Prioritization Index"
- Weighted sum of normalized metrics
  - 0pts for high cost (Over $500k)
  - 1pt for medium cost ($200-500k)
  - 3pts for low cost (Under $200k)
- Simplicity is attractive
- Can obscure important variation in costs and/or benefits

	Criteria	Scores
1.	Migratory habitat	
	• Long-distance migrants within Danube	4
	• Long-distance migrant habitat within Danube tributaries	2
	• Medium-distance migrants habitat	1
	• Short-distance migrants (head waters)	0
2.	First obstacle in river segment upstream of river mouth	
	• Yes – in Danube	2
	• Yes	1
	• No	0
3.	Distance from mouth (river segment)	
	• First river segment upstream of mouth	3
	• Second river segment upstream of mouth	2
	• Third river segment upstream of mouth	1
	• River segments upstream of third river segment	0
4.	Length of reconnected habitat (values in bracket are valid for Danube)	
	• >50 km (>100 km)	2
	• 20–50 km (40–100 km)	1
	• <20 km (<40 km)	0
5.	Protected site (Natura 2000)	
	• Yes	1
	• No	0

Table Source: Roni & Beechie (2013)

Closing:

- Introduced a simple, flexible **model** for considering alternative conservation plans
- Efficiency of targeting rules depends on the specific context
- Covered challenges in defining costs and benefits
- In the context of **fish passage**, but ideas can be applied in other systems as well

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Special Thanks to…

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