White-hat CBA hacking – 3 new hacks that skew benefit–cost ratios

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Abstract

'p-hacking' – the misuse of data analysis to find patterns in data that can be presented as statistically significant when in fact there is no real underlying effect – has received much recent attention in economics.

Cost–benefit analysis (CBA) is also susceptible to various 'hacks', intentional or otherwise. In the spirit of 'white hat' cyber-hackers, we describe three CBA hacks.

(1) Over-inflating co-benefits, by using the avoided social cost of abatement instead of the lowest available cost of abatement.
(2) Conflating marginal vs. average costs and benefits, particularly for projects large enough to shift prices, or in the presence of alternative or contemporaneous projects that affect prices.
(3) Multiple counting of completion benefits in staged projects.

It is important that readers and recipients of CBAs understand and can identify such hacks, so as not to be misled by apparently good (or bad) headline benefit–cost ratios.

Introduction

Social cost–benefit analysis (CBA) is a technique for assessing the economic efficiency of proposed public policies through the systematic prediction of social costs and social benefits. It compares the costs of a proposal to its benefits, where costs and benefits are valued in monetary terms. It is generally considered to outperform alternatives such as multi-criteria analysis, for reasons including that CBA is more

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objective, more transparent, and less susceptible to manipulation to return answers favoured by analysts and project proponents (Ergas 2009).

Economic agencies in many countries recommend CBA to identify and measure the impacts of different public policy alternatives (e.g., Office of Impact Analysis 2023; The Treasury 2015). In New Zealand, for example, CBAs are required as part of regulatory impact assessments for legislative changes, business cases, budget funding proposals, and as specified by governing legislation. The New Zealand Treasury has developed CBAx, a tool to assist analysts to perform evaluations of the fiscal and wider societal values of policy options (The Treasury 2022; Jensen & Thompson 2020). CBAx includes a comprehensive standardised list of estimated costs and benefits for over 250 activities and impacts. The CBAx guidance encourages analysts to plug these into their analyses. The production and availability of such lists of "plug-in values" reduces the costs of preparing CBAs (Dobes,2008).

Individual CBAs are only as reliable as the methodology adopted, the quality of available data, and the skills and objectivity of the analysts performing and reviewing them. The conventions surrounding CBAs improve their utility for informing public policy decisions. These conventions include that a CBA is explicit about the options it considers and methods it adopts, and that it specifies in detail the parameters used, assumptions made, and uncertainties considered. Transparency allows others to question the analysis, and to investigate the consequences of choosing different methodologies or changing parameter values and assumptions. Such questioning supports further refinement of both individual CBAs, and CBA methodology more generally.

This paper examines three ways in which standardised CBA methodology appears to be lacking. These 'hacks', as we term them, can distort the benefit-cost ratios of projects, potentially influencing decisions as to whether they proceed or not. We believe that a wider understanding among analysts of hacks is essential. Such understanding would reduce inadvertent use, and, by helping reveal their application, discourage deliberate abuse.

Hack 1: Over-inflating co-benefits

In its canonical form, policy analysis starts with a clearly stated problem, then explores possible solutions, narrowing these down into feasible options, including a "no action" (counterfactual) option. For each option, it identifies costs and benefits, then applies a methodology (e.g., CBA) to recommend a preferred option.

Real life can differ. Sometimes the initial problem statement is wrapped in a proposed solution (e.g., "we haven't got a bridge over that river" or "we need cycleways because obesity causes diabetes, and our hospitals are overcrowded"). A crucial first step, from a policy analysis perspective, is to separate the problem from possible solutions (options). Thus separated, in most cases it is possible to identify a main benefit, that being the social value arising from the resolution, mitigation or reduction of the problem.

Model 1: CBA with a main benefit

We denote the social value of resolving an identified problem (i.e., the main benefit) B_M, and the social cost of option *i* as C_I. Our model 1 is the following:

> *CBA is a search for the option,* LC*, with the lowest cost. If $C_{LC} < B_M$, option* LC *is recommended. The net present value of the social value created is $NPV_{LC} = B_M - C_{LC}$, which will be positive. The option's benefit–cost ratio is $BCR_{LC} = B_M/C_{LC}$, which will be greater than 1.*
>
> *Alternatively, if $C_{LC} \geq B_M$, the no-action counterfactual,* NA*, is recommended. No action (by definition) creates no social value ($NPV_{NA} = 0$), and BCR_{NA} is 1. But* NA *still outperforms the other options, all of which have BCRs ≤ 1.*

CBA is thus a price discovery mechanism. So long as $C_{LC} < B_M$, it will “discover” an alternative price for the problem. B_M, is, by definition, the price (social cost) of not resolving the problem The discovered alternative price C_{LC} is the lowest known social cost at which the problem can be resolved.

B_M and C_{LC} are prices with distinct purposes.[3] But it does raise the possibility of choosing the wrong price in specific situations. This becomes an issue when calculating the avoided social cost of co-benefits, as we describe below.

CBAs with co-benefits

A particular feature of much published CBA guidance is the imperative to scan widely in identifying potential costs and benefits. According to NSW Treasury (2023), for example, “CBA aims to capture all the benefits attributable to an initiative, including non-market benefits such as travel time savings, reduced carbon emissions and environmental amenity” (p. 24). Analysts are also encouraged to incorporate externalities arising from the policy or intervention (Treasury 2015, p. 15).

The effect has been CBAs that account for both the main objective and for a wide range of ancillary impacts. For clarity, following Graham et al. (2019), we define “ancillary impacts” as impacts other than the primary goal or objective of the policy or intervention (recognising that this primary goal or objective is not always precisely defined). Ancillary impacts include both positive (i.e., “co-benefit”) and negative (i.e., “countervailing risk”) effects (Graham & Wiener 1995).

Comprehensive assessment that includes ancillary impacts has become standard practice in CBAs. OMB (2012) directed that “[y]our analysis should look beyond the direct benefits and direct costs of your rulemaking and consider any important ancillary benefits and countervailing risks.” Similarly, Boardman et al. (2018) noted that in CBA “we try to consider *all of the costs and benefits to society as a whole … CBA is a policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society”* [emphasis in original].

Many authors draw attention to the possible omission of co-benefits, even advocating for their inclusion. Karlsson et al. (2020), for example, state that “the evidence for climate policy co-benefits, that is, the benefits in addition to avoided climate change costs, is commonly overlooked in policy-making” (p. 292). They found “climate policy co-benefits in well-researched fields such as air quality and health are large, often equalling or exceeding mitigation cost”.

Yet critics have questioned the estimated magnitude, policy propriety, and (in some jurisdictions) the legal basis of counting ancillary effects, arguing for example, that co-benefits are overstated (e.g., Cox 2012; Smith 2015), or that other countervailing risks and costs are neglected (e.g., Dudley & Mannix 2018). These criticisms are not specifically addressed in standard CBA guidance (e.g., Treasury 2015, 2022; NSW Treasury 2023; Office of Impact Assessment 2023).

In this paper we concentrate on choices about co-benefit monetisation, and the risk of over-valuing such co-benefits. To be clear, we believe that co-benefits should be included in CBAs (symmetrically with countervailing risk), but that conventional methodologies risk systematically over-inflating them. Systematic inflation could be expected to distort CBAs, hindering the identification of lowest-cost options, or even recommending actions with a net negative social value.

[3] Having two prices for the same thing is not uncommon in economics, a prominent example is cost and opportunity cost.

CBAs with "game-changing" co-benefits

Climate Change Commission (2021), listed "leverage co-benefits" as a "key principle" for a low-emissions strategy:

> "The actions Aotearoa [New Zealand] takes to meet emissions budgets and targets should consider the wider benefits, including benefits to health, broader wellbeing and the environment. Co-benefits can provide further reason to take particular actions where the initial emissions reductions may be modest or appear relatively costly." (p. 72)

Climate Change Commission (2021) applied this principle when developing and recommending a "package of policies", not all of which appear to be justified by their main benefits alone:[4]

> "Actions to reduce emissions may also have other benefits, such as for health or for biodiversity. These [co-benefits] can justify certain policies to reduce emissions, even if when judged by their ability to reduce emissions alone, they are not cost-effective." (p. 217)

In a similar vein, Rashidi et al. (2017) looked at low-carbon waste and transportation projects in Indonesia, Kenya and Sri Lanka, reporting that

> "climate benefits have little effect on projects' financial viability, and can be effectively ignored. By contrast, we find, the monetization of development co-benefits significantly improves financial viability." (p. 69)

A review of selected climate and energy studies by Ürge-Vorsatz et al. (2014) has

> "shown that the assessment of co-impacts is indeed extremely important and that their incorporation may substantially change the outcomes of cost-benefit analyses. In the reviewed cases, the co-impacts amounted to as much as 50–350% of the direct or total benefits. Therefore, if properly considered, they can indeed become game changing". (p. 576)

If the inclusion of co-benefits in CBAs is indeed "game changing", then it becomes crucial that the co-benefits necessary to justify specific policies are *correctly* valued. Otherwise, analyses are at risk of incorrectly ranking projects, recommending sub-optimal options, supporting projects with negative net social value, or failing to support projects with positive net social value.

Model 2: CBAs incorporating co-benefits

We add a co-benefit CB to our model.[5] CB_I are the co-benefits generated by option *i*. Our model 2 is:

CBA is a search for the option, HR, with the highest BCR: $BCR_{HR} = (B_M+CB_{HR})/C_{HR}$. If $BCR_{HR} > 1$ (or equivalently: $C_{HR} < B_M+CB_{HR}$), option HR is recommended. The net present value of the social value created is $NPV_{HR} = B_M+CB_{HR}-C_{HR}$, which will be positive.

Alternatively, if $BCR_{HR} \leq 1$ (or equivalently: $C_{HR} \geq B_M+CB_{HR}$, the no-action counterfactual, NA, is recommended.

[4] We have not investigated the specific policies recommended in Climate Change Commission (2021). Rather, we use quotes from their report as an example of current policy development practice.

[5] We restrict the model to a single co-benefit for simplicity of exposition. Adding multiple types would not change the analysis and conclusions of this paper. Further, we assume that CB_I is a net benefit, that is, it has been reduced by any additional costs involved in realising the co-benefit if option *i* is implemented.

Clearly, when CB_I is large relative to B_M, then the option recommended by model 2 may differ from that of model 1.

We characterised model 1 as a price discovery mechanism, which finds C_{LC}, an alternative price for B_M. Model 2 also discovers an alternative price for B_M, that being C_{HR}-CB_{HR}. Model 2 does not, however, discover alternative prices for co-benefits. CB_I are inputs, not outputs, of model 2.

An alternative price for co-benefits

Suppose for a moment that our policy aim was the co-benefit itself. Applying standard CBA, as per model 1, would discover an alternative price to achieve that co-benefit: CB_{LC}.

We argue here that the discovered price CB_{LC} should be used for the co-benefit in model 2, not the social value of that co-benefit B_{CB}. More specifically, the price that should be used is the smaller CB_{LC} and B_{CB}. This accounts for the fact that price discovery may not find an economically viable (i.e., net socially positive) option to directly target the co-benefit. We denote this revision as “model 3”.

Table 1 is an (admittedly constructed) illustration of how this might matter. In case #1 we apply model 1 to our main benefit (M) and recommend no action. Case #2 applies model 2, incorporating a co-benefit (CB) valued at the social value created (2 units), recommending a go-ahead. Case #3 applies model 1 to our co-benefit, discovering an alternative lower price CB_{LC} of 0.8 units. Case #4 applies model 3 to our original main benefit, valuing the co-benefit at the discovered price CB_{LC}.

Table 1. Standard CBA recommendations can diverge from the social optimum, illustrative example

	Case #1 M alone	Case #2 M with CB	Case #3 CB alone	Case #4 M with CB_{LC}
Model applied	Model 1	Model 2	Model 1	Model 3
Main benefit B_M	1.0	1.0	2.0	1.0
Co-benefit (social value created)	-	2.0	-	-
Co-benefit (lowest cost of achievement)	-	-	-	0.8
Total benefits	1.0	3.0	2.0	1.8
Cost C	2.0	2.0	0.8	2.0
BCR	0.5	1.5	2.5	0.9
NPV	-1.0	1.0	1.2	-0.2
Model recommendation	Stop	Go	Go	Stop
Social optimum	Stop	Stop	Go	Stop

The socially optimal option across these cases is to seek CB independently (case #3), and to not proceed in the pursuit of M (cases #1, #2 and #3). Importantly, model 2, despite following standard CBA guidance, offers incorrect advice (case #2, cell highlighted in light blue).

Bundled main and co-benefits

Model 3 implicitly assumes that a co-benefit can be pursued independently of the identified main benefit. This may not always be the case. We have identified two edge cases.

First, if the main benefit and a co-benefit are produced together with fixed quantity ratios, and the co-benefit cannot be produced independently. In this case we recommend bundling the two and treating the bundle as the main benefit.

Second, if the main benefit and a co-benefit are produced together with non-fixed quantity ratios, and the co-benefit cannot be produced independently. In that case we again recommend bundling, but exploring variations on the quantity ratios as options within the CBA.

Co-benefits, like main benefits, should respond to technology improvement

A simple example further demonstrates the problem of using social value created to quantify co-benefits.

Type 2 diabetes is a common, debilitating disease than reduces quality of life and expected life span. A simple calculation estimates the health cost of a case of diabetes at NZ$225,482.[6] Costly diseases can, and do, invite CBAs that compare mitigation options for that disease, and diabetes is no exception (e.g., Singh et al. 2022). Diabetes is closely associated with obesity, so diabetes mitigation is an expected co-benefit of programmes to reduce obesity.

New classes of drugs, which have come to market in the past year, look to vastly reduce the incidence of diabetes (The Economist 2023), and thus its health costs at a societal level. Any CBA with diabetes mitigation as a main benefit has this gained new options, which may well out-compete the previously best-performing options. (And these should improve over time if drug prices follow their usual downward trend over time.) Logically, those CBAs with diabetes mitigation as a co-benefit should also be affected.

Co-benefit valuation should not be immune to technology changes. But, under current CBA guidance, it is immune.

Policy implications

Co-benefits should be valued in CBAs at the least-costly way to produce that benefit. Non-adherence to this principle is widespread, leading to poor policy recommendations. This, we believe, justifies us labelling this problem the *co-benefit fallacy*.

We are not aware of any standard CBA guidance or academic papers that address this issue. It is not mentioned in any of the references cited in this paper.

We identify three implications for policy:

- CBA guidance should be updated to recognise the existence of multiple prices for social benefits, and recommend the correct price choice for main and co-benefits.
- Standardised plug-in lists of benefits, such as those provided by Treasury (2022), should contain two prices for each benefit listed: the social value produced (for use as a main benefit) and the least-cost means of production (for use as a co-benefit).
- Until, and unless, CBAs correctly price co-benefits, readers should be extremely wary of recommendations that rely on the magnitude of co-benefits.

Hack 2: Conflating marginal vs. average costs and benefits

The standardised plug-in lists central to CBAx lists a single dollar value per unit impact or activity, where negative values are costs and positive ones are benefits. This as can be seen Table 2, an excerpt from Treasury (2022).

[6] This estimate comes from multiplying the estimated average of 5.4 QALYS lost per case (CDC 2016) by the value of QALY of NZ$41,756 (Treasury 2022).

Table 2. A single dollar price for impacts is insufficient for most purposes

CBAx impact (selected rows)	Value (2023NZ$)	Unit
Cost to health system from fatal crash	-18,635	Per incident
Cost to health system of serious crash	-21,916	Per incident
Physical health gain from walking	6	Per pedestrian km
Physical health gain from cycling (conventional)	3	Per pedestrian km
Physical health gain from cycling (electric-assisted)	1	Per pedestrian km
Shadow Emissions Value CO_2 - lower price path (Present – 2030)	-115	Per tonne
Shadow Emissions Value CO_2 - central price path (Present – 2030)	-172	Per tonne
Shadow Emissions Value CO_2 - higher price path (Present – 2030)	-255	Per tonne

Are CBAx prices average or marginal costs?

An open question is whether the values in plug in lists are marginal (MC, correct for one unit of supply), or average (AC, correct for exactly N units of supply)? And, in the latter case, what is N? MC=AC is only true in the general case if N=1 or the supply curve is flat over the range 1 to N. But out there in the real world, supply curves are rarely flat.

Why does this matter? Let's say the project under consideration would avoid one tonne of CO_2 emissions in 2030. Using the central price path, as recommended by Treasury (2022), the avoided emissions benefit $172/tonne.[7] But the New Zealand government has other options. It could, for example, eliminate a tonne of CO_2 from the atmosphere at the current NZU spot price, which was $48 at time of writing.[8] This suggests that MC is $48. AC is also $48, for the limiting case of N=1, and other small numbers of N.

The $172 figure can be interpreted the AC, where N covers every single tonne that that needs to be avoided to stay on the desired emissions reduction path, in this case corresponding to a target of limiting global warming to less than 2 degrees Celsius (Waka Kotahi NZ Transport Agency 2021).

What about a project that avoids emitting say 1 million tonnes of CO_2 in New Zealand? A reasonable assumption would be a price a bit higher than $48/tonne. What about 100 million tonnes, a quantity higher than New Zealand's total annual emissions? That price is likely to be much closer to $172/tonne. Plug-in lists such as CBAx deny the possibility of prices that vary with quantity, let alone helping analysts to find the right one.

Multiple, independent CBAs with overlapping cost or benefit impacts

Large projects can affect other projects via their impact on prices

Standard CBA guidance is fulsome in its recommendations to incorporate externalities. Its coverage of externalities is, however, restricted to *technological* externalities (Pigou 1920). Technological externalities are the positive and negative effects of market transactions on third parties outside that market.

Pecuniary externalities, the effect of activities on prices, are rarely mentioned in standard CBA guidance (e.g., OMB 2012; NSW Treasury 2023; Treasury 2015; Department for Transport 2023). Pecuniary

[7] Waka Kotahi NZ Transport Agency (2021) explains the rationale for, and the source of, these shadow prices.

[8] Price obtained from https://www.mynativeforest.com/carbon-price-nz at 3:30pm on June 22, 2023. Under New Zealand's capped emissions trading scheme, any buyer (including government) can reduce, by one tonne, others' emissions of CO_2 into the atmosphere by buying one New Zealand Unit (NZU) on the open market, and either (a) surrendering the NZUs without making matching emissions; or (b) holding them perpetually. Government has the additional, but less transparent, option (c) of refraining from issuing an equivalent number of NZUs for auction. Government may face a credible commitment problem with options (b) and (c).

externalities can matter for CBAs in specific circumstances (Price 1990). In this paper we consider circumstances additional to those mentioned by Price.

The standard guidance is to ignore pecuniary externalities in CBAs, on the grounds that they are internalised within a CBA – a price increase experienced by one party is a price decrease for another. This logic is also applied to transfers, that is, payments from one party to another.[9] Pecuniary externalities, however, are not internalised across CBAs.

Consider the CBAs for two projects. Project A would avoid emitting 1 million tonnes of CO_2, which, following the logic above, we might value at a marginal benefit of $50/tonne. Project B would avoid emitting 100 million tonnes of CO_2, which we might value at an average benefit of $150/tonne. A problem arises, however, if both projects go ahead. The correct benefit price for both projects is now the one appropriate for a quantity of 101 million tonnes, say $151/tonne. While this is not a significant shift in benefits and thus BCR for project B, it is very likely significant for project A.

This leads us to a more general point: all CBAs are potentially affected by presence of alternative or contemporaneous projects that involve large enough quantities to shift the prices of overlapping costs or benefits.

Multiple projects can over-book benefits

In the 1980s, politicians in the Australian island state of Tasmania were lobbied by individuals, businesses, and community organisations to improve road access between the island's sparsely populated northwest corner and its even-more-sparely populated west coast. The State Government identified three alternative road projects, all paralleling the sole, pre-existing highway. Each could be justified, individually, by the benefits created by linking those regions.

Much to commentators' surprise, the State Government announced, and subsequently proceeded to build, all three roads. While the costs of each road were additive, the likely benefits of a second road were much reduced in the presence of the first road. The benefits of a third road were presumably even more truncated.

A failure to identify relevant alternative or contemporaneous projects can lead to the over-statement or mispricing of costs and benefits.

A wide search for co-benefits increases the likelihood of overlap

Guidance that encourages analysts to search widely for potential benefits from policy changes to justify specific projects proceeding will likely exacerbate these problems. If many projects under consideration, for example, offer air quality improvements as a co-benefit, then the CBAs for each of those projects need to take into the account the possibility that one or more other projects goes ahead, adjusting expected benefits as required. At best, the relevant benefit needs to be abated in yet-to-be-decided CBAs. At worst, the benefit may cease to be "on the table" for the subsequent projects.

That said, it can be difficult to know what is under consideration within an administrative unit, let alone across multiple units or jurisdictions.

Take, for example, two projects with primary benefits to reduce CO_2 emissions, but with co-benefits of reducing nitrogen runoff into a stream. The first units of runoff avoided will be more highly valued than subsequent reductions. That is, the marginal benefit of runoffs avoided that reduce the level of nitrogen in the stream below a specified acceptable level will be less than the marginal benefit of reducing the nitrogen to this level. If both projects assume they are the only ones "in the field", then both will value their benefits as if they are the first reductions. Neither will adjust their co-benefit valuations to take

[9] The standard guidance implicitly assumes both the payer and recipient have equal marginal utility with respect to income. This is not always the case. However, we will not explore that issue further in this paper.

account of the other's presence, because neither knows that the other is claiming the same co-benefits for their project. The result will be over-much attribution to the project of nitrogen reduction benefits. Indeed, if the first project reduces the runoff to acceptable levels, the second project if implemented may in fact turn an anticipated co-benefit into a countervailing risk (for example, if runoff is reduced below the levels needed for the survival of some nitrogen-dependent downstream species).

This is like the problem when firms in a monopolistically competitive market fail to take account of the effect of the others' entry decisions on residual demand when deciding to enter the market. Each makes their decision on the basis that they face the entire residual demand curve, so over-much entry occurs (Carlton & Perloff 2005). The situation is resolved in markets ex post by either the exit of unsuccessful firms (along with the loss of the sunk costs invested to enable entry) or firm mergers. The potential ex-ante solution – collaboration before entry – is not attainable in markets due to competition concerns. However, some form of information-sharing or co-ordination may be feasible when government-sponsored CBAs are incorporating – and in some cases relying upon – co-benefits to justify their case.

Policy implications

In the general case, marginal cost ≠ average cost, and marginal benefit ≠ average benefit. It is incumbent on CBA analysts to use appropriate values in their analyses.

Projects that create significant quantities of benefits, or consume significant quantities of resources, can shift prices in one or more markets. A single value for a cost or benefit is inadequate in these instances. Further, even projects that involved quantities too small to shift prices, may be affected by other projects with claims on the same benefits or resources.

While the purpose of this paper is to draw attention to the problem rather than to propose a solution, it would seem that maintaining central registers of analyses in development and the co-benefits involved, and active reporting of when and how accepted projects alter the value of these common co-benefits (or indeed may lead to countervailing risks that must be taken into account if more than one project addresses the same ancillary impacts) may be helpful.

We are not aware of any standard CBA guidance or academic papers that address these issues. They are not mentioned in any of the references cited in this paper.

We identify four implications for policy:

- CBA guidance should be updated to recommend the calculation of costs and benefits appropriate to the quantities demanded or supplied.
- Standardised plug-in lists of costs and benefits, such as those provided by Treasury (2022), should clearly identify whether the values supplied are marginal or average. Ideally, both should be provided, along with indication of the applicable quantity ranges.
- CBA authors should prominently identify assumptions made about inter-project pecuniary externalities, including those producing co-benefits.
- A failure to identify relevant alternative or contemporaneous projects, particularly in small economies like New Zealand, can lead to the over-statement or mispricing of costs and benefits. The risks are perhaps higher for projects justified by substantial co-benefits, as it is harder to verify the existence or non-existence of alternative projects that make claims on the same resources.

Hack 3: Staging projects to over-count completion benefits

For practical reasons, large projects are often staged. Reasons include budgeting and demand uncertainty. However staged projects, when combined with flexibility about how to treat a *completion* *benefit* – something that only materialises once all stages are complete – creates the conditions for this hack.

A staged road that should not be built

We use a roading project with 5 stages as an example.[10] The cost of each stage is greater than its benefit. In addition, there is a completion benefit that, while sizeable, is insufficient to lift the project's BCR above 1. If we realise the completion benefit once all stages are finished, then nothing will be built (Table 3).

Table 3. Completion benefit realised at project end – nothing built

Stage	#1	#2	#3	#4	#5	Total
Stage cost	1.00	1.05	1.10	1.15	1.20	5.50
Stage benefit	0.90	0.85	0.80	0.75	0.70	4.00
Stage BCR	0.90	0.81	0.73	0.65	0.58	0.73
Plus: completion benefit						1.00
Project BCR						0.91

On these numbers, the overall project should not proceed. Nor should any individual stage, unless four have already been built.

But what happens if we split the completion benefit into 5 equal parts (Table 4)? Then the first 2 stages get built, as their stage BCR ≥ 1. But the completion benefit never gets realised. The 2-stage project is a dud, with an actual project BCR of 0.85**.**

Table 4. Completion benefit realised in 5 equal parts – 2 stages built

Stage	#1	#2	#3	#4	#5	Total
Stage cost	1.00	1.05	1.10	1.15	1.20	5.50
Stage benefit	0.90	0.85	0.80	0.75	0.70	4.00
Plus: completion benefit	0.20	0.20	0.20	0.20	0.20	1.00
Total stage benefit	1.10	1.05	1.00	0.95	0.90	5.00
Stage BCR	**1.10**	**1.00**	0.91	0.83	0.75	0.91

Exploiting sunk costs

An analyst can "improve" on this situation by exploiting sunk costs – those already incurred that cannot be recovered, and so are no longer relevant to future rational decision-making.[11] If the project's costs and benefits re-evaluated after each stage is completed, then each stage has a BCR ≥ 1, and the whole project gets built (Table 5). The problem with this approach is that the completion benefits get multiply counted – they end up being 2.28 times the "real" value.

Table 5. Completion benefit realised in N equal parts, N reducing as prior costs become sunk – 5 stages built

Stage	#1	#2	#3	#4	#5	Total
Stage cost	1.00	1.05	1.10	1.15	1.20	5.50
Stage benefit	0.90	0.85	0.80	0.75	0.70	4.00
Plus: completion benefit	0.20	0.25	0.33	0.50	1.00	2.28
Total stage benefit	1.10	1.10	1.13	1.25	1.70	6.28
Stage BCR	**1.10**	**1.05**	**1.03**	**1.09**	**1.42**	1.14

[10] The numbers in this example are contrived to serve as an in-principle demonstration. This hack should be considered theoretical, as we lack a real-world example.

[11] Strictly speaking, the main sunk "costs" discussed here are unrealised completion benefits. However, "sunk unrealised completion benefits" lacks both brevity and the helpful associations with the widely understood sunk cost fallacy.

Real options to the rescue

A more principled approach is to calculate the real option value of the decision to proceed from one stage to another. The real option value of the decision to commence stage $i + 1$, having completed stages 1 to i, is the largest expected surplus (of benefits over costs) from completing stage $i + 1$, plus zero or more subsequent stages (Table 6).

Table 6. Real options analysis with completion benefit realised at project end – nothing built

Stage	#1	#2	#3	#4	#5	Total
Stage cost	1.00	1.05	1.10	1.15	1.20	5.50
Stage benefit	0.90	0.85	0.80	0.75	0.70	4.00
Stage BCR	0.90	0.81	0.73	0.65	0.58	0.73[12]
Plus: completion benefit						1.00
Project BCR						0.91
Value of real option to proceed with stage, with previous stages completed	-0.10	-0.20	-0.20	0.10	0.50	
Stage BCR including real option to proceed to next stage	0.90	0.81	0.82	1.09	1.42	

The real options analysis in Table 6 show that the project should not be commenced.

Policy implications

Staging is common practice for large projects. Analysts should be aware of the specific trap of reasoning forward about sunk costs. Costs are not sunk until they are truly irreversible, which should never be the case in forward-looking CBA.

Conclusion

CBA is susceptible to various 'hacks', intentionally made or otherwise. It is important that readers and recipients of CBAs understand and can identify such hacks, so as not to be misled by apparently good (or bad) headline benefit–cost ratios. There is a role for white-hat hackers in the economics and policy analysis communities, to identify hacks and bring them to wider attention.

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[12] 0.73 is the project BCR, excluding the completion benefit.

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