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Lost in Taxation

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Lost in taxation

Abstract

Cost-Benefit Analysis (CBA) was developed to assess the net socioeconomic benefits of a wide variety of projects in many fields. In this context, it is relevant to investigate how this method is actually used for project evaluation, and whether its merits and limitations are properly understood by a wider community of economists. In this study, we showcase a debate that took place in Italy in 2019 about an important high-speed rail project, following the publication of a CBA that received much criticism.

To learn from this episode, we find it useful to set up a meta-model of CBA that allows the formalisation of a large number of CBA calculations (including potentially ill-funded calculations) and to verify their validity. With this meta model, we review the criticisms formulated during the 2019 CBA debate focusing on two salient topics; whether CBA should include taxation and whether the Rule-of-Half measure of users' surplus is valid.

Our analysis suggests: (1) That the proposed meta-equation can help in structuring the scientific debate regarding CBA and the relevant economic discussion about a given project; (2) with few exceptions, the criticisms formulated regarding the 2019 CBA on these topics were incorrect, mostly incoherent from an axiomatic point of view. This indicates that ill-founded methods are at risk of becoming well-accepted in the larger community of economists, with the risk of lowering the general quality of policy recommendations formulated by economists. This underlines the need for economists to revise the misguided views of CBA.

Keywords: Cost-Benefit Analysis, transport infrastructure, welfare function,

1. Introduction

Cost-Benefit Analysis (CBA) is occasionally at the centre of important public debates covering decades, various topics, and many political contexts. Such examples include the third London Airport (Roskill commission back in the 70's), the Boston Big Dig at the eve of the century, and more recently, the Stuttgart 21 Rail Project in Germany, the New Nantes International Airport in France or, in health policy, the Herceptin debate in New Zealand. In 2019, Italy has witnessed an unprecedented episode of public debate triggered by a CBA, relating to pursuing the construction of an international tunnel for a High-Speed/High-Capacity rail project on the Lyon-Turin corridor. In February 2019, an evaluation report done on this infrastructure was released by a working group of the Ministry of Infrastructure and Transport. The analysis provided a stark negative result with a Net Present Value (NPV), in one scenario, of minus 8 billion euros.

Quickly, the public debate converged, pointing to claims of inconsistencies and striking paradoxes in the results. More than in other circumstances, many methodological aspects of the study have been heavily debated. The debate entailed numerous claims by academics or experts in the field about whether and how a CBA should be conducted. However, many of the criticisms seemed to be in stark contrast with the well-known results and consolidated methods of CBA and transportation sciences. More so, the debate was so intense that it has likely shaped the future of project evaluation for years, at least in Italy.

Thus, it is relevant for the community of economists to explore the economic arguments introduced in these discussions. This endeavour may result in different outcomes. First, if these criticisms, or a large number of them, are correct, the proposed investigation would provide a dispassionate, scientifically scrutinised record of the study's inconsistencies. This result would also imply that most of the evaluation procedures used worldwide are wrong and provide misleading policy recommendations—an important message to the international community of evaluators. Another possibility is that some of these criticisms resulted from misunderstandings. In this case, the proposed investigation would be beneficial; as such, a *quid-pro-quo* could be clarified. It would also be an opportunity to provide a deeper understanding of a proper evaluation method; highlighting for instance the 'devils in the details' for more fruitful discussions among scientists. Third, another possibility is that these criticisms would be misguided by acceptable scientific criteria of soundness. Such a result would need to be shared with the community of economists so that future evaluation procedures do not operate with ill-funded approaches endorsed by these criticisms. Additionally, this would provide material for the epistemology of science and the study of the spread or persistence of errors in the scientific community. This investigation complements, in a more detailed and formalised manner, elements provided in recent literature (Massiani & Maltese, 2022) showing that CBA methods are at risk of being misunderstood and misinterpreted in public discussions.

Therefore, this study contributes to the discussion on proper evaluation methods and to the progress of knowledge in evaluation in two specific ways. First, it proposes a meta-equation that contains of various possible CBA calculations as special cases and allows for formal comparison. Second, using this meta-equation, it systemises and disambiguates the various criticisms related to the 2019 CBA. It examines their validity by focusing on criticisms formulated by academics and experts and on the two most heavily discussed issues—the inclusion of taxation impacts and rule of half (RoH) computation of users' benefits.

This paper is structured as follows. Section 1 presents the 2019 CBA results and a synopsis of the criticisms formulated by academics. Section 2 defines the project, describes various available evaluation measures, and summarises them in a meta-equation, which allows for comparison among methods and verification of methodological claims. Section 3 systematically uses this meta-equation to review the criticisms of the 2019 CBA on two key topics, RoH and taxation. In the concluding section, we discuss the implications of the analysis.

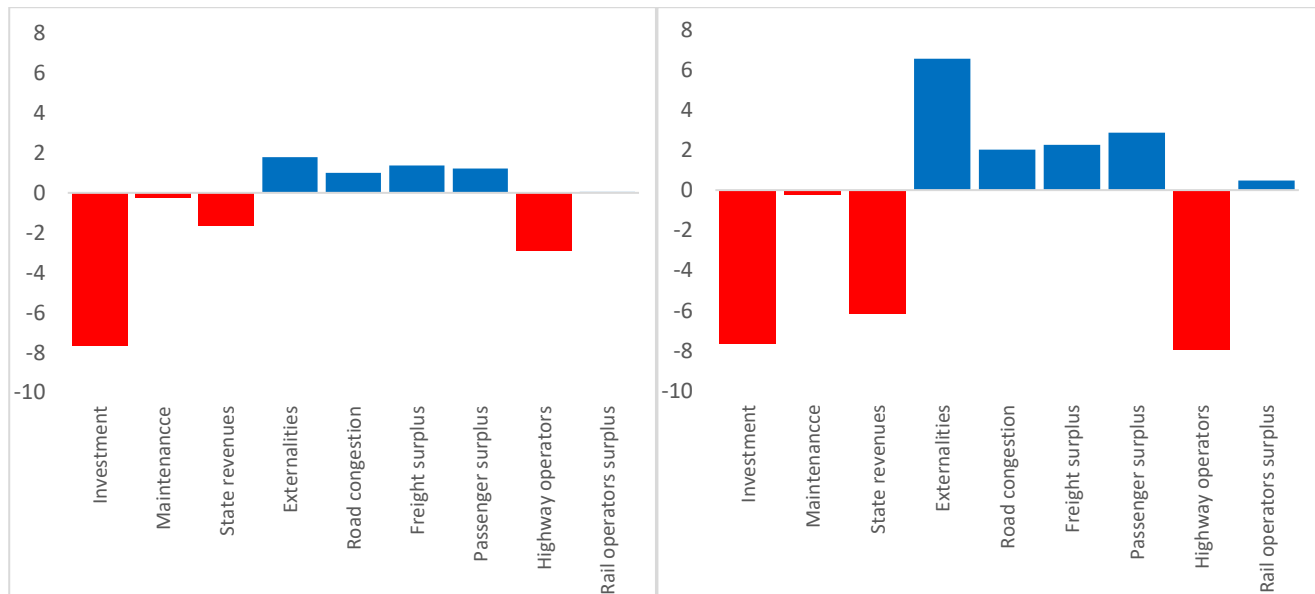
2. A highly discussed evaluation

We first present the main results of the 2019 CBA and then a synopsis of the criticisms raised, restricted to those formulated by academics.

A negative outcome

In May 2018, a CBA of various important transport projects was undertaken, with its masterpiece being the international tunnel of the Lyon-Turin ‘high-speed’ line project. The results of these studies were published in February 2019 (MIT 2019). This CBA followed a series of other studies on the Lyon-Turin project (for instance CIG, 2000; OAFTL, 2011). The various studies gave very different results. However, to be fair, they often dealt with different defined project configurations; for instance, by different sections ranging from 60 km to more than 280 km. The results of NPV of the 2019 study are synthesised in Figure 1 for two traffic scenarios, ‘realistic’ and ‘high traffic.’

Figure 1 Outcomes of the 2019 Cost-Benefit Analysis for two scenarios (net present value in bln Euro)



a- Realistic scenario (Figure 12.6, MIT 2019)

b- High traffic scenario (Figure 12.3, MIT 2019)

Essentially, both traffic assumptions provide negative Net Present Values. Immediately comments were formulated on the large social costs corresponding to fuel duties and highway operators’ losses. The item ‘costs for the state’ consisted of lost excise rights (fuel tax); fewer vehicle-km implied smaller fuel tax income for the state. The project benefits (such as externalities, road congestion, freight surplus, and passenger surplus) are sizeable; all larger than one billion euros, however not sufficient to compensate for costs. Some paradoxical effects also appeared. Most strikingly, the more the tunnel, the less beneficial for society, or at least for freight transportation. Another striking paradox is that even if the tunnel were built costlessly, it would have a negative NPV. This generated scepticism among experts and public discussions.

In the next section, we present the criticisms formulated by experts and academics.

Table 1 – Synopsis of criticisms to MIT working group study covered in this article¹

Category	Issue	Quotation		Summary claim
		In OAFTL (2019)*	Others	
RoH inappropriate	Considers only half of the benefits or reduced costs	(text 09) ⁱ (text 10) ⁱⁱ (text 18) ⁱⁱⁱ (text p. 25) ^{iv}	Percoco (2019) ^v Bergantino & Boitani (2019) ^{vi}	1: The RoH estimate of users' surplus records only half of users' Generalized Cost reduction 2: The RoH estimate of users' surplus would be half of users' benefits 3: Measuring transferred users' benefits as half of the reduction of Generalized Costs of the destination mode underestimates benefits by 50% 4: The RoH estimates of users' surplus record only half of the tax income reduction (or toll reduction) 5: Considering half of cost savings penalises projects aimed at modal shift
	Underestimate benefits if generalized costs are incomplete	(text 01) ^{vii}		6: With unobserved attributes RoH underestimates benefits 7: With unobserved attributes the larger the modal shift, the more RoH underestimates user benefits
	Invalid for multimodal choice	(text 01) ^{viii}		8: The RoH estimate is adequate only for single mode studies
	Inappropriate linear assumption	(text 09) ^{ix}		9: The RoH estimate of users' surplus is invalid because the linear assumption behind is discussible
	Would require an additional correction	(text 10) ^x		10: The RoH would be correct only if taxes were deducted from costs and benefits
Taxation	Not conform to state of the art or to Guidelines	(text 19) ^{xi} (text 01) ^{xii}	Forte e del Vecchio (2019) ^{xiii}	11: Considering taxation in CBA is not conform to the state of the art 12: Considering taxation in CBA does not conform to guidelines
	CBA should generally be net of taxation	(text 10) ^{xiv}	Forte e del Vecchio (2019) ^{xv}	13: Cost-Benefit Analysis should be made net of taxation
	MIT CBA wrongly considers lost tax income (but does not consider reduced consumers' tax expenditures)	(text 09) ^{xvi} (text 25) ^{xvii} (text 18) ^{xviii} (text 36) ^{xix} (text 22) ^{xxi}	Moesch (2019) ^{xx}	14: The 2019 CBA should not consider the reduced fuel tax revenues among Costs 15: NPV calculation should not include tax income loss 16: With a distortive taxation, transferring users to a mode with reduced taxation should reduce distortion
	Would weaken sustainable mobility policies	(text 12) ^{xxii} (text 29) ^{xxiii}		17: The 2019 CBA method would question sustainable mobility policies
	Fuel tax loss compensated by externality reduction	(text 32) ^{xxiv}		18 The project reduces externality and tax revenues in the same measure, thus reduced tax revenues should be discarded from the computation

*Note: two-digit numbers in quotation column refer to the text number in OAFTL (2019). When the text is not numbered, we indicate the page.

¹ Column one indicates a topic, column 2 a specific issue, column 3 contains references to the original text quoted in OAFTL (2019). Each text is referenced by a two-digit number as used in OAFTL (2019). We also add another column where we document observations not sensed in the OAFTL (2019). It could be that OAFTL was not aware of these documents or that they were issued after OAFTL concluded its review. Eventually, in the last column, we propose claims that summarise these criticisms in a way that make them suitable for scientific inquiry.

Summary of criticisms

We used two sources of information to identify the issues at stake. First, we reviewed claims made by economists in the public debate. Second, we used a compendium published by the Observatory of the Turin-Lyon Rail Project (OAFTL, 2019), a national body charged with organising the public consultations and local stakeholders about the project. This source gathers comments that academics, together with technicians and experts made on the MIT Working Group's CBA during the weeks following its publication.

summarises the issues examined in this study². Table 4 available as a supplementary document, complements other topics that, because of space limitations, we do not investigate in this paper. Generally, criticisms were related to a number of topics, such as, inconsistency with Italian or international guidelines, lack of consideration for wider economic effects, arbitrariness in traffic assumptions, underestimation of benefits, erroneous consideration of taxation, and misuse of the Rule of Half.

The latter two topics are arguably the most discussed. We will focus on them for the remainder of this study.

1. Consideration of taxation

This point was immediately and heavily criticised by many economists who stated that this is inconsistent with the logic of CBA—taxes are a transfer; thus, a reduction in taxes coincides with an identical benefit, and these two terms cancel out. In the 2019 CBA, the loss in tax revenues was included, while no corresponding benefit (less tax paid) was directly visible. This observation supports the idea that the analysis is distorted by the project. Other economists have accepted the view that the item 'users' surplus' (freight and passenger surplus) could actually include the benefits of lower taxation. However, scepticism is expressed in this solution. For instance, one may notice that users' benefits were smaller than the reduction in taxation, whereas the expectation would be that they were larger because the former includes the latter. Others commented that if distortionary taxation actually exists on fuel (this is apparent in the 2019 CBA input data where taxation on fuel is much higher than the corresponding externalities), lower tax revenues would reduce the distortions and should be included as a benefit or reduced cost in the project evaluation.

2. Use of the rule of half (RoH)

In the 2019 CBA, users' benefits were computed based on the Rule of Half, a well-known rule in transportation science, whose derivation is briefly presented in Appendix A. It essentially states that the benefit of users transferring from one mode to another can be estimated as half of the product between the change in quantity and change in generalised cost. With Q_i being the quantity and C_i the generalised cost of mode i , the rule of half measure of users' surplus is $\sum_i \frac{1}{2} \Delta Q_i \cdot \Delta C_i$, which is sometimes simplified by considering only the most impacted mode (let us assume it is mode 1): $\frac{1}{2} \Delta Q_1 \cdot \Delta C_1$. This result is sometimes found exotic by experts from other fields; the difference in generalised costs between the origin mode and mode 1, $(C_i - C_1)$, would be the most obvious measure of transferred users' benefits. Why then does it not appear in this calculation? For this reason, the RoH computation was generally criticised and dismissed in the 2019 debate; as if the $\frac{1}{2}$ fraction in its expression would discard half of the cost reduction.

Checking the validity of these claims has an epistemological dimension and requires an operational definition of correctness. A frequent view in economics is that there is nothing strictly true or false, nothing correct, or incorrect (Little, 1995; O'Donnell, 1989). This view results, for instance, from the fact that, in many economic investigations, the popperian condition of empirical testability/falsifiability is not fulfilled.

² Note that in this synopsis, we restrict methodological issues and discard criticisms related to other issues: discrepancies with previous results (like in text 37 in OAFTL (2019)) or procedural issues, like whether one should have followed a given Guideline because it is compulsory (text 06 in OAFTL (2019)).

We selected criticisms, but occasionally some academics also approved certain methodological choices. Limiting ourselves to the texts quoted in OAFTL (2019) and looking at the crucial issue of taxation, we found isolated supports to the method used in the CBA; Perotti (2019) confirms the validity of the method; Nicolazzi says the method accounting for tax loss as a social cost is correct... yet, he continues, its consequences would be politically difficult to handle (text 29, in OAFTL (2019)).

However, whenever possible, the criterion of correctness can refer to the internal consistency or axiomatic consistency of claims. For instance, when a measure, such as the Rule of Half is defined, one can investigate its properties. Another criterion is consistency with observation, which occurs even when the epistemology and sociology of science warn that scientists sometimes tend to confound facts with factoids (Caldas, 2016; Latour & Wollgar, 1986). We are aware of this literature and direct our investigation to elementary facts that are easily accessible to readers.

These two criteria are sufficient for a large part of our assessments and will be discussed later. In some cases, more complex assessment criteria must be used. For instance, one criticism is that it is coherent with mainstream economics yet contested by some economists. In another criticism, we found that the proposed method corresponds to a simplified assumption that is often non-testable, as neither would be an alternative assumption. In this context, we posit that the most scientific solution is to report this outcome and discuss its implications.

Once some assessment criterium are provided, the next step is to formalise the definition of a project as well as a project evaluation.

3. Formalisation of a project and its evaluation

In this section, we formalise a meta-model that contains a large variety of possible CBA computations. This model facilitates the comparison between competing CBA calculations and claims. We then formalise the welfare function used in the 2019 CBA, with its main assumptions that allows for formal verification of claims on its correctness.

A project and its impacts

Economic evaluation usually involves comparing two states of the world, each corresponding to scenarios with or without a project. The analyst desires a comprehensive representation of the economy to quantify 'all' the impacts of the project and successively assess them in a welfare function. However, the analyst must make some simplifications or epistemic reductions:

1. Generally, one concentrates attention on a limited set of markets, which is commonly labelled partial equilibrium analysis.
2. Distinctively, they often have to consider simplification in the functioning of the economy. For instance, in practice, the impact of infrastructure on regional development is sometimes not considered in estimated traffic flows.

In subsequent sections, we describe a typical project. Later, we examine how a welfare function $W()$ can be defined to evaluate such projects by considering the two simplifications above.

What is a project?

We assume that a project impacts two goods, labelled 0 and 1. We concentrate on the case in which these goods are substitutes, as two competing modes would normally be. These could be two transport modes but also a set of alternative goods proposed for the consumer. In a very general sense, a project involves capital costs and improves the quality of at least one consumption alternative. First, it shifts consumption from one alternative to another. Normally, it can also impact markets other than the improved good and its closer substitute. These are usually labelled as General Equilibrium effects. The analyst must consider if and how to include these impacts and carefully consider its impact on the evaluation.

The investigated market is usually decomposed into various segments (typically demand segments or transport projects: Origin-Destination pairs, purposes, etc.). For each segment, users face a market price and attributes for a set of goods, sometimes labelled in transportation science as levels of service. For the sake of legibility, we do not use a segment subscript in the following formalisation. This avoids an extra notation and summation across segments. This choice situation can be analysed using utility functions and, with some

assumptions, such a constant marginal utility of income (Delle Site & Salucci, 2018), in terms of generalized costs. Since it is more suitable for evaluating the RoH claims, we will use this latest concept.

The generalised cost has two components: an observed part and an unobserved individual part. The alternative assumption where all components of the generalised costs are perfectly measured and identical for all individuals has little support³. We compare the project and no-project situations as follows.

	No-project	Project
Mode 0	$C_0 + \varepsilon_{i0}$	$C'_0 + \varepsilon_{i0}$
Mode 1	$C_1 + \varepsilon_{i1}$	$C'_1 + \varepsilon_{i1}$

It results from these definitions that $(\varepsilon_{i1} - \varepsilon_{i0})$ is an individual unobserved difference in generalised cost (or specific preference, penalty, or demand shifter) between alternatives 1 and 0⁴. We focus on a typical situation in which $C'_1 < C_1$, $C'_0 \leq C_0$ and $(C_1 - C'_1) > (C_0 - C'_0)$. This latest condition $(C_1 - C'_1) > (C_0 - C'_0)$ may not hold for all segments; however, our assumption remains since in typical projects, segments that respect this condition dominate others. Referring to the rail project, this condition simply means that a project, improving rail, can have a positive impact on roads through decongestion; however, it normally improves rail more than roads for many demand segments.

When the project takes place, the number of users is impacted in two ways. First, there is a mode change (Q_{01}). Second, there are induced quantities Q_{z0} and Q_{z1} . Thus, the quantities in project situations can be expressed as initial (no-project) quantities \pm modal shift + induced quantities. Namely:

$$Q'_1 = Q_1 + Q_{01} + Q_{z1} \quad (1)$$

$$Q'_0 = Q_0 - Q_{01} + Q_{z0} \quad (2)$$

Interest occurs when $Q_{01} > 0$; $Q_{z1} \geq 0$; $Q_{z0} \geq 0$. These changes, observed in the two markets of interest, also impact the other markets. For instance, when there is induced traffic in mode 1, $Q_{z1} > 0$, the consumption of other goods changes by $Q_{z1} \cdot (p_1/p_z)$.

For reader convenience, Text box 1 summarises these notations and others that will be useful throughout this analysis.

Text box 1 - Notations

Indices	
n,	Year
$j \in (1, \dots, J)$	Index for various components of capital costs
δ_n	Discounting factor for year n, for instance $\left(1 + \frac{\text{discount rate}}{100}\right)^n$.
Features of alternative modes or goods	
C_0, C'_0	Observed component of Generalised Cost for mode 0 in the no-project and project situation
C_1, C'_1	Observed component of Generalised Cost for mode 1 in the no-project and project situation
$\varepsilon_{i1}, \varepsilon_{i0}$	Unobserved individual-specific component of Generalised Cost for mode 0 and 1
t_0, t_1, t_z	Taxation of mode 0 or 1, and on the alternative good
p_0, p_1, p_z	Prices of mode 0 or 1, and on the alternative good

³ There are several reasons for this. Attributes that form the Generalised Cost do not cover the entire set of choice determinants. Other elements influence the choice, even a fine OD system averages access and egress to the transport service in each OD pair; thus, some unexplained variability persists, similar in Random Utility Maximization models. Readers can easily check that if no variety is considered among users, the model produces the unrealistic conclusion that all users of a given segment choose the same mode in each single scenario (with or without the project); a problematic outcome in its own. Note that, for simplicity, and in line with the Random Utility Maximization paradigm, we assume the preference $(\varepsilon_{i1} - \varepsilon_{i0})$ is not changed by the project.

⁴ We assume the project does not impact the unobserved component of generalised costs. If instead, the analyst wants to consider possible variations of this component, additional assumptions are needed.

Quantities	
z	Quantity of generic (non-transport) goods
Q_1, Q_0	Initial number of users in mode 0 and 1
Q'_0, Q'_1	Final number of users in mode 0 and 1
Q_{01}	Number of users shifting from mode 0 to mode 1
Q_{z0}, Q_{z1}	Number of induced users on mode 0 and 1
Users Benefits	
B, B^{PE}, B^{GE}	Total users' benefits (discounted value), Partial Equilibrium (PE) and General Equilibrium (GE) components
B_{00}, B_{11}	Benefits of users staying on mode 0 and 1 (PE and GE superscript components can be added)
B_{z0}, B_{z1}, B_{01}	Benefits for induced users of mode 0 and 1, for users switching from 0 to 1 (PE and GE superscripts can be added)
B^{ROH}, B_{01}^{ROH}	Rule of Half estimate of total users' benefits and transferred users' benefits
B^{NT}	Net-of-tax benefits for users
Capital costs	
K_j, K_j^{PE}, K_j^{GE}	Capital cost of the project for the expenditure category i (discounted value), PE and GE components
K^{BCA}	Weighted capital costs as used in MIT CBA 2019
Other project impacts	
T, T^{PE}, T^{GE}	Impact of the project on tax revenues (discounted value); PE and GE components included
E, E^{PE}, E^{GE}	Impact of the project on enterprises or producers (discounted value); PE and GE components included
X, X^{PE}, X^{GE}	Other impacts of the project as externalities (discounted value); PE and GE components included
Evaluation function	
W	Net Present Benefits of the project
W^{CBA}	Evaluation function used in the 2019 MIT CBA
W^{ROH}	RoH estimate of the project net benefits.
W^{NT}, W_{ROH}^{NT}	Net-of-tax benefit of the project; net-of-tax benefit of the project using RoH estimate
W^{NT}	Project net benefits after deduction of tax; impact from user benefits and public account
W^{nonROH}	Generic notation W that would use a method other than RoH
Methodological parameters	
$\omega_T \geq 1, \omega_k \geq 1$	Factor representing the opportunity cost of public funding (for taxes and for capital expenditures)
$\pi_B, \pi_X, \pi_t, \pi_k$	Methodological parameters for PE impacts
$\gamma_b, \gamma_x, \gamma_t, \gamma_{kj}, \dots, \gamma_{kj}$	Methodological parameters for GE impacts
ϕ_j	Correction factor for expenditure category j (as meant in the EU guidelines)

Project impacts

The analyst is interested in the various impacts of this project. The project has a capital cost K . This cost can be decomposed into various categories K_i whenever necessary. K is also suitable in representing the infrastructure maintenance costs. The project also generates user benefits and can provide net benefits to company, E , through market power. Finally, it can generate other impacts, X (typically externalities); T also affects tax revenues, although the inclusion of this component is controversial. These variables are discounted by a factor δ_n in year n , allowing for whatever discounting mechanism is found appropriate; for instance, but not uniquely: $\delta_n = \left(1 + \frac{\text{discount rate}}{100}\right)^n$.

Formalising the project impacts in more detail, we discuss the **users' benefits**: The project will impact transferred users, additional (induced) users, and users remaining on the same alternative. The proposed notations are B_{z0} and B_{z1} for induced users of modes 0 and 1; B_{01} for transferred users; and B_{00}, B_{11} for users staying in their mode. The last two components, B_{00}, B_{11} , have a straightforward calculation. For instance, the benefits of users staying in mode 0 will be the difference in generalised costs multiplied by the number of such users: $B_{00}(C_0 - C'_0)$. Other components (B_{z0}, B_{z1}, B_{01}) do not have such a direct expression. In the literature, two proposals are competing, RoH and less frequently, logsum. We will focus on RoH since it is most frequently used,

can be implemented with minimal data, is recommended in many guidelines, and is part of the discussion in the 2019 CBA.

Whenever relevant, we can consider that part of the users' costs consists of **mode-specific taxes** t_0 and t_1 ; taxes, t_z , also exist in other goods. The consumption of other goods is potentially modified if transport expenditure changes. If t_z is the tax on each unit of the alternative good, then an extra unit consumption of mode 1, resulting from induced users, will decrease the consumption of other goods by p_1/p_z and the corresponding tax revenues by $\frac{p_1}{p_z} \cdot t_z$. Overall, the project's impact on tax revenues T_n in year n is derived from the fiscal impact of transferred users and induced users. Starting from the expression $T = \Delta Q_0 t_0 + \Delta Q_1 t_1 + \Delta Q_z t_z$ we can write⁵ the following expression (where T has a negative value whenever the project reduces tax revenue):

$$T_n = Q_{01,n} \left(t_1 - t_0 - \frac{p_1}{p_z} t_z + \frac{p_0}{p_z} t_z \right) + Q_{z0,n} (t_0 - (p_0/p_z) t_z) + Q_{z1,n} (t_1 - (p_1/p_z) t_z) \quad (3)$$

and the corresponding discounted value will be:

$$T = \sum_{n=0}^N \frac{Q_{01,n} \left(t_1 - t_0 - \frac{p_1}{p_z} t_z + \frac{p_0}{p_z} t_z \right) + Q_{z0,n} (t_0 - (p_0/p_z) t_z) + Q_{z1,n} (t_1 - (p_1/p_z) t_z)}{\delta_n} \quad (4)$$

One can easily distinguish two parts in this equation, one corresponding to the tax impact observed in the market for alternatives 0 and 1: $\sum_{n=0}^N \frac{Q_{01,n}(t_1-t_0) + (Q_{z0,n}t_0 + Q_{z1,n}t_1)}{\delta_n}$; and one that can be observed in other markets: $\sum_{n=0}^N \frac{Q_{01,n} \left(-\frac{p_1}{p_z} + \frac{p_0}{p_z} \right) t_z + (-Q_{z0,n} \cdot (p_0/p_z) t_z - Q_{z1,n} \cdot (p_1/p_z) t_z)}{\delta_n}$. Induced demand reduces the consumption of the alternative basket of goods and thus impacts the corresponding tax revenues. Additionally, a mode shift can also impact taxes on alternative goods if it changes the budget allocated to transport. This distinction would typically be labelled by economists as Partial Equilibrium versus General Equilibrium impacts and corresponds to a more general distinction between the effects that are observable in the model and the effects that are not (at least not directly). This distinction will be useful in future developments. Whatever this distinction, some questions (which turned important on at least one occasion) were whether and how an analyst may want to consider T in a welfare function or whether to discard it on the grounds that taxes are just a transfer.

In addition to taxation, we consider **other impacts**, such as externalities associated with trips. x_1 is the positive externality associated with one use of mode i ; if mode i has more negative externalities than positive ones, $x_i < 0$. This is often considered in road transport. The model generalises to a non-constant marginal externality; however, we focus on a simplified case to avoid cumbersome notations. The impact on externalities for year n has an expression comparable to the impact of taxation⁶. Generally, the various quoted impacts are compatible with traffic induction; induced traffic actually reduces the budget available for other goods, which generates side effects corresponding to part of what is called 'GE impacts'.

In this section, we formalise the project and its impacts. We pursue our investigation by examining how an evaluation function can be proposed for such projects.

⁵ We use the following identities $\Delta Q_0 = Q_{z0} - Q_{01}$; $\Delta Q_1 = Q_{z1} + Q_{01}$; $\Delta Q_z = -\frac{p_1}{p_z} \Delta Q_1 - \frac{p_0}{p_z} \Delta Q_0$

⁶ It will be: $X = \sum_{n=0}^N \frac{Q_{01,n} (x_1 - x_0 - \frac{p_1}{p_z} x_z + \frac{p_0}{p_z} x_z) + (Q_{z0,n} \frac{p_0}{p_z} x_z + Q_{z1,n} \frac{p_1}{p_z} x_z)}{\delta_n}$

The first term $Q_{01,n} (x_1 - x_0)$ of the numerator corresponds to the change in externalities due to mode transfer. Mode transfer also impacts emissions on the other goods whenever the price on modes 1 and 0 are different. This is due to the possibility of reallocating consumption among transport goods 0 and 1 and other goods. The second term of the numerator corresponds to the change in externalities for induced demand; when consumption shifts from the generic good to the transport goods, externalities are impacted. Another way to decompose the impacts is to look at X as made of two parts;

$\sum_{n=0}^N \frac{Q_{01,n} (x_1 - x_0) + (Q_{z0,n} x_0 + Q_{z1,n} x_z)}{\delta_n}$ takes place on the observed markets while $\sum_{n=0}^N \frac{Q_{01,n} \left(-\frac{p_1}{p_z} x_z + \frac{p_0}{p_z} x_z \right) + \left(-\frac{Q_{z0,n} p_0}{p_z} x_z - Q_{z1,n} \frac{p_1}{p_z} x_z \right)}{\delta_n}$ takes place on other markets.

Possible formulations of project evaluation functions

A general expression for an evaluation function is proposed. Here, we propose a meta-equation of CBA that is apt to summarising a large number of potential functions. This general expression includes various CBA measures, which assists the analyst in making his assumptions explicit and allows for the comparison of various competing CBA formulations. This formalisation can be used successively to assess the claims made regarding the 2019 CBA.

A meta-equation for evaluation

In its more general form, a CBA generally makes use of an equation such as:

$$W(B^{PE}, X^{PE}, E^{PE}, T^{PE}, K_j^{PE}, \dots, K_j^{PE}, B^{GE}, X^{GE}, E^{GE}, T^{GE}, K_i^{GE}, \dots, K_i^{GE}; \pi_B, \pi_X, \pi_t, \pi_k, \omega_T, \omega_k, \gamma_b, \gamma_x, \gamma_t, \gamma_{kj}, \dots, \gamma_{ki}) \quad (5)$$

$$= (\pi_B B^{PE} + \pi_X X^{PE} + \pi_E E^{PE} + \pi_T (1 - \omega_T) T^{PE} - \pi_k (1 + \omega_k) (\sum_i K_i^{PE}) +$$

$$\left(\gamma_b B^{GE} (B^{PE}) + \gamma_x X^{GE} (X^{PE}) + \gamma_e E^{GE} (E^{PE}) + \gamma_t T^{GE} (T^{PE}) + \sum_j \gamma_{kj} K_j^{GE} (K_j^{PE}) \right)$$

where,

- $W()$, is welfare function;
- $B^{PE}, X^{PE}, E^{PE}, T^{PE}, K_j^{PE}, \dots, K_j^{PE}$ are impacts of the project (user benefits, producers, tax revenues, externalities, and capital cost) on observed markets in the model;
- $B^{GE}, X^{GE}, E^{GE}, T^{GE}, K_j^{GE}, \dots, K_j^{GE}$ are other impacts of the project (outside of the observed market or not captured by the modelling approach);
- π_B, π_X, π_t , and π_k represent methodological parameters for the first category of impacts;
- $\gamma_b, \gamma_x, \gamma_t, \gamma_{kj}, \dots, \gamma_{ki}$ are methodological parameters for other impacts;
- ω_T, ω_k are methodological parameters for the cost of public funds;

This welfare function has two noticeable features that we discuss below.

Modelled vs non-modelled impacts

The proposed meta-equation recognises that the analyst always splits the impacts of a project in two parts. The first corresponds to the impacts that are both included in the modelling approach used and visible on the investigated markets. The second corresponds to other impacts that are not included in the model by definition.

When performing an assessment, an analyst will generally make two types of simplifications: s/he will concentrate on a limited set of goods and corresponding markets and consider only certain economic mechanisms. These can impact other (unobserved) markets or the observed market that the selected modelling approach does not consider. It gathers impacts that are labelled in various ways in the literature, such as, general equilibrium impacts—defined as occurring in other markets; or Wider Impacts—partly occurring in observed markets or in other markets. However, analysts are aware that the model is a simplification; mechanisms that are not embedded in the model could have some effect on the investigated policies. These latest impacts are labelled as Wider Impacts. This formulation recognizes that what one considers as Wider Impacts is contingent upon what one delimitates as the investigated markets. Rarely, CBA deals with only one market, an elusive concept on its own. Often, the boundaries elected for the investigated markets can be set with some discretion. Consistency derives from the fact that for each definition of the realm of the modelled impact, the other wider impacts are defined as complementary impacts.

Interestingly, the investigated impacts contain information on other impacts. This happens whenever consumer- or producer-optimisation generates equilibrium conditions that link the impacts in these two domains. Typically, measures of B^{PE} are defined in a way that makes them inclusive of various impacts that would otherwise be classified as Wider Impacts. A maximising process takes place in consumer choice; thus, if we use

the so called ‘utility’, the marginal utility of the newly consumed good is linked to the marginal utility of the other goods: $\frac{\delta U}{\delta x_i} = \frac{\delta U}{\delta x_j} \frac{p_j}{p_i} \forall i, j$ (with usual notations). This occurs for consumer benefits, different from externalities and taxation, as consumer choices generate a link between the marginal utility of goods and prices across markets. Similar linkages can also be exploited for E^{PE} by linking marginal costs, prices, and marginal utility, giving rise to interesting properties that go beyond the scope of this study. Exploiting such information from E^{PE} usually requires accounting for possible distortions which create a wedge between market prices and producer costs (Kanemoto, 2011; Rouwendal, 2001).

Methodological parameters

Second, the master equation contains a set of methodological parameters, indicated by Greek letters, corresponding to several methodological options open to analysts. We have commented on a few methodological parameters below.

- π_B is typically set to 1. However, analysts may want to include equity considerations and weigh user benefits on distributional grounds by decomposing B across various segments (Florio, 2014);
- π_T is a methodological parameter that triggers the inclusion of PE taxation incidence;
- π_X relates to other impacts such as externalities. Many reasons could justify that $\pi_X \neq 1$, for example, the fact that when an evaluation is made with net of tax prices, an adjustment should be made to make the shadow costs of externalities consistent with the evaluation price system (Sugden, 1998);
- π_E represents the weight of the companies’ benefits in the welfare function. An analyst may consider profits to have a value different from that of consumer benefits. Weisman (2016) argues that market regulators weigh different profits and consumer surpluses in their regulations. Although it is rarely argued in CBA, Meta-equation (5) allows for this. The proposed formulation is also compatible with the more common choice, where $\pi_E = 1$.

Some discussion also needs to be spent on γ parameters. $\gamma_b, \gamma_x, \gamma_t, \gamma_{kj}, \dots, \gamma_{kJ}$ are variables that indicate how much GE impacts will be considered in addition to properly defined PE impacts. In this context, the welfare function $W()$, defined in equation (5), may have undesirable properties when some parameters are set to given values or given combinations of values. When an incoherent or flawed CBA is implemented, Equation (5) allows a comparison with other appropriate parametrisations. This presentation may make the CBA appear extremely ductile, although this is only partly true. What makes the CBA appear ductile is that there are incoherent ways of producing a CBA. To be fair, the actual variety of methods is much smaller than the combinatorial of methodological parameters; analysts use a reduced number of methodological configurations.

Generally, it appears beneficial to have a general formula to represent alternative computations.

Going partial

In this context, the majority of CBA applications omit the additional impact section of equation (5). Choosing Partial Equilibrium analysis (i.e. : $\gamma_b, \gamma_x, \gamma_t, \gamma_{kj}, \dots, \gamma_{kJ} = 0$) is frequent in project evaluation (e.g.: Carteni et al., 2019); however, GE impacts (or at least the definition of such effects, as used in Equation (5)) are ignored. To clarify, this does not mean that the analysis has omitted any effects outside or in the investigated markets; this means that such effects are considered only as much as they are already visible in the investigated markets. One reason is that, when adequate methods are used, the investigated markets contain information on the value of the alternative uses of resources.

Choosing a PE analysis may appear inappropriate for analysts with limited knowledge of CBA, yet it elaborates a rigorous tradition that was nicely summarised by Mishan in an early treatise:

“(...) a new good, x, is introduced into the economy (...) this necessarily implies smaller expenditures on other goods. Now the reader may suspect that if expenditures is withdrawn from other goods in the economy, losses are incurred there, and that these losses ought to be offset against the

consumer's surplus for was conventionally measured. Such a suspicion is in general, unwarranted- at least under the usual assumption of maximizing behavior.” (Mishan, 2007, pag. 37)

Reasons for holding valid this partial equilibrium setting are proposed repeatedly in the literature (e.g. Lesourne, 1972).

The opposite temptation of expanding Partial Equilibrium to General Equilibrium could also generate distortions: in 1975, Whalley already warned: “The most striking feature (...) is that extended partial equilibrium analysis gives a much poorer prediction of the change in product than simple partial equilibrium analysis.” (Whalley, 1975). Additionally, there is no a priori reason that a PE analysis provides less favourable results than a GE analysis: Kanemoto and Mera show that the GE measure is smaller than the PE measure if import demand in one region is more price elastic than in other region, along the entire equilibrium path.

“the prices of goods and services other than transportation services are taken as fixed in the PE measure whereas their changes are fully taken into account in the GE measure. It is shown that the second aspect works in the opposite direction in the MD case: the GE measure tends to be smaller than the PE measure.” (Kanemoto, Y. & Mera, K., 1985, pag. 357 MD refers to Marshal Dupuit surplus).

It is fair to conclude that Partial Equilibrium analysis is the dominant practice in CBA, that its limitations are less than they appear *prima facie*. There is no surprise thus, that it is used ubiquitously for infrastructures evaluation including large projects like the channel tunnel (Anguera, 2006) or Oresund bridge (Knudsen & Rich, 2013).

CBAs are parametrizations of a welfare function

In this setting, various evaluation methods can be compared, as they refer to various parameterisations of equation (5). For instance, the EU Guidelines or the 2019 MIT CBA elected specific values for methodological parameters.

Referring to EU Guidelines, notwithstanding the variety of ways these Guidelines are implemented, the elected parameters mostly correspond to: $\pi_T = 0$, $\omega_k \geq 0$, and $K_j^{GE}(K_j^{PE}) = K_j^{PE}$, $\gamma_{kj} = (\varphi_j - 1)$, where φ_j refers to the correction factors for expenditure category i . So $\gamma_{kj} K_j^{GE}(K_j^{PE}) = (\varphi_j - 1) K_j^{PE}$. For a railway project, B^{PE} was set equal to B^{ROH} (DG Regio, 2014, p. 110).

Referring to the 2019 CBA, we can identify the following parameters:

- $\pi_T = 1$; different from the EU Guidelines, it fully considers tax incidence such as, changes in excise right revenues;
- $\omega_k > 1$; the opportunity cost of funding is applied to the cost of capital expenditure;
- $\omega_T = 1$; it does not apply the opportunity costs of funding to the tax incidence;
- $B^{PE} = B^{ROH}$; it estimates users' benefits using the RoH;
- capital expenditures can be written as $(\omega_k \cdot K_{NL}^{PE} + \omega_L \cdot \varphi_L \cdot K_L^{PE})$, which applies a factor to the opportunity cost of public funds and selectively, an additional factor to labour-related capital expenditures.

Finally, the elected welfare function can be written as:

$$W^{CBA} = B^{ROH} + X^{PE} + E^{PE} + T^{PE} - (\omega_k K_{NL}^{PE} + \varphi_L \cdot \omega_L \cdot K_L^{PE}) \quad (6)$$

where K_L^{PE} relates to labour costs of capital expenditures, and K_{NL}^{PE} relates to other non-labour capital costs. For practical use, this can be rewritten using a shorter notation for capital cost as $K^{CBA} = \omega_k \cdot K_{NL}^{PE} + \varphi_L \cdot \omega_L \cdot K_L^{PE}$. Thus, the W^{CBA} is expressed as

$$W^{CBA} = B^{ROH} + X^{PE} + E^{PE} + T^{PE} - K^{CBA} \quad (7)$$

or, making explicit the first term B^{ROH} (see Appendix A):

$$W^{CBA} = \sum_{n=1}^N \frac{\frac{1}{2}(Q_{0,n}+Q'_{0,n}) \cdot (C_{0,n}-C'_{0,n}) + \frac{1}{2}(Q_{1,n}+Q'_{1,n}) \cdot (C_{1,n}-C'_{1,n})}{\delta_n} + X^{PE} + E^{PE} + T^{PE} - K^{CBA} \quad (8)$$

Combining these elements, we obtain a formal expression, equation 7, of the welfare function used in the 2019 MIT CBA. Such a parameterisation is not unusual and is similar, as much as it is documented in the previous CBA of the Lyon-Turin projects, applied to a variety of project sections, project configurations, and traffic assumptions; notably, focusing on T, the impact on tax incomes (Debernardi et al., 2011; LTF - RFI, 2011; OAFTL, 2011; Prud'homme, 2014). Based on this formulation, we can review various claims regarding the 2019 Lyon-Turin CBA.

Before doing so, we summarise the content presented thus far. In this section, we provide a simple formalisation of a transport project. We define a family of evaluation functions where practitioners explicitly delimit their analysis. They select investigated markets, which expand beyond the directly impacted transport markets and specify how their analysis considers the impacts outside of these markets and the modelled impacts. This can typically be performed using correction factors, which represent GE impacts; or by restricting the analysis to a defined PE setting. This latest choice is consistent with practice, and has a large theoretical body of knowledge. Interestingly, due to consumer and producers' trade-offs, the PE measure of users' benefits reflects the missed benefits of alternative consumption or a first-order approximation of them. In this setting, most CBA analysts use the RoH measure of the transferred users' benefits. This is consistent with the fact that not all variables relevant to users are measured in terms of generalised cost. However, it is possible to eliminate these unobserved components by examining the indifference conditions for marginal individuals. With the extra assumption that intermarginal individuals distribute uniformly (or any equivalent assumption), this will give rise to the RoH formula, where, surprisingly, the transferred users' benefits can be expressed as a function of the variation in Generalized Costs on each single mode. Therefore, we can use the formal expression of our welfare function to review claims about the 2019 CBA on two key topics: taxation and the RoH.

4. A review of the claims on the 2019 MIT CBA

In this section, we use the meta-equation of the CBA developed in Section 3 to evaluate the claims made from the MIT 2019 CBA as described in Section 2. In turn, we review the two topics of the RoH and taxation.

RoH issues

We start from the RoH computation of the transferred users' benefits, which in year n are whenever the unobserved G.G component is linearly distributed (or any equivalent assumption; see Appendix A for details).

$$B_{01,n}^{ROH} = (\sum_i (C_{0,n} + \varepsilon_{0i,n}) - (C'_{1,n} + \varepsilon_{1i,n}) \mid (\varepsilon_{0i,n} - \varepsilon_{1i,n}) \sim U) = \frac{1}{2} Q_{01,n} \cdot ((C_{0,n} - C'_{0,n}) + (C_{1,n} - C'_{1,n})) \quad (9)$$

The benefits of all users (including induced and existing traffic) for year n are

$$B_n^{ROH} = \frac{1}{2}(Q_{0,n} + Q'_{0,n}) \cdot (C_{0,n} - C'_{0,n}) + \frac{1}{2}(Q_{1,n} + Q'_{1,n}) \cdot (C_{1,n} - C'_{1,n}) \quad (10)$$

and, for the whole life duration of the project,

$$B^{ROH} = \sum_{n=1}^N \frac{\frac{1}{2}(Q_{0,n} + Q'_{0,n}) \cdot (C_{0,n} - C'_{0,n}) + \frac{1}{2}(Q_{1,n} + Q'_{1,n}) \cdot (C_{1,n} - C'_{1,n})}{\delta_n} \quad (11)$$

Using these formulas, we can investigate different claims dealing with the use of the RoH, starting from Claims 1, 2 and 3.

Claim 1, 2 and 3: The RoH estimate of users' surplus records only half of users' Generalized Cost reduction

Claim 1 materialises for instance in: ‘One euro less for highway operators is worth 50 c. as car users saving’ (text 10 in OAFTL 2019). Similar claims are made for Claims 2 and 3.

Claim 2: The RoH estimate of users' surplus would be half of users' benefits. Literally,

“the method used for the CBA (...) estimates consumer surplus accounting for excise rights and tolls paid, but divides by 2 the resulting value, by a generalized and uncritical application of the Rule of Half. The value of tolls and excise rights are accounted as half among the benefits... (Text 09 in OAFTL, 2019).

Claim 3: Measuring transferred users' benefits as half of the reduction of Generalized Costs of the destination mode underestimates benefits by 50%.

In contrast, we can observe that the Rule of Half does not halve benefits; the difference in generalised costs across modes, $(C_0 + \varepsilon_{0i}) - (C_1 + \varepsilon_{1i})$, is entirely accounted for in this calculation. The $\frac{1}{2}$ fraction results from a mathematical transformation of $(\varepsilon_{0i} - \varepsilon_{1i})$ and the assumed Uniform distribution (or any equivalent assumption) of this random term, and not from an ungrounded reduction of benefits. The formula does not rely on half of the change in Generalized Costs between modes $(C_0 - C_1)$, but on half of the other quantity: $(C_0 - C'_0) + (C_1 - C'_1)$. Equation (9) $\frac{1}{2} Q_{01,n} \cdot ((C_{0,n} - C'_{0,n}) + (C_{1,n} - C'_{1,n}))$ could be modified, leaving out the $\frac{1}{2}$ fraction, only if all individuals were identical to the one that obtains the maximum benefits from the project, but nothing would support this assumption.

Thus, we conclude that Claim 1 and its companions Claims 2 and 3 are analytically inconsistent. We now proceed with another related claim:

Claim 4: The RoH estimates of users' surplus record only half of the tax income reduction (or toll reduction)

This claim is very similar to the previous ones. Literally: ‘[using RoH] implies that reduced State income are accounted for twice compared with consumer savings. A choice far from neutral’⁷. We can start from equation (9):

$$B_{01,n}^{RoH} = (\sum_i (C_{0,n} + \varepsilon_{0i,n}) - (C_{1,n} + \varepsilon_{1i,n})) | (\varepsilon_{0i,n} - \varepsilon_{1i,n}) \sim U = \frac{1}{2} Q_{01,n} \cdot ((C_{0,n} - C'_{0,n}) + (C_{1,n} - C'_{1,n}))$$

A direct observation of this equation shows that the Rule of Half accounts for the entire change in transferred users' generalised costs. This also holds when one wants to make the tax component of generalised costs explicit, as claim 4 suggests. If, with self-evident notations $C_0 = C_0^{NT} + t_0$, $C_1 = C_1^{NT} + t_1$, then

$$B_{01,n} = \sum_i (C_{0,n}^{NT} + t_{0,n} + \varepsilon_{0i,n}) - (C_{1,n}^{NT} + t_{1,n} + \varepsilon_{1i,n}) \quad (12)$$

If, additionally, $(\varepsilon_{0i} - \varepsilon_{1i}) \sim U$ (or any equivalent assumptions), then

$$B_{01,n}^{RoH} = \frac{1}{2} Q_{01,n} \left(((C_{1,n}^{NT} + t_{1,n}) - (C'_{1,n}^{NT} + t_{1,n})) - ((C_{0,n}^{NT} + t_{0,n}) - (C'_{0,n}^{NT} + t_{0,n})) \right) = \frac{1}{2} Q_{01,n} \left((C_{1,n}^{NT} - C'_{1,n}^{NT}) - (C_{0,n}^{NT} - C'_{0,n}^{NT}) \right) \quad (13)$$

We observe that the benefit of reduced taxation for transferred users is fully accounted for in eq (12); hence, its RoH corresponding measure eq (13). Taxes may not appear explicitly in B_{01}^{RoH} but a closer inspection suggests that the benefits of reduced taxation are included in the RoH formula. Therefore, claim 4: ‘The RoH estimates of users' surplus record only half of the tax income reduction (or toll reduction)’ is analytically incoherent.

⁷ ‘Questo implica che i minori introiti dello Stato pesano il doppio rispetto ai risparmi dei consumatori. Dunque, una scelta tutt'altro che neutrale.’ (Text 18 in OAFTL 2019)

Claim 5: Considering half of cost savings penalises projects aimed at modal shift

Moving to the next claim, we find the following quotation: ‘the value of excise rights and tolls accounted for half seems (...) compensated subtracting their full value as a cost: if so, this would represent a systematic and ungrounded penalization of whatever modal shift’⁸. It is already clear at this stage that this assertion is based on a misunderstanding of what the RoH really is.

The RoH does not halve costs; therefore, the claimed penalisation is ungrounded.

Claim 6 and 7: With unobserved attributes RoH underestimates benefits; With unobserved attributes the larger the modal shift, the more RoH underestimates user benefits

Literally, ‘the higher the modal shift towards a mode that presents non-measured characteristics (...), the larger the underestimate of the surplus, or users’ benefits’⁹.

Formally, this quotation contains two claims:

Claim 6: RoH underestimates users’ benefits. Rigorously :

$$\text{If } (\varepsilon_{0i} \neq 0 \text{ or } \varepsilon_{1i} \neq 0), \text{ then } B_{01} - B_{01}^{ROH} > 0,$$

Claim 7: RoH underestimation increases when there is a large modal shift. Formally:

$$\text{If } (\varepsilon_{0i} \neq 0 \text{ or } \varepsilon_{1i} \neq 0) > 0, \text{ the larger } Q_{01}, \text{ the larger } (B_{01} - B_{01}^{ROH}).$$

Claim 6 is analytically ungrounded. Moreover, it contradicts the concept of Rule of Half, whose role is to account for unobserved components in generalised costs. If both ε_{0i} and ε_{1i} are non-zero, this is exactly why one requires the RoH estimate. If they are both zero, there is no reason to use RoH. Instead, we can demonstrate a proposition contrary to Claim 6. If ε_{0i} and $\varepsilon_{1i}=0 \forall i$, then

$$(B_{01} | (\varepsilon_{0i} = 0; \varepsilon_{1i} = 0)) = \sum_i ((C_0 + \varepsilon_0) - (C'_1 + \varepsilon_{1i}) | (\varepsilon_{0i} = 0; \varepsilon_{1i} = 0)) = \sum_i (C_0 - C'_1) \quad 14$$

Under such conditions, where unobserved components are zero, the Rule of Half would be unnecessary; thus, we can reject claim 6.

Claim 7 is related to the previous one and relies on the following premise; it assumes $(B_{01} - B_{01}^{ROH}) > 0$. This premise has limited support. If the distribution of the unobserved component of general costs is not uniform, B_{01}^{ROH} may well overestimate the real benefits, or equivalently, the sign of $(B_{01} - B_{01}^{ROH})$ may well be negative. In fact, various comparisons converge, suggesting that RoH provides higher benefits than other methods (Bates, 2005; Kohli & Daly, 2006; Ma et al., 2015). Thus, we can generally reject Claim 7 together with Claim 6.

Claim 8: The RoH estimate is adequate only for single mode studies

Literally: ‘This rule (RoH) consists in a simplification typically accepted when the analysis deals only with one component of demand (single mode studies) but it is much discussed when one needs to consider the demand on various modes (car, train, air) with different operating costs and benefits for users (multi modal analysis)’¹⁰.

However, in single mode studies, there are no transferred users. Therefore, by definition, B_{01} is meaningless. Thus, the benefits to users can be expressed without reference to $(\varepsilon_{0i} - \varepsilon_{1i})$; this term would be undefined. Noting

⁸ ‘Il valore delle accise e dei pedaggi, conteggiato a metà tra i benefici, sembra (usiamo questa cautela perché nessuna tabella esplicitiva è stata pubblicata) essere compensato sottraendo per intero il loro valore come costo: se così fosse, ci troveremmo di fronte a una strutturale e immotivata penalizzazione di ogni cambio modale’ (text 9 in OAF TL 2019).

⁹ ‘Risulta che quanto maggiore è la diversione della domanda verso un modo di trasporto che presenta caratteristiche non misurate (ad es. il confort del viaggio, la possibilità di lavorare e/o di riposare durante il viaggio, etc.) tanto maggiore è la sottostima del surplus, ovvero dei benefici per gli utenti’ (text 1 in OAF TL 2019).

¹⁰ ‘Il surplus del consumatore, che rappresenta il beneficio diretto per i passeggeri e le merci che utilizzano la nuova opera, è calcolato attraverso la ‘regola della metà’. Tale regola costituisce una semplificazione che è tipicamente accettata quando l’analisi interessa principalmente una sola componente di domanda (analisi mono-modale), ma è molto controversa quando occorre prendere in considerazione la domanda su diverse modalità di trasporto (auto, treno, aereo) che presentano costi operativi e vantaggi di utilizzo differenti (analisi multi-modale)’ (text 01 in OAF TL 2019).

that the presence of $(\epsilon_{0i} - \epsilon_{1i})$ was one reason for using RoH, one can conclude that multimodality is one of the motives for using RoH together with induced traffic. Thus, claim 8: The RoH estimate is adequate only for single mode studies' appears ill-founded. In contrast, multimodality and the unobserved component of generalised costs are one of the reasons (together with induced demand) that make RoH useful.

Claim 9: The RoH estimate of users' surplus is invalid because the linear assumption behind is discussible

It is claimed that the Rule of Half embeds a linear demand curve deriving from the uniform distribution assumption for the unobserved components (with our notations: $\epsilon_{i1} - \epsilon_{i0}$) and that such assumption makes it unsuitable. For instance,

“besides the assumption of linear distribution of Utility” (..) “[answers to a 5500 interviews survey] shows that the stated benefit is much higher than the one computed with the Rule of Half, and that the distribution of utility is absolutely not linear.”¹¹

Several detailed claims can be discerned here:

- 9.1 - RoH in general assumes a linear demand/distribution;
- 9.2 - the 2019 MIT CBA, in particular, assumes linear demand/distribution;
- 9.3 - the real distribution/demand is not linear;
- 9.4 - due to the linear assumption, RoH underestimates the real benefits.

One could be more precise in relation to the first claim. The RoH is valid in a wider set of assumptions than the linear one. Whenever the average of the unobserved components is the middle point of the interval between the extreme values of $(\epsilon_{i1} - \epsilon_{i0})$ or $\sum_{i=\min}^{i=\max} \frac{(\epsilon_{i1} - \epsilon_{i0})}{N} = \frac{(\epsilon_{i\min} + \epsilon_{i\max})}{2}$. The uniform distribution is only one special case and, as such, should be considered a sufficient condition, but not a necessary one, for the validity of the RoH.

Regarding the second claim, the 2019 MIT CBA does not explicitly refer to the linearity of the demand function. One may think that linearity is the key assumption to the Rule-of-Half, but this would not be rigorous, as illustrated in the previous paragraphs.

Regarding points 9.3 and 9.4, scientists usually use one of two assumptions:

The linear assumption corresponding to the uniform distribution of the unobserved components (or any equivalent assumption leading to RoH)

The sigmoid assumption corresponding to various Extreme Value distributions.

The results of transportation science suggest that:

- The choice between these two assumptions has little influence on the results (de Jong et al., 2005; Kohli & Daly, 2006; Ma et al., 2015). Generally, the transferred users' benefits differ by less than 5% between these different computations, and this item represents only a fraction of the project benefits; often a small one whenever the initial users of the mode are a sizeable number in the no-project scenario. In the specific case of Lyon-Turin, even under the extreme hypothesis that the whole user surplus would correspond to transferred users, a 5% difference in users' surplus for freight and passengers represents, in each scenario, 2.3% and 1.8% of total benefits. After subtracting the surplus of previous users, the real impact of this assumption would only be a fraction of this figure, and the sign of the deviation could not be known with certainty.

¹¹ 'A parte la supposizione che la distribuzione di utilità sia lineare, il problema è che si valuta il differenziale di utilità facendo solo riferimento alla variazione di Cgt' (...) 'L'anno scorso abbiamo realizzato oltre 5.500 interviste a viaggiatori a bordo dei treni alta velocità e le risposte hanno dimostrato che il beneficio dichiarato è molto più alto di quello calcolato con la regola della metà e la distribuzione dell'utilità percepita non è affatto lineare'. (text 09 in OAFTL 2019).

- The choice between these two assumptions, linear or sigmoid, can hardly be based on theory. Some economists have occasionally taken position on this; however, they have not converged on a single answer (Allen, 2008; Neuburger, 1971; Scott, 1997).
- Empirical data are of limited use when choosing these assumptions. Available demand functions are mostly calibrated at a scale—whether national, regional, or sectorial—which is of little use in distinguishing various possible curvature assumptions at the level of interest of a given project. Additionally, in many instances, estimation procedures produce nonlinearities whenever the underlying phenomenon is linear, owing to spurious data or a priori imposition of a functional form (Massiani & Maltese, 2019). To be thorough, some procedures have been proposed (Ye et al., 2017) to test the adequacy of the Gumbel distribution. The results obtained suggest that such a distribution is inadequate for the investigated data. Other studies also suggest the choice of Extreme Value distributions has little support (Paleti, 2019).

The conclusion on this point is that one may well doubt that the relevant demand functions are linear. Yet there is no firm reason, besides convenience (Cox & Snell, 1989), to prefer alternative assumptions, mostly embedded in the logit choice model and the corresponding logsum welfare measure. Additionally, the choice between the various assumptions appears to have a limited foundation and influence on the estimated benefits.

We can now close this section on RoH with claim 10: The RoH would be correct only if taxes were deducted from costs and benefits. This latest claim yet already brings us to the issues of taxation, which deserve a treatment of their own. This will be done in the next section, not without providing a summary of the claims analysed so far (Table 2).

Table 2 – Summary of claims regarding rule of half

Claim	Evaluation
1: The RoH estimate of users' surplus records only half of users' Generalized Cost reduction	Analytically incorrect
2: The RoH estimate of users' surplus would be half of users' benefits	Analytically incorrect
3: Measuring transferred users' benefits as half of the reduction of Generalized Costs of the destination mode underestimates benefits by 50%	Analytically incorrect
4: The RoH estimates of users' surplus record only half of the tax income reduction (or toll reduction)	Analytically incorrect
5: Considering half of cost savings penalises projects aimed at modal shift	Factually ungrounded: the RoH does not halve benefits

6: With unobserved attributes RoH underestimates benefits	Incorrect Unobserved components of generalised costs is one reason for using the RoH
7: With unobserved attributes the larger the modal shift, the more RoH underestimates user benefits	The premise that RoH underestimates benefits is unwarranted and conflicts with available evidence
8: The RoH estimate is adequate only for single mode studies	Formally incorrect A multimodal setting provides an additional rationale for using the RoH.
9: The RoH estimate of users' surplus is invalid because the linear assumption behind is discussible	The linear assumption is discussible; however, it is not a necessary condition for RoH Other assumptions are generally not more testable than this one Choosing among the various possible assumptions has very limited impact on the results.
10: The RoH would be correct only if taxes were deducted from costs and benefits	(see section on taxation)

Our analysis strongly suggests a general misunderstanding of RoH. Generally, the issues raised were not coherent with the essential features of RoH. We have now to shift to another series of issues related to taxation.

Taxation issues

The taxation issue was the most discussed during the 2019 CBA debate. The *leitmotiv* was that CBA as a method should not contain taxation which should be confined to the financial analysis. This point deserves further clarification.

To accomplish this, we proceed in two steps. First, we recall several possible computation methods of the net benefits of a project that differ by their treatment of taxation, some of them providing correct results and others incorrect results (Appendix B provides a detailed exposition). Successively we review the various tax related claims.

Generally, most claims formulated about taxation suggested to simply discard the tax impact from the welfare function. This would change equation (7):

$$W^{CBA} = B^{ROH} + X^{PE} + E^{PE} + T^{PE} - K^{CBA} \quad (7)$$

to the following

$$W_{ROH}^{NT} = B^{ROH} + X^{PE} + E^{PE} - K^{CBA}, \quad (15)$$

a computation where the impact for public finance is discarded and which is occasionally referred to as 'net-of-tax' measure (Percoco, 2019; Trento & Spaziani, 2019).

However, this computation is inconsistent. This result conforms to a recent contribution (Massiani, 2021) and is presented in more detail in Appendix B. The important point is that the proposed correction on T would impose an equivalent correction on transferred users' benefits because they also depend on taxes; users enjoy reduced taxation when they shift to a mode with less taxation. In other words, when the impact of the project on tax income is cancelled from the NPV, a corresponding correction must be made on the transferred users' surplus, which cancels out with the former and does so exactly unless second-order effects of taxation are considered.

Based on this result and using the proposed meta-equation, we investigate Claims 11 to 18 as well as Claim 10 which covers both RoH and taxation.

Claim 11 and 12: Considering taxation in CBA is not conform to the state of the art; Considering taxation in CBA does not conform to guidelines

We group Claims 11 and 12 as both regarding practice and recommendations rather than substance. An illustration of these claims is: *'In fact, in the Cost-Benefit Analysis technique, taxes are deducted from fuel price, as for all productive factors used in the project, as they distort the market price of the economic asset'*¹².

Claim 11 is incorrect. Worryingly, we find a large variety in the ways in which CBA deals with taxation. CBA are often made with full consideration of taxation. Examples include evaluations made by academics (new tunnel in Antwerp by Proost et al. (2014)), consultants (Rail Baltica by Ernst Young (2017)), and administrative bodies (initial Nantes Airport CBA (commented in Brinke & Faber, 2011)). Similarly, the 2011 CBA of the Lyon-Turin (LTF - RFI, 2011), to the best of our knowledge, includes tax impacts. To be fair, however, a number of CBAs state that they excluded fuel taxes. Examples include the evaluation of the new Lisbon Airport (NERA Consulting, 2007) and the new Trujillo-Caceres Road (INECO, ITM Ingenieria, s.d.). This choice is often implemented with explicit reference to EU guidelines (DG Regio, 2014).

To be more complete, analysts often deduct project VAT from the project's price (e.g. Grignon-Massé, 2010), but this does not extend to the general exclusion of taxation. Generally, the claim that the state-of-the-art CBA excludes taxation is, at best, discussible if not misinformed.

Switching to guideline recommendations, a recent publication (Massiani, 2021) clarified that a sizeable share of guidelines, the largest one in the investigated sample, mandates the inclusion of taxation; examples are, Spain (Ministerio de Fomento, 2010); France (Ministère de l'écologie du développement durable et de l'énergie, 2019); HEATCO (COWI A/S, 2005); and World Bank (The World Bank, 2005).

The picture emerging from this analysis may be confusing; CBA practitioners adhere to different paradigms and guidelines are not unified. This appeals to CBA theorists to investigate this question more thoroughly. However, for the finality of the present paper, *stricto sensu*, the important conclusion is that Claims 11 and 12 are far too selective, at best discussible, and substantially misinformed.

Claim 13: Cost-Benefit Analysis should be made net of taxation

This claim deserves its own treatment. It refers to substance rather than practice. One rationale for this claim can be, for instance: *'the distortion of these assumptions is obvious (..) as they evaluate the validity of an investment based on the actual system of indirect taxation that is fully based on fuel'*¹³.

This point is important, as it is at the fracture between two traditions in CBA: the international development stream (active at the World Bank) and the transport economics stream. The first tradition has gained traction in recent years, especially considering its influence through EU. The most important element here is that no reason emerges to ban taxation from the CBA, as long as its inclusion is performed coherently.

The idea that taxes should be excluded from the CBA because **they are a transfer is also illogic**. If taxes are actually a transfer, it provides no support to exclude them but rather dictates to include them coherently. This was discussed for single mode studies by de Rus (2010, pag. 23). If this coherent approach is implemented, taxes will cancel out by construction, in the computation of the NPV, or affect the latter (rightfully) if second-order effects are considered. Interestingly, one should be aware of the existence of the CBA for taxation (Avi-Yonah & Edrey, 2018; Russo, 2004; Weisbach et al., 2018). Thus, one may wonder how a CBA of tax reforms can be made if the CBA has to exclude taxation.

To conclude, a CBA including taxation is coherent and fully compatible with taxes being a transfer, as long as the various surpluses are estimated consistently; namely, users and governments (not to mention producers if relevant) net benefits all include tax impacts. The alternative method of excluding taxation is cumbersome and

¹² *'in realtà nella tecnica dell'Analisi Costi-Beneficio, il prezzo della benzina viene depurato dalle imposte, esattamente come tutti i fattori produttivi utilizzati nel progetto, in quanto distorcono il prezzo di mercato del bene.'* Forte & del Vecchio (2019), English translation revised by the original authors.

¹³ *'È evidente la distorsione di queste ipotesi che confondono analisi economica ed analisi finanziaria e valutano la convenienza di un investimento sulla base dell'attuale sistema di tassazione indiretto tutto basato sui carburanti.'* Cascetta (text 10 in OAFTL 2019)

requires taxes to be eliminated in two accounts. Importantly, the method of discarding tax impact for the public sector, without a corresponding correction for users, generates wrong results, such as in some so called ‘net of excise’ computations.

Claims 14 and 15: The 2019 CBA should not consider the reduced fuel tax revenues among Costs, and NPV calculation should not include tax income loss

The two claims can be grouped together. Claim 14 can be illustrated by the view that state taxes should be accounted for as a transfer and doubts the 2019 analysis does this correctly:

“I have some doubts on the method used (...) In a correct cost benefit analysis that take the point of view of society as a whole, one has to consider that taxes are collected by the State but are paid by economic agents.”¹⁴

“it has no sense to compensate this [user benefit] with a corresponding, but with opposite sign, variation of the benefits for the State”¹⁵

As analysed, these claims were incorrect. If one wants to eliminate taxation from any expression of a welfare function, the users’ surplus must be adjusted accordingly. The only correct provision is that tax has to be considered consistently, which can be made by adopting the formula W^{BCA} or any equally valid implementation of the meta-CBA equation.

Claim 16: With a distortive taxation, transferring users to a mode with reduced taxation should reduce distortion

‘Literally “a reduction of the fuel taxes paid, thanks to the traffic diverted toward less polluting modes, would imply a reduction in the distortion level.”¹⁶’ (Text 22 in OAFTL 2019). This means that the opportunity cost of public funds should apply to the reduction in tax revenues. Such a computation would reduce the corresponding welfare loss. The proposed correction would generally benefit the project, whenever it reduces tax revenues.

This claim relies on the assumption that the opportunity cost of public funds should apply to tax loss as it does to project expenditures; this position is endorsed by mainstream CBA (Boardman et al., 2010). However, some authors argue that the opportunity cost of public funds should not be applied to reduced tax revenues: ‘under certain frequently made separability assumptions of the utility function, one can disregard excess burden effects of the lost tax revenues associated with public subsidies of, for example, electric vehicles’ (Carlsson & Johansson-Stenman, 2003). The question seems to have varying answers depending primarily on the features of consumer preferences.

To conclude, claim 16 appears consistent with the mainstream economic analysis, although it is not universally accepted. This claim also requires that taxes be included in the computation, a position in contrast with other claims, which we investigate in the present section.

Claim 17: The 2019 CBA method would question sustainable mobility policies

A literal statement would be, ‘Whenever one would imagine considering among project costs the reduced incomes (from the state and highway concessionaires), the whole environmental policy for emission reduction and the development of electric vehicles, shared mobility systems, (...) would be rediscussed’¹⁷. This claim is not scientific in nature. It assumes that the method should be chosen based on its outcome rather than on its internal

¹⁴ ‘Io ho qualche dubbio sui metodi che Ponti usa nel suo articolo di qualche mese fa (vedremo, quando sarà reso pubblico, se gli stessi metodi sono stati adottati nel rapporto della commissione che ha presieduto). In una corretta analisi costi benefici che prenda come punto di vista quello della collettività bisogna tenere conto che le imposte sono percepite dallo Stato ma pagate dai soggetti economici.’ (text 25 in OAFTL 2019)

¹⁵ ‘Non ha quindi senso ‘compensare’ questa posta con una corrispondente, ma di segno opposto, variazione del ‘beneficio dello Stato’. (text 9 in OAFTL, 2019).

¹⁶ ‘Una riduzione delle accise pagate, grazie alla diversione di traffico verso modalità meno inquinanti, implicherebbe una riduzione del livello di distorsione’ (Text 22 in OAFTL 2019)

¹⁷ ‘Se si immaginasse di considerare ‘costo del progetto’ la perdita di ricavi (dello Stato e dei concessionari) si metterebbe in discussione tutta la politica ambientale per la riduzione delle emissioni ed anche lo sviluppo dei veicoli stradali a trazione elettrica, i sistemi condivisi, lo sviluppo dei percorsi ciclo pedonali e così via’ (text 12 in OAFTL).

consistency¹⁸. Additionally, it neglects that, *ceteris paribus*, in the method used in the 2019 CBA, as in equation (7), the larger the environmental benefits of the project, the higher its net social value.

We can also check a slightly different claim, which follows.

Claim 18: The project reduces externality and tax revenues in the same measure, thus reduced tax revenues should be discarded from the computation¹⁹

Literally,

: “the car traffic that could shift to the rail (...) generates negative externalities for 1,785 million euro, nearly perfectly compensated by excise rights for 1,619 million. But even if compensated, the damage would occur anyway. Instead, if the project were achieved, on the one side the damages would be avoided (and would be, as they are, computed as project benefits). But the corresponding excise lost by the State, accounted as a cost for the project, should not be considered because the losses for the State are actually 0: lower excise rights but also minor health expenditures to bear (...).”²⁰

This is a more complex statement than the others investigated in this study. It relies on the belief that, thanks to the project, the state would benefit from a reduction in externality-related expenditures. One can find some intuition for this reflection. However, it is well-known that public expenditure savings are only partially connected to externality reductions. In some cases, public expenditures are a sizeable part of negative externalities, while in others it is a proxy; in many cases, both are poorly connected. Additionally, in a simplified situation in which a given externality merely consists of a reduced state expenditure, this benefit is already correctly considered in the externality account, so there is no reason to duplicate this benefit by discarding the reduced tax revenues from the computation.

Strictly speaking, the investigated claim can be expressed more formally as ‘If $X^{PE} = T^{PE}$, W_{ROH}^{NT} which is $B_{ROH} + X^{PE} + E^{PE} - K^{CBA}$ is a correct estimate of benefits’. We find no analytical support for this claim. The inclusion or (coherent) exclusion of taxes is always necessary and does not depend on the relative magnitudes of the various items involved²¹.

Claim 10: The RoH would be correct only if taxes were deducted from costs and benefits

Until now, we have left claim 10 which relates both to RoH and taxation. This claim appears at the conclusion of the following sentence:

One euro less for highway concessionaire is valued as 50 cents saving for car users, a consequence of a traditional method, theoretically superseded, for computing consumer benefits which assumes that (fiscal) transfers are eliminated from costs and benefits, something that is not done in the MIT analysis²² (our emphasis).

¹⁸ When checking with one of the authors of the quoted papers, our correct understanding of this statement, he agreed that the reported motive was improper. We thank the author for this constructive comment.

¹⁹ An author of this criticisms also proposes the following formulation for this claim ‘The project reduces externality and reason for taxation; thus reduced tax revenues should be discarded from the computation’.

²⁰ ‘(...) il traffico automobilistico che potrebbe passare al ferro secondo lo scenario ‘realistico’ della Struttura tecnica genera esternalità negative per 1.785 milioni, quasi perfettamente compensate dalle accise per 1.619 milioni. Ma, anche se compensati, i danni ci sarebbero comunque. Invece, se si realizzasse il progetto, da una parte i danni sarebbero evitati (e sarebbero, come sono, computati come benefici del progetto), ma le corrispondenti accise perdute dallo Stato, che la Struttura tecnica computa come costi del progetto, non vanno considerate perché le perdite dello Stato sono in realtà pari a zero: minori accise, ma anche minori costi sanitari da sostenere. Dunque, nel metodo ha ragione l’Unione europea’. (Text 32 in OAFTL, translation reviewed by the original author)

²¹ Additionally, if taken literally, the investigated claim would imply a discontinuity in evaluation based on whether the equality $X^{PE} = T^{PE}$ holds; a project could have positive net value when $X^{PE} = T^{PE}$, but a negative one both for $X^{PE} > T^{PE}$ and for $X^{PE} < T^{PE}$. This would imply a point where, when the project worsens (more negative externalities), it obtains a larger Net Present Value.

²² ‘Ancora, risulta molto discutibile il metodo utilizzato per calcolare i benefici. Un euro in meno per i concessionari autostradali vale solo 50 centesimi come risparmio dell’automobilista. Una conseguenza di un metodo tradizionale, e teoricamente superato, di calcolare i benefici dei consumatori che però presuppone che vengano eliminati dai costi e dai benefici i trasferimenti, cosa non fatta nella analisi del MIT’. (text 10 in OAFTL 2019)

From the formulation of RoH estimates and from its derivation (Appendix A), the correctness of RoH estimates does not depend on the exclusion of taxation. RoH can be computed with or without taxes; what matters is that other parts of the computation are performed accordingly. Therefore, this claim appears unconvincing.

We have now reviewed various claims formulated regarding the role of taxation in the CBA. Table 3 summarises these findings. It is apparent that most criticisms were ill-founded.

Table 3 - Claims on taxation

Claim	Analysis
10: The RoH would be correct only if taxes were deducted from costs and benefits	Unfounded
11: Considering taxation in CBA is not conform to the state of the art	Factually incorrect
12: Considering taxation in CBA does not conform to guidelines	Factually incorrect, guidelines adopt various positions on this
13: Cost-Benefit Analysis should be made net of taxation	Discarding taxation is not necessary It can be done but it is often done incoherently
14: The 2019 CBA should not consider the reduced fuel tax revenues among Costs	Analytically incorrect The proposed modification would distort the evaluation unless an equivalent correction is performed on user surplus
15: NPV calculation should not include tax income loss	Analytically incorrect The proposed modification would distort the evaluation unless an equivalent correction is performed on user surplus
16: With a distortive taxation, transferring users to a mode with reduced taxation should reduce distortion	Internally consistent and coherent with mainstream CBA Depends on the assumptions on preferences
17: The 2019 CBA method would question sustainable mobility policies	Discussible epistemological value; supposes that a method should be chosen for its consequences and not for its consistency
18: The project reduces externality and tax revenues in the same measure, thus reduced tax revenues should be discarded from the computation	Factually, externalities (and neither their reduction) do not necessarily result in public expenditures (and their reduction). Analytically incoherent. If the tax impact is discarded, externality should be discarded as well. Incidentally, excluding taxation in this specific case would be contradictory with EU Guidelines; for those, if externalities are equal to taxes, tax impact should substitute externalities as a proxy rather than being discarded.

Our review strongly suggests that the claims expressed about the Rule of Half and taxation in the CBA during the 2019 Italian debate were incorrect, with few exceptions. We can now draw the following conclusions from our research.

5. Conclusions

In this paper, we have examined the criticisms formulated by academics toward the 2019 CBA of the Lyon-Turin High-Speed/High-Capacity Line. In a context that is now less passionate and is disconnected from the pressure of policy discussions, there is an opportunity to reflect on how CBA calculations should be implemented.

To do so, we first proposed a meta-equation of CBA evaluation, which can be used to reduce ambiguity in comparing CBA methods and verifying claims; it can also formalise incoherent methods, tracking of sources of inconsistencies. We hope that this formalisation will be useful for a large number of analysts.

We then reviewed the criticisms of the 2019 CBA using this meta-equation. We concentrated on comments from academics collected in a Compendium by the Observatory of the Lyon-Turin Rail Corridor, an Italian governmental body in charge of concertation on the Lyon-Turin Project. We concentrated on two salient topics: Rule of Half and the inclusion of taxation and analysed 18 claims.

We generally find that these claims misunderstand or misrepresent CBA. Two claims partly escape this conclusion.

- One claim that bears no inconsistency but requires assumptions:
 - o Reduced tax revenues would reduce distortions, and this reduction should be considered among the benefits of a CBA when a project reduces levied taxes. To be more precise, this position is not endorsed by all economists; some instead show that under alternative assumptions on preferences, such impacts should be discarded. Interestingly, we can also note that this claim would also make tax inclusion necessary and would invalidate all other claims where taxes should be excluded. The claim that lower fuel tax revenues should be specifically reflected in a lower distortion may however require further investigation due to its intricacy.
- One claim that is approximate in its premise and whose conclusion is discussible:
 - o This is related to the linearity assumption behind the Rule-of-Half. To be precise, linearity is a sufficient condition for the validity of Rule of Half calculation but not a necessary condition. However, even restricting to the specific assumption of linearity, the conclusion that this assumption invalidates the results of a given study is problematic. Neither this assumption nor the alternative sigmoid assumption embedded in the logsum computation, is generally testable; although isolated proposals have been formulated to do such checks. If the underlying criticism were taken literally, it would mean that any economic calculation based on a reasonable yet untested or untestable assumption should be banned. It would make economic evaluation aporetic and would have a number of epistemological limits (Chapter 6 in Wimsatt, 2011). Pragmatically, this would leave the floor to other methods that have no reason to be more rigorous, although their lack of rigor may only be less apparent.

The other claims analysed appear based on a misunderstanding or misrepresentation of what a CBA is, or what it should be. Most typically, the proposed ‘correction’ of discarding tax loss from the NPV introduces a sizeable inconsistency, sometimes in the order of magnitude of billions of euros, in the appraisal of important infrastructure projects. The proposed modification would indeed dictate a similar correction on consumer surplus so that, in the best case, these changes would exactly compensate one another; in the worst case, the proposed elision of taxation would just make the consideration of second-order effects of taxation impossible.

The issues that we explored also have epistemological and deontological implications. First, it appears possible that a community of experts embraces misguided and mostly incoherent interpretation of a well-established analysis technique. This is in line with the literature on the rise and persistence of errors in the scientific community. For instance, this is analysed in the works by Smaldino (2020) on the use of ill-funded statistical methods; Ioannidis (2012) on the lack of self-correction in science; and the abundant literature on the misuse of significance testing in economics and other disciplines (McShane et al., 2019; Ziliak & McCloskey, 2008).

As a community and individual, scientists are committed to diffusing sound knowledge. The 2019 debate contradicts the collaborative and incremental nature of progress in science and arguably in society. If no further discussion takes place after the 2019 CBA episode, one of the rare moments where CBA was in the heart of the public debate (at least in one country), the endorsement of inconsistent claims by a large majority of academics raises concern and could deteriorate the quality of policy evaluation. Occasionally, efforts have been made to

bring economists to the same table and to reduce misunderstandings. Efforts have already been made in this area²³. These isolated efforts and structured exchanges among experts must continue.

We hope the present writing contributes to this aim.

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²³A working group organised by Sipotra (Sipotra is an association that gathers professional interested in transport economics and policy) converged towards a shared understanding, consistent with the contents of the present analysis.

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Appendix A – The rule of half, synthetic presentation

In this appendix we present concisely the Rule of Half, a well-established measure used in evaluation (Button, 2006; Neuburger, 1971; Quinet & Vickerman, 2004) with well-known properties (Massiani & Maltese, 2019). We discuss its area of validity and its merits, compared with alternative measures, which have been repeatedly analysed (Bates, 2005; Batley, 2008; de Jong et al., 2005; Kohli & Daly, 2006; Ma et al., 2015).

Derivation of the rule of half

We present a simple analytical derivation of the RoH as a measure of user benefits. The total users' benefits of a project can be seen as consisting of several benefits.

- B_{00} for users staying on mode 0: $B_{00} = \sum_i (C_0 + \varepsilon_{i0}) - (C'_0 + \varepsilon_{i0}) = Q_{00}(C_0 - C'_0)$
- B_{11} for users staying on mode 1: $B_{11} = \sum_i (C_1 + \varepsilon_{i1}) - (C'_1 + \varepsilon_{i1}) = Q_{11}(C_1 - C'_1)$
- B_{z0} for induced demand for mode 0
- B_{z1} for induced demand for mode 1
- B_{01} for users switching from 0 to 1.

Transferred users

This last category ' B_{01} ' deserves specific interest as it concentrates difficulties. Indeed, it is written as (with subscript n for year n; this will be omitted in other equations for the sake of simplicity)

$$B_{01,n} = \sum_i (C_{0,n} + \varepsilon_{i0,n}) - (C'_{1,n} + \varepsilon_{i1,n}) = \sum_i (C_{0,n} - C'_{1,n}) + (\varepsilon_{i0,n} - \varepsilon_{i1,n}) \quad (16)$$

This expression cannot be directly computed due to the presence of $(\varepsilon_{i0,n} - \varepsilon_{i1,n})$, which is the difference of two unobserved components. To compute B_{01} , one needs to substitute these terms with known terms. This is done by assuming a distribution for these terms (Cox & Snell, 1989) and using indifference conditions for the marginal individuals. In the resulting formulation, transferred users' benefits depend only on the change in observed generalised costs on each single mode. A surprising outcome that indeed could (and did) generate misunderstanding.

In detail, the derivation process relies on:

- 1- writing indifference conditions for marginal individuals;
- 2- using the resulting equations to express marginal individuals' benefits based on an observed variable;
- 3- assume a distribution of the unobserved terms to compute the benefits of intermarginal individuals (individuals whose preferences place them in between the two marginal individuals).

We first consider the individual that is indifferent between the two modes in the original situation (*max*, since the maximum benefit will be gained from the change), such that

$$C_0 + \varepsilon_{0,max} = C_1 + \varepsilon_{1,max} \quad (17)$$

so that,

$$C_0 - C_1 = \varepsilon_{1,max} - \varepsilon_{0,max} \quad (18)$$

The corresponding benefit is

$$B_{max} = (C_0 + \varepsilon_{0,max}) - (C'_1 + \varepsilon_{1,max}), \quad (19)$$

Which, given equation 17, provides:

$$B_{max} = (C_1 + \varepsilon_{1,max}) - (C'_1 + \varepsilon_{1,max}) = C_1 - C'_1 \quad (20)$$

Similarly, the individual who is indifferent in the project situation ($i=\min$, since s/he gets no benefit from the project, s/he is indifferent between alternatives in the project situation), is such that:

$$C'_1 + \varepsilon_{1,\min} = C'_0 + \varepsilon_{0,\min} \quad (21)$$

$$B_{\min} = (C_0 + \varepsilon_{0,\min}) - (C'_1 + \varepsilon_{1,\min}) = (C_0 + \varepsilon_{0,\min}) - (C'_0 + \varepsilon_{0,\min}) \quad (22)$$

$$B_{\min} = C_0 - C'_0 \quad (23)$$

These two expressions, B_{\min} and B_{\max} , provide the maximum and minimum values of individual benefits. To estimate the benefit for intramarginal users, we require an additional assumption relating to the distribution of individual-specific benefits between B_{\min} and B_{\max} . If one assumes that these distribute uniformly on the relevant interval (or any equivalent assumption), the resulting estimate of benefits B_{01}^{ROH} will be

$$B_{01}^{ROH} = \frac{1}{2} \cdot Q_{01} \cdot (B_{\max} + B_{\min}) = \frac{1}{2} \cdot Q_{01} \cdot ((C_1 - C'_1) + (C_0 - C'_0)) = \frac{1}{2} \cdot Q_{01} \cdot (C_1 - C'_1) + \frac{1}{2} \cdot Q_{01} \cdot (C_0 - C'_0) \quad (24)$$

At this point, we observe that it is possible to suppress the unobserved component of the generalised cost formulation. We also observe that the benefits could be computed based on each mode in isolation,

$$B_{01}^{ROH} = \left(\sum_i (C_0 + \varepsilon_{i0}) - (C'_1 + \varepsilon_{i1}) \mid (\varepsilon_{i0} - \varepsilon_{i1}) \sim U \right) = \frac{1}{2} Q_{01} ((C_0 - C'_0) + (C_1 - C'_1)) \quad (25)$$

Most strikingly, if the improvement on the origin mode were assumed 0, the benefits would depend on the change in the destination mode; an intriguing result on its own that may generate misunderstandings.

Instead, when $(\varepsilon_{i0,n} - \varepsilon_{i1,n})$ is not distributed uniformly (or with another distribution that makes RoH valid) the distortion in RoH measure will be:

$$B_{01}^{ROH} - \left(\sum_i (C_0 + \varepsilon_{i0}) - (C'_1 + \varepsilon_{i1}) \right) = \sum_i (\varepsilon_{i0} - \varepsilon_{i1}) - \frac{((\varepsilon_{1\max} - \varepsilon_{0\max}) - (\varepsilon_{1\min} - \varepsilon_{0\min}))}{2} \quad (26)$$

The Rule of Half measure will be distorted, and the sign of such distortion will depend on the distribution of $(\varepsilon_{i0} - \varepsilon_{i1})$ around the midpoint of $[\varepsilon_{i\max}; \varepsilon_{i\min}]$.

Complete RoH formulation

Additionally, one wants to include induced traffic (a full demonstration can be found in Neuburger (1971) or, more recently in (Delle Site & Salucci, 2018), in Italian) the RoH can be used to compute B_{z1}^{ROH} and B_{z0}^{ROH} . Adding as well B_{11} and B_{00} , the benefits of users staying in their mode, one obtains the total RoH estimate of users benefits:

$$B^{ROH} = B_{01}^{ROH} + B_{z1}^{ROH} + B_{11} + B_{z0}^{ROH} + B_{00} \quad (27)$$

$$B^{ROH} = \sum_{n=1}^N \frac{\frac{1}{2}(Q_{0,n} + Q'_{0,n}) \cdot (C_{0,n} - C'_{0,n}) + \frac{1}{2}(Q_{1,n} + Q'_{1,n}) \cdot (C_{1,n} - C'_{1,n})}{\delta_n}$$

where we explicitly define the notation n corresponding to year; RoH is applied to yearly data and discounted. Eventually, to simplify future computations, it should be noted that if $\delta_n > 0 \forall n, B_n^{ROH} > B_n \Rightarrow B^{ROH} > B$.

Appendix B - A coherent treatment of taxation

In this appendix, we focus on the tax impacts on transferred users. Indeed, while users staying in their mode simply benefit from the reduction in Generalized Costs, transferred users generate impacts that are more complex: their individual benefit is $(C_0 + \varepsilon_0) - (C'_1 + \varepsilon_1)$. We compare various competing measures W , which differ in how they treat taxation.

A first possible measure is the one used in the 2019 CBA, denoted W^{CBA} :

$$W^{CBA} = B^{ROH} + X^{PE} + E^{PE} + T^{PE} - K^{CBA} \quad (28)$$

However, this computation may not be convincing, and it has been criticised; taxes are a transfer, so they should not appear as a cost in the project NPV. This motivated numerous authors to propose another computation, the net tax. This can be achieved in two different ways.

Firstly, by using a consistent net-of-tax computation where taxes are eliminated from T and from B . This measure is labelled $W^{NT,NT}$ to clarify that taxes are subtracted both from benefits and from costs.

Second, only T^{PE} was discarded. This is correspondingly labelled W_{ROH}^{NT} , to indicate that taxes are subtracted from only one side of the computation. In summary, the two measures are written as:

$$W^{NT,NT} = B^{NT} + X^{PE} + E^{PE} - K^{CBA} \quad (29)$$

$$W_{ROH}^{NT} = B^{ROH} + X^{PE} + E^{PE} - K^{CBA} \quad (30)$$

The first of these two formulas is consistent with the notion of net-of-tax computation; costs and benefits are both net-of-tax. The comparison between these two measures is detailed in the following paragraphs.

Net-of-tax computation

We examine the coherent net-of-tax computations, denoted $W^{NT,NT}$. We omit n subscripts and discount for the sake of simplicity. We first decompose the generalised costs of each mode in two parts by singling out the tax component in each mode, for instance: $C_0 = C_0^{NT} + t_0$, and $C'_1 = C'_1{}^{NT} + t_1$, where the NT subscript corresponds to the net-of-tax generalised costs. Based on these definitions, the net-of-tax benefit of a transferred user would be $(C_0 - t_0) - (C'_1 - t_1) + (\varepsilon_{0i} - \varepsilon_{1i})$, and expanding this formulation to all transferred users, the aggregate transferred users' benefit would be

$$B_{01}^{NT} = \sum_i \left((C_0 - t_0 + \varepsilon_{0i}) - (C'_1 - t_1 + \varepsilon_{1i}) \right) = \sum_i \left((C_0 + \varepsilon_{0i}) - (C'_1 + \varepsilon_{1i}) + (t_1 - t_0) \right) \quad (31)$$

The first term of the latest equation is the (gross of tax) benefit of transferred users, B_{01} ; while the second term of the latest expression is the individual tax gain multiplied by the number of transferred users.

$$B_{01}^{NT} = B_{01} - Q_{01}(t_0 - t_1) \quad (32)$$

This expression B_{01}^{NT} is made of B_{01} , the transferred users' benefit minus the tax impact $Q_{01} \cdot (t_0 - t_1)$, a positive value whenever $t_0 > t_1$ (some readers prefer to read B_{01} plus the negative impact $Q_{01} \cdot (t_1 - t_0)$).

For users' categories, other than transferred users, the net-of-taxes benefit can be computed as:

- $B_{11}^{NT} = B_{11}$: users staying in their modes do not have such tax benefits, *ergo* net-of-tax benefits for users staying in the same mode are the same as gross benefits
- $B_{z1}^{NT} = B_{z1} - Q_{z1}((p_1/p_z)t_z - t_1)$: For induced users, the net-of-tax benefit is different from the gross benefits, and the sign of the difference will depend on the difference in taxation between mode 1 and other goods. For instance, if z is more taxed than mode 1, there will be a tax benefit for induced users. If one wants to compute a net-of-tax computations, this tax benefit has to be deducted from the users' benefits. In PE, the impact of generic good taxes $(p_1/p_z)t_z$ will be neglected so that the relevant benefit will be $(B_{z1} + t_1 Q_{z1})$.

Consequently, if an analyst wants to compute a consistent net-of-tax result, $W^{NT,NT}$, two changes need to be made: T^{PE} should be discarded from the calculation and the net-of-tax users' benefits, B^{NT} , should be used rather than B . Therefore $W^{NT,NT}$ should be written as (We neglect subscript n in some equations for simplicity of notations) :

$$W^{NT,NT} = B^{NT} + X^{PE} + E^{PE} - K^{CBA} = (B_{00}^{NT} + B_{11}^{NT} + B_{z0}^{NT} + B_{z1}^{NT} + B_{01}^{NT}) + X^{PE} + E^{PE} - K^{CBA} \quad (33)$$

$$W^{NT,NT} = B_{00} + B_{11} + (B_{z0} + t_0 Q_{z0}) + (B_{z1} + t_1 Q_{z1}) + (B_{01} \cdot (t_0 - t_1) \cdot Q_{01}) + X^{PE} + E^{PE} - K^{CBA} \quad (34)$$

$$W^{NT,NT} = B_{00} + B_{11} + B_{z0} + B_{z1} + B_{01} + (t_0 Q_{z0} + t_1 Q_{z1} - (t_0 - t_1) \cdot Q_{01}) + X^{PE} + E^{PE} - K^{CBA} \quad (35)$$

Recalling from Section 3 that, $T^{PE} = -(t_0 - t_1) \cdot Q_{01} + (t_0 Q_{z0} + t_1 Q_{z1})$, we can show that:

$$W^{NT,NT} = B_{00} + B_{11} + B_{z0} + B_{z1} + B_{01} + T^{PE} + X^{PE} + E^{PE} - K^{CBA} = W^{CBA} \quad (36)$$

In other words, if an analyst wants to make a net-of-tax estimate, this should impact both the state and users, thus leaving the result unchanged; at least if no second-order effects of taxation are considered. If such effects must be considered, only the inclusion of taxation allows us to do so.

Inconsistent Net-of-tax computation

The correct net-of-tax computation can be compared to another candidate measure, where the change in government revenues is discarded and users' benefits are not corrected accordingly. This has been referred incidentally as a 'no excise' ('senza accise') calculation and proposed, suggested (Cini et al., 2019; Percoco, 2019) or implemented (Trento & Spaziani, 2019). MIT Working Group (MIT 2018, pag. 30) presented this calculation, stating it was erroneous, at the beginning of the 2019 debate. This so-called net-of-tax calculation can be conveniently written as W^{NT}

$$W^{NT} = W^{BCA} - T^{PE} = B + X^{PE} + E^{PE} - K^{BCA} \quad (37)$$

This is not a proper net-of-tax computation, as it does not recognise that taxes are a transfer.

$$W^{NT} = W^{NT,NT} - T^{PE} \quad (38)$$

This measure is distorted; if the project reduces tax revenues, T^{PE} will be negative; thus, that W^{NT} will overestimate benefits.

This welfare function W^{NT} would be inconsistent and would not recognise that taxation is a transfer; therefore, it affects both public funds and users. In fact, users' surplus is defined for a given level of taxation; if taxes are excluded from the computation, the surplus needs to be recalculated or complemented with the change in taxation. In other words, users' surplus includes the benefits of reduced taxation; correcting for taxation in state revenues actually requires a corresponding correction of users' benefits.

Appendix C

The following table presents additional criticisms made on the 2019 CBA which are not investigated in this paper. A more documented version of this table, including exact quotes, is available as additional material.

Table 4 – other critics formulated on the 2019 CBA.

Topic	Argument	Quotation	
		IN OAFTL	Other texts
CBA inappropriate	For a strategic infrastructure	Cantarella & alii (text 12) Cascetta (text 11) Camagni (text 32)	Matteoli (2019)
	If seen as supreme criteria	Zucchetti (text 6)	
	For large project	Tavoni e Percoco (text 18)	Boldrin (2019)
	For long term project	Giuricin (text 28)	
	If we don't compare solutions	Ingegneri provincia di Torino (text 37)	
	If project already started		Bergantino e Boitani (2019)
Highway and railway tolls	Accounting for toll loss is not valid	Cantarella & altri (text 12) Cottarelli & Galli (text 17) Tavoni e Percoco (text 18)	
	Toll loss does not reflect change in operating costs	Cini e altri (text 9) Camagni (text 32)	
	Railway toll loss should be treated as highway	Costa (text 38)	
Discounting	Discount rate is too high	Causi (text 25) Coppola (text 1) Forte (text 27)	
Standing improperly defined	Europe is not the right scale	Trento & Spaziani (text 36) Cottarelli & Galli (text 17) Cascetta (text 10) Ingegneri Torino (text 37)	Perotti (2019)
	Inconsistence between costs and benefits	Cantamessa (30)	
Improper Costs	Investment cost overestimated	Foietta & altri (text 5)	
	Technical Costs, Penalties, subvention loss and reputational costs not included	Giuricin (text 28) Caruso & Rodà (text 34) Forte (text 27) Zucchetti (text 6)	
	Cost of modernizing existing line omitted	Coppola (text 1) Boitani (text 15)	
	Sunk costs erroneously considered	Cantamessa (text 30)	
	Financial costs erroneously considered	Tavoni & Percoco (text 18)	
Infrastructure lifetime	Lifetime is improperly quantified	Coppola (text 1) Foietta & altri (text 5) Ingegneri Provincia di Torino (text 37)	
Confuses economic and financial analysis	Confusion of economics and financial analysis	Florio (text 21)	Moesch (2019)
Benefits overestimated	Car use costs (and benefits of their reduction) overestimated	Tavoni & Percoco (text 18)	
Benefits underestimated	Quality of service benefits	Coppola (text 1) Camagni (text 32)	
	Environment benefits	Trento & Spaziani (text 36) Florio (text 21) Tavoni & Percoco (text 18)	
	Value of time underestimated	Tavoni & Percoco (text 18)	
	Reduced roads accidents wrongly omitted	Trento & Spaziani (text 36)	

	Residual value	Ingegneri Provincia di Torino (text 37)	
	Tunnel traffic underestimated	Foietta (text 5)	
Macro and network effects	Macro impacts	Cottarelli & Galli (text 17)	Griseri (2019) Castronovo (2019)
	Wider economic impact Territorial development	Cantamessa (text 30)	Griseri (2019)
	Technological evolution not considered	Arrigoni (text 41)	
	Other indirect impacts	Gilardoni (text 31)	
	Network effects not accounted for	Costa (text 13) Florio (text 21)	
Arbitrary forecast	Lack of a proper demand model and arbitrary traffic assumption	Florio (text 21) Coppola (text 1) Foietta & altri (text 5) Cascetta (text 10) Tavoni & Percoco (text 19)	
Lack of Sensitivity Analysis		Boitani (text 14) Florio (text 21)	
Does not recognize technological development		Coppola (text 1)	
Does not follow Guidelines	Italian guidelines	Coppola (text 1) Coppola (text 2) Tavoni & Percoco (text 19)	Percoco (2019)
	EU guidelines	Coppola (text 1) Florio (text 21)	
	Navigates across guidelines important	Boitani (text 14)	
Paradoxes	More traffic worsens NPV	Cottarelli & Galli (text 17) Zucchetti (text 6)	Ingegneri della provincia de Torino (2019)
	Result depends on the existing taxation system	Cascetta (text 10)	
	If the tunnel is built it would be better not to use it	Cascetta (text 10)	

Appendix D – original quotation o claims in table 1 (as endnote)

- ⁱ “Il metodo utilizzato per l’Analisi Costi-Benefici del Terzo Valico e della Torino Lione stima il surplus del consumatore conteggiando le accise e i pedaggi pagati, ma divide per due il valore ottenuto, per una generalizzata quanto acritica applicazione della regola delle metà. Il valore delle accise e dei pedaggi, conteggiato a metà tra i benefici, sembra (usiamo questa cautela perché nessuna tabella esplicativa è stata pubblicata) essere compensato sottraendo per intero il loro valore come costo: se così fosse, ci troveremmo di fronte a una strutturale e immotivata penalizzazione di ogni cambio modale”.
- ⁱⁱ “Ancora, risulta molto discutibile il metodo utilizzato per calcolare i benefici. Un euro in meno per i concessionari autostradali vale solo 50 centesimi come risparmio dell’automobilista.”
- ⁱⁱⁱ “In seconda istanza, i benefici sociali prodotti dai consumatori che si spostano dalla gomma al ferro valgono solo per metà (la cosiddetta “regola del mezzo”, ovvero la regola per cui, per ottenere l’incremento di benessere, si stima il triangolo al di sotto della curva di domanda dividendo per la metà il valore ottenuto dal prodotto tra i risparmi unitari e il traffico deviato). Questo implica che i minori introiti dello Stato pesano il doppio rispetto ai risparmi dei consumatori. Dunque, una scelta tutt’altro che neutra”.
- ^{iv} “Il tener conto delle accise applicando la regola della metà comporta che sono sempre considerate integralmente come “costo” e solo al 50% come “beneficio” introducendo una deformazione strutturale del risultato”.
- ^v “La diversione modale comporta una riduzione delle accise (e dei pedaggi autostradali) (...) Tali riduzioni sono dei costi nell’ACB. Ma ci sono anche dei benefici... perché i consumatori non pagano, ma il loro beneficio conta la metà”
- ^{vi} “Il contributo delle minori accise pagate all’aumento del surplus del consumatore – misurato dall’area di un triangolo di base $t(qs-tp)$ e altezza t è, dunque, esattamente pari alla metà delle minori entrate da accise per lo Stato, misurate dall’area del rettangolo di uguale base e uguale altezza. Così facendo, ogni spostamento modale dalla strada alla ferrovia che generi, quindi, una riduzione di consumo di carburante si risolve in una perdita netta di “benessere” per la collettività. Discorso del tutto analogo può essere fatto per i pedaggi autostradali.”
- ^{vii} “Risulta che quanto maggiore è la diversione della domanda verso un modo di trasporto che presenta caratteristiche non misurate (ad es. il confort del viaggio, la possibilità di lavorare e/o di riposare durante il viaggio, etc.) tanto maggiore è la sottostima del surplus, ovvero dei benefici per gli utenti. Se la regola del mezzo viene applicata ugualmente in analogia ai casi mono-modalità, occorre essere consapevoli che è possibile andare incontro a tali sottostime, in alcuni casi in maniera anche molto significativa.”
- ^{viii} “Il surplus del consumatore, che rappresenta il beneficio diretto per i passeggeri e le merci che utilizzano la nuova opera, è calcolato attraverso la “regola della metà”. Tale regola costituisce una semplificazione che è tipicamente accettata quando l’analisi interessa principalmente una sola componente di domanda (analisi mono-modale), ma è molto controversa quando occorre prendere in considerazione la domanda su diverse modalità di trasporto (auto, treno, aereo) che presentano costi operativi e vantaggi di utilizzo differenti (analisi multi-modale)”.
- ^{ix} “A parte la supposizione che la distribuzione di utilità sia lineare, il problema è che si valuta il differenziale di utilità facendo solo riferimento alla variazione di Cgt (...) “L’anno scorso abbiamo realizzato oltre 5.500 interviste a viaggiatori a bordo dei treni alta velocità e le risposte hanno dimostrato che il beneficio dichiarato è molto più alto di quello calcolato con la regola della metà e la distribuzione dell’utilità percepita non è affatto lineare.”
- ^x “Una conseguenza di un metodo tradizionale, e teoricamente superato, di calcolare i benefici dei consumatori che però presuppone che vengano eliminati dai costi e dai benefici i trasferimenti, cosa non fatta nella analisi del MIT.”
- ^{xi} “Citando un documento di un progetto europeo del 2006, il gruppo di lavoro considera queste voci come costi. Si tratta tuttavia di una prassi non condivisa da tutti. Nel manuale sull’analisi costi-benefici di E. J. Mishan e Euston Quah (pag. 240) le correzioni dell’onere fiscale in eccesso sono considerate un errore. Le linee guida della Commissione europea, poi, chiariscono che le tasse sono trasferimenti e non costi.
- ^{xii} “L’approccio convenzionale dell’analisi costi-benefici e le linee guida comunitarie e nazionali suggeriscono che le tasse vengano escluse dal calcolo, perché costituiscono un trasferimento dal consumatore alle casse dello Stato”
- ^{xiii} “in realtà nella tecnica dell’Analisi Costi-Beneficio, il prezzo della benzina viene depurato dalle imposte, esattamente come tutti i fattori produttivi utilizzati nel progetto, in quanto distorcono il prezzo di mercato del bene.”
- ^{xiv} “È evidente la distorsione di queste ipotesi che confondono analisi economica ed analisi finanziaria e valutano la convenienza di un investimento sulla base dell’attuale sistema di tassazione indiretto tutto basato sui carburanti.
- ^{xv} “in questa correzione ad esempio le accise vengono eliminate in quanto sono “trasferimenti””
- ^{xvi} “La distinzione tra analisi finanziaria ed economica aiuta a comprendere che, all’interno di quest’ultima, la variazione di un prezzo o di una tassa (per esempio, un’accisa) non è una risorsa consumata, e quindi un “costo”, ma viene considerata nel totale del “costo percepito” quale “spia” per “stimare un beneficio”; un indizio, cioè, che, misurando la disponibilità a pagare, ci suggerisce quanto quel viaggio valga per l’utente. Non ha quindi senso “compensare” questa posta con una corrispondente, ma di segno opposto, variazione del “beneficio dello Stato”.
- ^{xvii} “Io ho qualche dubbio sui metodi che Ponti usa nel suo articolo di qualche mese fa (vedremo, quando sarà reso pubblico, se gli stessi metodi sono stati adottati nel rapporto della commissione che ha presieduto. In una corretta analisi costi benefici che prenda come punto di vista quello della collettività bisogna tenere conto che le imposte sono percepite dallo Stato ma pagate dai soggetti economici.”
- ^{xviii} “Va da sé che, nel momento in cui si punta all’utilizzo di prezzi che si avvicinano al mondo ideale della concorrenza perfetta attraverso l’eliminazione delle distorsioni di mercato (tra cui, appunto, le tasse), è quantomeno bizzarro ritrovare i mancati introiti delle accise quale costo per la collettività. In sostanza, siamo davvero sicuri che ridurre il finanziamento della guerra in Abissinia (una delle ragioni per cui si introdussero quelle accise) sia un danno per la società?”.
- ^{xix} “Considerare le tasse “infatti, significa auspicare un maggiore consumo di carburante per avere maggiori accise; principio che contrasta con la politica ambientale di riduzione dell’inquinamento, per cui lo svecchiamento del parco auto euro -1-2-3-4- ad altri valori di CO2 in favore di auto elettriche o ibride non sarebbe un obiettivo da perseguire per la perdite delle accise sul carburante” Trento p. 9
- ^{xx} “tra i costi sono stati inclusi le accise che lo stato perderebbe che come è noto non sono altro che trasferimenti”
- ^{xxi} “(...) le accise superano in valore le esternalità negative prodotte: una loro riduzione, quindi, dovrebbe ridurre la distorsione attuale e quindi far tendere l’assegnazione delle risorse verso una situazione di maggiore efficienza”.

^{xxii} “Se si immaginasse di considerare “costo del progetto” la perdita di ricavi (dello Stato e dei concessionari) si metterebbe in discussione tutta la politica ambientale per la riduzione delle emissioni ed anche lo sviluppo dei veicoli stradali a trazione elettrica, i sistemi condivisi, lo sviluppo dei percorsi ciclo pedonali e così via”

^{xxiii} Ci guadagnate di più col Tir che con il treno. (...) Se la tassazione supera il danno, il motore a combustione interna diventa il motore della finanza pubblica. Gliene potrebbe derivare, ministro, l'obbligo di riaprire i centri storici al traffico privato, e anzi incentivarlo, o di vietare l'uso delle biciclette. Più macchine più accise; e anche soldi risparmiati in sussidi al trasporto pubblico.

^{xxiv} “Nel nostro caso, il traffico automobilistico che potrebbe passare al ferro secondo lo scenario “realistico” della Struttura tecnica genera esternalità negative per 1.785 milioni, quasi perfettamente compensate dalle accise per 1.619 milioni. Ma, anche se compensati, i danni ci sarebbero comunque. Invece, se si realizzasse il progetto, da una parte i danni sarebbero evitati (e sarebbero, come sono, computati come benefici del progetto), ma le corrispondenti accise perdute dallo Stato, che la Struttura tecnica computa come costi del progetto, non vanno considerate perché le perdite dello Stato sono in realtà pari a zero: minori accise, ma anche minori costi sanitari da sostenere. Dunque, nel metodo ha ragione l'Unione europea”.