About positive and negative synergies of social projects: treating correlation in participatory value evaluation.

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1. INTRODUCTION

The conventional approach to address the social evaluation of government projects relies upon the principles of Cost-Benefit Analysis (CBA). CBA, in turn, builds upon the principles of welfare economics and Kaldor-Hicks efficiency. Consequently, a given project would be implemented if its benefits outweigh its costs (including opportunity costs). However, contrasting costs and benefits is not straightforward, as their units and magnitudes are not directly comparable and, therefore, it is customary to express them on a common basis (normally monetary units) in terms of their net present value (Boardman et al, 2017). This is the point, in where the evaluation of private and public goods differs: while in case of the former, costs and benefits are monetarized on the basis of private trade-offs (which are known for the decision-maker), the latter requires the use of societal values for non-monetary units.

Establishing societal values to monetarize costs and benefits is not an easy task. For this purpose, early approaches considered the actual costs and benefits (in monetary terms) that society would experience, i.e. how costs and benefits would reflect upon the national accounts. Such approaches have been, however, criticized for their pure monetary utilitarianism and for not reflecting the actual preferences of the population (e.g. under this approach preserving the life of retirees has a null or negative value, while travel time only represents a cost if it translates into a loss of working hours or productivity; Bahamonde-Birke et al, 2015). The current approach to establish societal values is based upon the willingness-to-pay approach (WTP), which represents the willingness of individuals to pay an amount of money from their private income for an improvement of their current life conditions (willingness-to-pay) or to accept an amount to tolerate a deterioration (willingness-to-accept, WTA; Mishan, 1971). Hence, the costs and benefits ascribed to a given project would be based on the aggregated WTP/WTA of all individuals and, therefore, it should completely capture changes in social welfare.

One of the main criticisms raised against the former approach is based upon the fact that WTP/WTA is derived from individuals' preferences in a private choice context, which may differ from the societal preferences of the same individuals (e.g. Ackerman and Heinzerling, 2004; Sagoff, 1988; Sunstein, 2005). In other words, WTP/WTA are derived from the behavior of the individuals as consumers of private or public goods (depending on the costs or benefits being monetarized). These preferences may, however, differ from the preferences individuals exhibit at societal level, i.e. it is possible that group behavior differs from the sum of the individual decisions of the members of the group. The existence of this dichotomy between individual's and group's choices has been described as early as by Buchanan (1954), but it acquires broader implications when policy makers need to establish societal values to monetarize costs and benefits of social projects. In this context, Mouter et al. (2018) define this dichotomy as consumer/citizen duality and present an extensive qualitative analysis on possible causes for consumer's and citizen's preferences differing from each other.

For the purpose of capturing societal/citizen's preferences, novel approaches have been developed during recent years, such as participatory budgeting (e.g. Cabannes, 2004; Capaccioli et al., 2017; Sintomer et al. 2008) and participatory value evaluation (PVE; Mouter et al, 2019), with PVE being a more appealing approach, as it allows for a more representative participation, diminishing the bias inherent to participatory budgeting and deriving societal values that are consistent with the principles of welfare economics. In principle, in PVE individuals are no longer treated as consumers of public goods and asked regarding their personal preferences; instead, they are treated as public resources allocators (policy makers), and asked to allocate limited public budgets to different social projects. This way, individuals are asked to select a portfolio of projects, consisting of one or more projects, that satisfy the budget constraint.

Opposite to the classical discrete choice framework, in PVE the respondents are no longer selecting a single option, but a portfolio consisting of different investment projects. Consequentially, the expected social utility of each portfolio is a function of the social utility of the different projects contained in the portfolio. Dekker et al. (2019) present an elaborate framework to address preferences in the context of PVE and to derive social values in accordance with the underlying principles of welfare economics. They assume that the utility of a given portfolio is given through the sum of the utility of all projects considered in the portfolio (and of the saved resources, in case the entire budget is not allocated). This depiction of the utility however, is limited, as it does not consider that different projects may exhibit important positive (or negative) synergies, if they are implemented jointly. Along the same lines, it can be argued that individuals may refrain from budgeting similar projects, or favoring the same group of people, due to fairness criteria, even if considered independently, these are the projects exhibiting the highest social utilities in the pool. Similarly, given the fact that (social) marginal utilities are decreasing, the social utility of a given portfolio may be much lower than the sum of the parts, if they result in benefits associated with the same variables (e.g. two highway projects reducing travel time between A and B). While it is possible to impose the restriction that similar projects cannot be selected, such an exogenous restriction does not seem to be necessary, as it seems better to let decision-makers evaluate by themselves, whether a given combination of projects is meaningful or not.

The aforementioned problem requires the development of a framework capable of capturing gains and losses in utility due to the existence of positive and negative synergies, respectively. The main contribution of the current work is to develop the aforementioned methodological framework. Note that the ability of capturing positive and negative synergies among projects goes beyond the limits of the PVE, offering also powerful insights for the evaluation of projects in the context of conventional CBA by tackling one important limitation (namely that all projects are evaluated independently). Policy makers also perceive that this is an important problem of CBA (Mouter et al., 2013). Finally, the proposed approach is tested with the help of two illustrative examples (one synthetic and one real dataset).

2. METHOLOGICAL APPROACH

Given that the focus of this paper is set upon the composition of the portfolios, the proposed methodological approach will substantially differ from the treatment previously suggested by Dekker et al. (2019), which is based upon the multiple discrete-continuous extreme value (MDCEV) model (Bhat, 2008). Under the assumptions of the MDCEV, a given discrete item will we consumed if and only if its expected utility is larger than the marginal utility of money (Lagrange multiplier of the budget constraint), or, in the context of PVE, a given project will be selected if its expected social utility is larger than the marginal utility of additional governmental budget (assuming a fixed budget) or of the private consumption (assuming a flexible budget). Therefore, the inclusion of a given project in the portfolio is independent from the inclusion of other projects. While, under this approach, it would be straightforward to include correlation among the utility functions of different projects, this correlation would merely refer to the way, in which the expected utility of the correlated projects is perceived by the decision-makers and not to the utility that is ascribed to their joint inclusion in a portfolio. To illustrate this situation, let us consider one individual favoring private transportation; this decision maker may ascribe higher utility functions than the average population to road infrastructure projects, which would be captured by including correlation terms in expected utility functions of such projects, but this correlation does not provide information on whether this decision-maker would prefer including such projects in the chosen portfolio at the same time.

Addressing positive and negative synergies between projects necessarily requires considering interactions between individual projects thereby treating the chosen portfolios as a whole. Therefore, it is convenient to consider the choice probabilities of the entire portfolios and not of the independent projects and, consequently, to frame the decision as a choice between portfolios which consist out of potentially interdependent projects (and not whether to include a given project in a portfolio). This framing, however, may be expensive in terms of statistical and computational efficiency, as it would require considering the entire set of feasible portfolios A_P (combinations of projects k satisfying the budget constraint B). Under these circumstances, the decision-maker i would opt for the portfolio p providing the highest expected social utility SU, so that the choice probability of the portfolio p is given by:

$$P_{ip} = P(SU_{ip} > SU_{iq}) \quad \forall p \neq q \in A_p \qquad [1]$$

The social utility of a given portfolio, in turn, will be given by a function of the social utility of the different projects k contained in p.

$$SU_{ip} = f(SU_{ik} \mid \forall k \in p) \qquad [2]$$

Then, assuming additive linearity, the social utility of a given portfolio can be expressed as:

$$SU_{ip} = \sum_{\forall k \in p} SU_{ik} + \sum_{\substack{\forall k \in p \\ \wedge m \neq k \in p}} \alpha_{km} + \alpha_B \cdot (B - \sum_{\forall k \in p} C_k) + \varepsilon_{ip} \qquad [3],$$

where α_{km} are parameters to be estimated and account for the changes in the expected social utility of the portfolio p (relative to sum of the independent social utility of the projects $k \in p$), given that both k and m are included into the portfolio. Hence, α_{km} represents a measure of the synergy given the joint inclusion of both projects[1]. C_k represents the cost of implementing project k and, consequently, α_B (to be estimated) stands for the marginal utility of a monetary unit in the budget not being allocated to investment projects. Lastly, ε_i represents an error term that can follow any desired distribution, but, for practical reasons, it would be assumed to i.i.d. EV1-distributed. Under this assumption, the choice probabilities P_{ip} would be given by a Multinomial Logit. Finally, the social utility of a project k is given by:

$$SU_{ik} = \beta_k + \beta_C \cdot C_k + \sum_j \beta_{kj} \cdot x_{ikj} + \eta_{ik} \qquad [4],$$

where β_k, β_c, and β_{kj} represent the project specific constant (PSC), the marginal social utility of the project's cost (which may differ from α_B) and the marginal social utility of the projects characteristics x_{ikj}, while X is an error term that can follow any desired distribution (or eventually be ignored, as it is not required for the model's estimation).

It is important to note that different portfolios including the same projects would be necessarily correlated. However, this correlation would be addressed implicitly by the model through the inclusion of eq. [4] (including the error the error term η_{ik}) into the social utility function of all portfolios containing the same project.

3. ILLUSTRATIVE EXAMPLES

The framework has been tested with help of a real and synthetic dataset. Because of space constraints, in the following, we will merely present the illustrative example relying upon the synthetic dataset. For details on the real dataset, the reader is referred to de Geus (2019).

The synthetic dataset was constructed in the following fashion: 5,000 pseudo-individuals, are supposed to select investment portfolios by maximizing the expected social utility promised by them, in accordance to equations [1], [3], and [4]. To construct the investment portfolios, the pseudo-individuals can choose among four different projects, each of which

[1] It is important to note that this specification allows addressing synergies between two projects only. It is straightforward to extend the specification in order to consider synergies between three or more projects, but it would result in an important increase in the numbers of parameters to be estimated and in important losses in terms of statistical efficiency.

has a cost of one monetary unit. It is assumed that the pseudo-individuals can assign up to 3 monetary units. Thus, there are 15 feasible portfolios including the empty set. The expected social utility of projects 1 to 3 are characterized by a project specific constant (PSC) and single project specific variable x_i, $i=1..3$, multiplied by the marginal social utility of β_{xi} (x_i, $i=1..3$ follow i.i.d. standard uniform distributions). The social utility function of project 4 is characterized by a PSC only. Furthermore, it is assumed that not allocating all resources results in a positive utility, as resources are saved. It is also assumed that projects 1 and 2 as well as projects 3 and 4 exhibit negative synergies. The joint inclusion of projects 1 and 3, in turn, is associated with a positive synergy. No synergies are associated with the remaining combinations of projects. Finally, the error terms ε_i follow i.i.d. EV1 distributions with equal mean and scale parameter 1. No project specific error terms η_{ik} were considered. Table 1 summarizes the values used in the generation of the dataset (the table follows the nomenclature introduced in the previous section).

PSC_1 :	0	β_{X1} :	2	α_B :	0.8
PSC_2:	0.333	β_{X2}:	1.333	α_{12} :	-0.5
PSC_3:	0.666	β_{X3} :	0.666	α_{34} :	-0.5
PSC_4:	1	β_C :	0	α_{13} :	0.5

Table 1 – Values used in the generation of the synthetic dataset.

Note the β_c was assumed to be equal to 0 for all projects. It basically means that the negative marginal social utility of the projects' cost does not differ from marginal social utility of a monetary unit in the budget.

A model was estimated following the exact same specification used in the generation of the dataset, even though it was allowed for the entire set of synergy parameters α_{km} (some of them were considered to be zero in the generation of the dataset). As described in Section 2, the estimation was performed at the level of the portfolios and the parameters were estimated by maximizing the likelihood. Table 2 reports the results of the estimation.

Table 2 – Estimated parameters. Synthetic dataset

Variable	*Target Value*	*Estimated model* Estimate *(st. dev.)*	
PSC_1	0	**0**	*(fixed)*
PSC_2	0.333	**0.369**	*(0.105)*
PSC_3	0.666	**0.684**	*(0.102)*
PSC_4	1	**1.04**	*(0.088)*
β_{X1}	2	**1.97**	*(0.105)*
β_{X2}	1.333	**1.43**	*(0.103)*
β_{X3}	0.666	**0.66**	*(0.099)*
α_B	0.8	**0.914**	*(0.082)*
α_{12}	-0.5	**-0.472**	*(0.06)*
α_{13}	0.5	**0.539**	*(0.062)*
α_{14}	0	**0.132**	*(0.063)*
α_{23}	0	**0.052**	*(0.063)*
α_{24}	0	**0.024**	*(0.064)*
α_{34}	-0.5	**-0.530**	*(0.061)*

As it can be observed, it is possible to recover the parameters used in the generation of the dataset without major problems, as it is not possible to reject the hypothesis of equality between the estimated parameters and the target values. The only surprise relates to the synergy between projects 1 and 4, which was not considered in the generation of the dataset and was found to be slightly statistically significant in the estimation; however, its effect is neglectable compared with the other estimated parameters.

Consequently, the synthetic dataset reveals that if the population indeed behaves as assumed in Section 2, the proposed framework is capable of capturing positive and negative synergies between projects. Hence, it provides evidence sustaining the validity of the approach to evaluate the social utility individuals assign to different social investment projects as well as to capture positive and negative synergies among projects in the construction of investment portfolios.

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