The Gains and Losses Puzzle in Discounting for Long-Term Investments: Reinterpreting Ramsey Approach for Intergenerational Perspective

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Abstract In the appraisal of intergenerational public investments due to their extraordinary long life-cycle special attention must be given to the value of discount rate that influences greatly the net present value of a project in appraisal procedures. Of tremendous importance is the issue of including uncertainty via discounting due to the fact that intergenerational investments face high uncertainty which is coupled with the lack of unambivalent theoretical foundations and variety of empirical estimations of discount rates. The paper contributes to the discussion of social discount rate based on the Ramsey formula in the context of intergenerational allocations as well as discrepancies in treatment of costs and benefits from individual and social perspective. The reconstructed social discount rate formula that is proposed in the paper differentiates: firstly, between intra- and intergenerational frame due to discontinuity between generations, and secondly, between project's costs and benefits owing to opposite signs of risk premia and the differences in gains and losses valuation.

Keywords Intergenerational investment · Uncertainty · Social discount rate · Risk-aversion

1 Introduction

Uncertainty matters greatly in case of intergenerational projects, where effects endure for at least one generation, assuming generational switching point of 30 years. While short-term investment may be perceived as risky, while future outcomes and their probabilities are relatively well recognized, intergenerational projects face high level of uncertainty. The examples of such projects are numerous, including infrastructure like highways or railways, however the majority of such projects relate to environment, i.e. coal based and nuclear power plants, climate change mitigating activities or biodiversity protection, where effects stretch over hundreds of years. The passage

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P. Linsley et al. (eds.), *Multiple Perspectives in Risk and Risk Management*, Springer Proceedings in Business and Economics,
https://doi.org/10.1007/978-3-030-16045-6_12

of time combined with crossing generational border put appraisal of such long-time investments under specific threats in appraisal procedure.

There are numerous tools for dealing with uncertainty in project appraisal, i.e. expected Net Present Value (NPV) and related statistical methods, certainty equivalent approach or real option approach (cf. Pindyck 2000; Marcinek et al. 2010; Pera 2010). Discounting procedure can be used to serve this purpose as well. However, in case of intergenerational activities, especially environmental investments, one must highlight the disagreement among scholars regarding the issue of discounting distant-future events, like climate change (cf. Gollier and Weitzman 2009). These controversies arise from number of sources.

Firstly, intergenerational rate of discount is not observable on the market. The attempt to adapt market rates to intergenerational investment appraisal is limited due to relatively short maturity of majority of securities (20–30 years). That makes intergenerational intertemporal preferences unobservable on the market and justifies moving to social appraisal where social discount rate (SDR) is applied. However, the theoretical foundations of social discount rate are vague, with a number of opposite views and diverse values of rates provided by empirical works (cf. Climate change 2014; Foltyn-Zarychta 2018).

Moreover, owing to the longevity of project cycle, some ethical issues arise. One of major difficulties is the fact that the investing generation is separated in time from the people who will bear the fruits of today's activity, which is combined with inability of future people to take the decision on their own: to accept or oppose to the decision being taken by their predecessors. Future people will face certain circumstances as a consequence of a decision they cannot influence. Furthermore, substantial number of such investments influence environmental quality or quantity. These areas are especially vulnerable to uncertain effects and harm inflicting coupled with irreversibility of actions. In long-term perspective intergenerational risks may be understood as threats to future generations (Hartzell-Nichols 2012).

In view of the concerns presented above, the first issue discussed in the paper embraces the stability of theoretical foundations of discounting under uncertainty when switching the appraisal perspective from intra- to intergenerational time frame. The paper investigates components of the Ramsey formula (Ramsey 1928), which is commonly adapted approach to deliver the value of social discount rate in intergenerational time-frame as well as analyses "precautionary effect" added to the Ramsey formula and deals with risk premiums pointing to the inconsistency between lowering Ramsey discount rate in long-term perspective and adding positive risk premium during myopic analysis. Furthermore, the paper aims at redefining the Ramsey formula components to suit intergenerational time-frame. We concentrate on risk aversion that impacts the shape of utility functions, both on individual as well as social and intergenerational level. We investigate discrepancies in individual attitudes toward risky gains (risk aversion) and losses (risk seeking) and their magnitude (Kahneman and Tversky 1979). Medvecky (2012) notices there seems to be an inconsistency between theoretical assumptions and empirical evidence for treatment of cost via discount rate. This inconsistency is also visible in valuation, i.e. differences in estima-

tions of willingness to pay (WTP) for gains and willingness to accept compensation (WTA) for losses.

The goal of the paper is to argue for the reconstructed social discount rate formula that encompasses simultaneously: (1) multiple generations and (2) discrepancies in costs and benefits perception under uncertainty.

The novelty of the study lies in elaborating a justification that differentiates: firstly, between intragenerational (individual) and intergenerational (social) frame attributable to discontinuity between generations, and secondly, between project's costs and benefits ascribed to opposite signs of risk premia and the differences in gains and losses valuation.

The methods of research included critical analysis of relevant literature sources. Logic abstraction and generalisation were used to reinterpret and develop the intergenerational social discount rate formula.

The implication of the results relates to possible facilitation of evaluation process via applying separate discount rates to negative and positive project's effects, that so far do not differentiate between gains and losses.

The paper starts with presenting an insight into social discount rate approaches that reflect uncertainty toward future effects and summarises the discrepancies in valuation of costs and benefits and risk aversion perception. Then, the reconstructed SDR formula is proposed starting with the rationale of discounting in the light of multiple-generation time-frame. The paper ends with discussion and conclusions, summarising the results.

2 Issues in Discounting for Project Appraisal Under Risk and Uncertainty

2.1 Uncertainty and Its Impact on Discount Rates: Long-Term Versus Myopic Perspective

Discount rates used by the private sector can be estimated with market-observable rates, that include inter *alia risk* premiums. These premiums are generally positive and added to a risk-free rate. It reflects assumptions behind investor's utility function comprised of return and risk (Markowitz 1952), where the increase in return boost investor's utility while increase in risk works in opposite direction pursuing investors to require higher gains for more risky outcomes.

In public projects appraisal the discounting takes place as well, however it does not have unambiguous foundations. Social discount rate can be estimated on the basis of rates of return from private investments, which are interpreted as opportunity cost of implementing public projects. It may also reflect a consumption rate of interest, based on individual intertemporal preferences observed on the markets (cf. Baumol 1968; Spash and Hanley 1994). Both—rates of return and consumption rates of discount—include risk premiums. Although it is proposed to exclude risk component

from the analysis in case of public projects, due to the assumption that they form a diversified portfolio, opposite views are also present (Cropper et al. 2014; Guidelines and discount rates for benefit-cost analysis of federal programs 2016).

As an alternative to market rates, the Ramsey formula is proposed (Ramsey 1928; Cropper et al. 2014), which depends on prospects of future per capita consumption growth (g) and elasticity of marginal utility of consumption (η) coupled with pure time preference (ρ):

$$\mathrm{SDR} = \rho + \eta g \tag{1}$$

Pure time preference emerges from the fact that a person prefers to consume earlier than later or, otherwise, feels the immediate discomfort of self-denial (Frederick et al. 2002). The ηg mirrors the opportunity cost lost when the consumption is delayed. Under positive consumption growth assumption, we expect that a society will be wealthier in the future thus consumption delayed in time is worth less today due to decreasing marginal utility of each additional unit of consumption. Additionally, elasticity of marginal utility of consumption may be referred to as inequality aversion, depicting social willingness to equalize opportunities for society members (cf. Arrow et al. 2012; Freeman and Groom 2013).

When non-deterministic circumstances are taken into account, Ramsey equation is modified to include risk component by lowering its value due to uncertainty about the consumption growth rate (Arrow et al. 2012; Gollier and Weitzman 2009). The value of this reduction Arrow et al. (2012) define as "a precautionary effect": since it reduces the discount rate, the social planner will save more at present. Gollier et al. (2008) argues that it justifies decline of discount rates with time. Weitzman (1998, 2001) also introduces uncertainty via time-declining discount rates schedule. The decrease in discount rates is justified by placing much higher weights on low discount rates scenarios associated with higher present value in relation to scenarios with high discount rates (and thus low present value) (cf. Fisher 2003; Arrow et al. 2012).

Apart from time-declining discount rates, uncertainty in the Ramsey formula is included via the interpretation of elasticity of marginal utility of consumption which could be perceived as a measure of relative risk aversion. Smith states that in modelling under risk "(…) higher η implies more disutility from exposure to risk" (Smith 2011). Weitzman follows this assumption arguing that higher values of risk aversion depicted by η are associated with lower future discount rates (Weitzman 2001, 2010).

All the above proposals generally lead to decreasing values of discount rate in time, which makes present value of delayed effects higher in comparison with a situation when no uncertainty is taken into account. However, what must be pointed out is that while in long-term analysis uncertainty lowers the discount rate, the short-term rates under uncertainty are increased by risk premiums—in case of risky outcomes, investors are willing to expect higher returns to compensate for additional uncertainty they face. This discrepancy is rarely referred to directly, although the discounting basics are common both for short-term as well as long-term allocations.

2.2 *Uncertainty and Its Impact on Discount Rates: Long-Term Versus Myopic Perspective Magnitude Effects for Costs and Benefits*

A canonical, utilitarianistic approach to appraisal rests on individual utilities, which are analyzed on an individual level or aggregated when it comes to social evaluation. However, such utility functions under risk are susceptible to behavioral biases. In the paper we concentrate on risk aversion impacts in utility functions on discount rate. The roots of the problem lie in separate treatment of gain and losses in individual utility functions. There are two issues that have to be analyzed when dealing with costs and benefits.

The first one refers to preferences for risk acceptance. Under the assumption of risk aversion, an individual is willing to pay a premium to avoid uncertainty: she is willing to pay a given amount to change uncertain expected benefits into certain payoff. For a risk averse individual utility function is concave for benefits, so expected utility of risky choices is lower than utility of expected outcome and risk premium, or option value, is positive. That justifies the increase in the discount rate and inclusion of risk aversion premium as one of factors constituting SDR for project appraisal.

However, when analyzing future possible losses, an individual is in fact a risk-seeker. Kahnemann and Tversky (1979) proved that individuals show risk-averse attitude towards gains, but risk-loving preference toward losses. Assumption of risk-loving attitude toward losses and risk-aversion toward gains follows the standard discount rate estimation, where positive element exhibiting risk attitude increase the value of the discount rate and makes present value of both—costs and benefits—lower.

On the other hand, when public long-term projects are involved, some researchers indicate that risk aversion should be ascribed to losses as well. Medvecky (2012) argues that "to accurately reflect risk aversion, the part of the discount rate which reflects risk aversion in regard to future costs should be negative". Then the discounted value of future costs is higher than the same value of discounted benefits. That is confirmed by Peccoro and Nijkamp (2012), who argue that "often individuals appear to have a discount rate lower for losses than gains, exhibiting what is called the sign effect". Furthermore, taking into account "precautionary effect" that lowers the value of Ramsey discount rate, we may infer the conclusion that in case of public projects there is some willingness to ascribe risk aversion to losses as well.

Then the question arises whether to keep the discount rate uniform in both domains, reducing the present value both for gains and for losses, according to Kahneman and Tversky's findings, or whether to follow opposite assumptions keeping discount rate lower for losses, and then increasing present value in comparison to comparable future benefits.

The second issue under consideration in case of discounting under risk and separate treatment of costs and benefits emerges due to unequal valuation of gains and losses (cf. Kahneman and Tversky 1979). Pearce and Turner (1990) indicate that "people value gains and losses asymmetrically, attaching a lot more weight to a loss

compared to the existing position than to a gain". It can be explained by several reasons, including pure loss aversion, or endowment effect, where people value goods which they are familiar with higher than other goods, and prospect theory, where individuals value gains and losses in comparison to some "reference point" and the negative deviations from this point (losses) are valued more than positive deviations (gains) (Kahnemann and Tversky 1979; Boardman et al. 2001).

The uneven weighting of gains and losses is also visible in contingent valuation studies, used in appraisal of public projects when non-market goods are delivered. In such cases a hypothetical market with willingness to pay (WTP) and willingness to accept compensation (WTA) is created to deliver the value of non-market effects. WTP is used to measure benefits (positive changes in quality or quantity of goods affected by the investment) while WTA serves as an illustration of a person's minimum acceptable compensation for losses (negative outcomes of the project). Whitehead and Blomquist (2006) highlight the difference in values of WTA and WTP and the general tendency in results of the contingent valuation studies showing WTA to be higher than WTP. The range of the difference can differ: Garrod and Willis (1999) indicate WTA to be higher than WTP from 2 to 5 times, while Boardman et al. (2001) suggest WTA to be higher from 4 to 15 times than WTP for the same good.

Such discrepancies in valuation may be also interpreted as a premise to diversify discount rates for gains and losses.

3 Restructuring Social Discount Rate Under Uncertainty and Intergenerational Perspective

3.1 Intergenerational Framework in Discounting: Individual, Social and Extended-Social Perspective

Apart from the vagueness in the sign and magnitude of uncertainty impact on discount rates, the issue of intergenerational time-frame makes the picture even more complex. Estimating the value of discount rate for very long-term investments is difficult due to multiple reasons.

The first obstacle is that intergenerational rate of discount is not observable on the market. While standard public investments, with life-cycles of 10, 15 or 20 years may use financial market rates as the basis of discounting, the maximum maturity dates for securities reach 20–30 years. For longer cycles some normative assumptions must be applied, whether by using Ramsey approach, or by creating intergenerational hypothetical markets to derive directly intertemporal stated preferences (cf. Drupp et al. 2018; Cropper et al. 1994).

Secondly, transition from intragenerational to intergenerational time frame creates discontinuity between the decision-makers (the present generation) and the beneficiaries of the decision (future generations). That involves irrevocably a normative

judgement as well and causes some serious consequences for basic assumptions in investment decision theory, based on utilitarian individual wealth maximization.

For intergenerational perspective, the important assumption that has to be made is that the models can no longer be designed from individual perspective. Escaping from individualistic welfare is perceived as one of crucial challenges for long term projects (Sussman et al. 2014). The change of approach is needed due to the fact that for intergenerational time frame the decisions cannot be made from individual point of view, which is, inevitably, limited to the lifetime of a person that makes the decision. While public projects aim at social welfare maximization, the foundations are still utilitarianistic, meaning that this social welfare is measured by a sum of individual utilities. Therefore, any investment exceeding the expected lifetime of the decision-maker (an individual or a member of society living at present) would not be accepted, unless the expected benefits for the decision-maker herself would be greater than costs she incurs. In other words, investment decision to accept the project would be positive only when NPV *for the individuals living at a moment of taking the decision* is positive. Staying at the individualistic intra-generational models for utility maximization would lead to rejection of any investment producing positive NPV for longer, intergenerational time but negative NPV for myopic, investing-generation perspective.

Intergenerational perspective extends the appraisal to multi-generational perspective in a similar way as financial appraisal (private rates of return) is extended to the economic one (social discount rates) by switching the maximization objective from individual (maximization of the company's value, maximization of the wealth of the shareholder) to social welfare (utility maximization aggregating contemporary living individuals' welfare). The transition from an individual to society must therefore be extended to many societies appearing with the passage of time, exceeding purely utilitarianistic perspective.

Economic analysis accepts as a bottom line the simple aggregation of individual preferences (which under utilitarianistic approach aim to maximize their own utility) that in total form a social welfare function. While this view can be accepted for one-generation perspective, where the one who invests, is the one who get back all the effects (actually or potentially), this is not enough for intergenerational time frame, due to non-coexistence of the investor and the receiver. We propose then to introduce the term: *extended social approach* to reflect between-generational aggregation.

We therefore argue for a *reconstructed approach to social discount rate in intergenerational time frame*. The need for reconstructing SDR under uncertainty and intergenerational time frame arises due to the discontinuity between generations and switching from individual to extended social perspective. Aiming at elaborating a unifying approach, two issues must be considered: (1) the redefinition of components in Ramsey approach, (2) unequal treatment of gains and losses.

3.2 Redefining the Ramsey Formula Components

Since market data for long-time horizon is unobservable, the prevailing approach to estimate discount rate is the Ramsey formula. Even though for long-time frame it is adjusted to deliver time-declining discount rate schedule, lowering the rate works in opposite direction in comparison with the requirement of gaining additional compensation for risky outcome. In addition, intergenerational framework creates very specific conditions that makes the Ramsey formula's parameters highly vulnerable to normative judgements.

In the light of intergenerational discontinuity, the very issue of discounting should be interpreted differently than in intragenerational perspective. The justification starts with analysing the reasons for changing value of money in time, which are: opportunity cost, pure time preference, and risk (uncertainty). All of them are reflected in the Ramsey formula (Eq. 1), where pure time preference depicts utility discount rate (ρ), opportunity cost is reflected by consumption growth rate (g) and risk aversion is depicted by elasticity of marginal utility of consumption (η).

Opportunity cost measures what is abandoned to go on with the investment. That is true for an individual and the society comprising of aggregated individual preferences as well as for intergenerational time frame, under extended social approach. From an individual point of view, the cost of opportunities that are lost is still present, irrespectively of whether the individual is enjoying the benefits from the investment or whether the gains accrue to future people. The only doubt that should be raised is the fact, that although an individual (or society) is resigning from something today, she cannot expect any compensation since the effects (all or some) will be enjoyed by future individuals, not by herself. However, turning to extended social perspective, the discontinuity issue disappears, so it is reasonable for multigenerational society to expect the reimbursement for investments done today.

Furthermore, discussing uncertainty, we must refer first to lowering discount rate due to uncertainty about future growth, the "precautionary effect". It works both, short-term as well as long-term, with the impact lowering discount rate more and more substantial with the passage of time due to higher and higher level of uncertainty. The uncertainty of future growth reflects future outcome volatility. The precautionary element does not disappear for future generations as well. Therefore, it may be defined as *intergenerationally stable*: its justifications hold within one generation just as when crossing generational border.

While opportunity cost justification holds when switching from individual to social perspective extended intergenerationally, the pure time preference becomes controversial. The impatience makes time-distant flows value less. However, in case of intergenerational effects, that affect future people, other than those making the investments decision, pure time preference is difficult to defend. The rationale behind applying zero as pure time preference comes from the non-existence of the individual at the moment where future generations are affected by investment impacts. The excitement from immediate consumption makes it less valuable when it is delayed, however, it is still expected by the investor. In case of intergenerational investments

there is no reason to expect future consumption due to the fact that it is a priori dedicated to someone else in the future. Additionally, when interpreting pure time preference as discount rate for utility, it becomes equal to zero to avoid unequal treatment of people only due to passage of time (cf. Weitzman 2010; Arrow et al. 2012; A social time preference rate for use in long-term discounting 2002). Newell and Pizer (2001) refer here to Ramsey opinion that it is ethically indefensible to discount the *utility* (i.e. well-being) of future generations, although it does not imply a zero-discount-rate for their *consumption* (e.g. measured in dollars). Opposite views suggest positive rate of utility discounting since human race faces extinction at a constant hazard rate (cf. Dasgupta 2008).

The third reason, elasticity of marginal utility of consumption (inequality aversion), need reinterpretation due to the discontinuity problem and the need of switching from individual perspective to social one. Elasticity of marginal utility of consumption should be then interpreted in intergenerational context as social aversion to inequality between generations. It follows risk aversion concept in a way that higher inequality aversion imply preference for lower but stable outcomes with passage of time instead of huge differences in consumption level between generations. Arrow et al. (2012) argue that it reflects the maximum sacrifice one generation should make to transfer income to another generation. So higher values of η imply lower inequality aversion and higher discount rates. The similar interpretation is proposed by Smith (2011), who argues that elasticity of marginal utility of consumption "(…) is equivalent to increased inequality aversion and a preference for more redistribution, both within and across generations".

Arrow et al. (2012) argue that inequality aversion can be inferred from the progressivity of the income tax structure. However, it should be noted, that such observations deliver only static inequality aversion estimates, due to the fact that they are made on the basis of present or past tax structures.

Nevertheless, since inequality aversion may only be measured by observing the preferences of contemporary generation, when it is applied for appraisal of intergenerational investments, in fact it serves as an illustration of contemporary people's ethical attitude towards future generations. The higher the inequality aversion, the lower the discount rate is and more weight is given to future people's consumption. The lower discount rate, the higher present value of future impact. As a consequence, we argue that inequality aversion reflects the willingness to equalize the weights of all generations and may be perceived as a reflection of ethical attitude, unrelated to risk attitude in myopic analyses.

Assuming this reinterpretation, and the exclusion of pure time preference for intergenerational perspective, we propose the Ramsey formula to be depicted as follows:

$$s_i = \eta g \tag{2}$$

where

s_i intergenerational social discount rate

η intergenerational inequality aversion (ethical parameter)
g projected long-run annual growth of *per capita* real consumption reflecting the opportunity cost for the investing society.

Then, Eq. 2 explains the value of intergenerational social discount rate with consumption growth rate in the future depicting opportunity cost weighted by intergenerational inequality aversion reflecting ethical stance of contemporary generation.

Equation 2 does not take into account uncertainty of future growth, which is dealt by in the Ramsey formula extensions by declining rates schedule. Since variability of *per capita* consumption growth rate in the future holds both intra- and intergenerationally, we do not refer to it directly, assuming that it will lower social discount rate with passage of time, irrespectively of crossing generational time-frame. Nonetheless, what must be looked into is the aforementioned discrepancy between positive risk premium and decline in discount rate value under uncertainty. We argue that this ambiguity may be explained by separating both issues: uncertainty over future growth rate refers to opportunities that may be lost by future people and reflect rather "precautionary effect" than simply the volatility of results, while risk premium added to the discount rate reflect compensation over possible future loses, which can be interpreted as risk aversion, positive for gains. Gollier et al. (2008) who also defines elasticity of marginal utility of consumption as inequality aversion points that it measures the curvature of the utility function, which depicts risk aversion in an individual utility function. Therefore, both may impact the value of discount rate independently from each other.

What needs to be highlighted is the fact that inequality aversion is an individual risk aversion applied in extended social perspective and illustrates the willingness of societies to equalize consumption though time. Nevertheless, the changed interpretation of elasticity of marginal utility into risk-aversion needs further investigation due to the fact that it is based on individual myopic utilitarianistic welfare maximization that does not hold in the intergenerational perspective.

3.3 Risk Aversion in Intergenerational Framework: Sign and Scale Effects in Intergenerational Discounting

The individual perspective of risk aversion toward gains and risk-loving attitude to losses corresponds with uniform discount rate applied for both, costs and benefits. It leads to adding positive risk premium to risk free rate that lowers benefits, for an individual with risk aversion for gains, and simultaneously lowers costs, for individual with risk-loving attitude for losses. However, this evokes a discrepancy between intergenerational justification of discounting and evaluation of investment, that must be analysed from extended social perspective. We argue that risk aversion may work as an additional element in social discount rate adjusting it to uncertainty and can be included on the basis of social attitudes toward risk instead of individual ones.

Society as a whole, in many cases exhibits preferences different from those of single individual maximizing her self-centred welfare. In case of intergenerational investments, where considerable share is devoted to environmental protection, it is depicted by a variety of concepts elaborated to provide effective pro-environmental measures and designed to suit long time perspective. The concepts like "strong sustainability", "safe minimum standard" or "precautionary principle" are adopted when human actions may cause adverse changes in environmental goods. According to them all possible *deteriorations* of environmental quality should be treated with special care (cf. Tietenberg 2006; Perman et al. 2003). Therefore, we may assume that while a consumer maximizes individual wealth and for losses may show risk-loving attitude, a citizen takes more precautious view (Perman et al. 2003). This is backed up by Sen's argument of different behaviour patterns of myopic consumer and farsighed citizen, where the latter includes in utility functions both, consumption and non-consumption goals (Sen 1987), that may potentially comprise of future generation welfare. If a special care can be given by increasing present value of future harms, it goes in concordance with individual risk averse behaviour, although justified on aggregate social level.

Based on the above, we propose the concept of *harm aversion*. It illustrates the "precautionary effect" in regard to losses that the society is willing to take into account, separately from intergenerational inequality aversion already included in reconstructed SDR as an ethical parameter. Therefore, we may argue that while individuals as consumers follow standard behaviour for risk-aversion for gains and risk-seeking for losses, the society, as a group of citizens, in regard to intergenerational investments with possible adverse environmental effects, shows risk aversion for both: costs and benefits.

The assumption can serve as a justification of the concavity of utility functions for both—gains and losses providing separate discount rates instead of uniform value for the former and the latter (Fig. 1).

Therefore, we propose to increase discount rates by positive risk premium for benefits and to lower them by negative risk premium for costs (*harm aversion*):

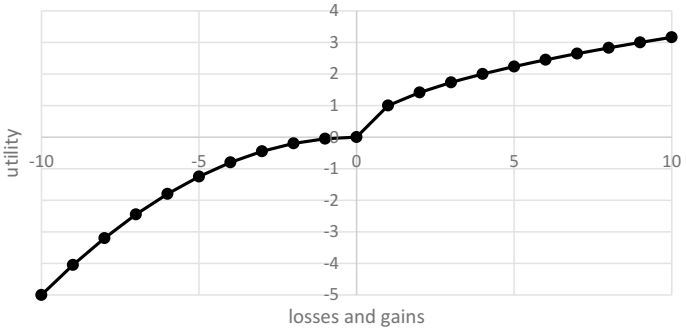

Fig. 1 A hypothetical extended social utility function for gains and losses with asymmetric valuation (losses value more) and uniform risk attitude (risk-aversion) for gains and losses

$$s_{i\,b/c} = s_i + r_{RV} = \eta g + r_{RV} \tag{3}$$

where

$s_{i\,b/c}$ social intergenerational discount rate for costs or for benefits,
s_i social intergenerational discount rate assuming indifference to risk,
r_{RV} premium for risk aversion,

and

$r_{RV} > 0$ for benefits,
$r_{RV} < 0$ for costs.

Finally, we should refer to "magnitude effect" regarding differences in valuation for gains and losses. As it was mentioned, losses are valued more, i.e. in contingent valuation studies. Looking at those discrepancies from social, intergenerational perspective, the justification may refer to irreversibility and growing scarcity of environmental goods, as it is applied in double discounting concept by i.e. Kula and Evans (2011) or Weikard and Zhu (2005). Since people put more weight on losses than gains (WTA > WTP), the unequal treatment may find its illustration in separate value of risk premiums for gains and losses which can be illustrated by the following premise: The value of negative outcomes of the project is higher than the value of positive changes of the same degree (measured in physical units) leading to higher negative discount rate premium on losses than positive premium for gains, given in absolute terms.

That is illustrated by Fig. 1, where utility functions for losses and gains reflect risk aversion and, furthermore, the change in utility for losses is faster than for gains, which justifies the higher present values placed on costs.

As a consequence, we propose two discount rate formulas, with risk aversion premiums separately estimated for costs and benefits:

$$s_{ib} = \eta g + r_{RVB} \tag{4}$$

and

$$s_{ic} = \eta g + r_{RVC} \tag{5}$$

where

s_{ib} intergenerational social discount rate for benefits,
s_{ic} intergenerational social discount rate for costs,
r_{RVC} premium for risk aversion for costs (negative),
r_{RVB} premium for risk aversion for benefits (positive)

and

$$|r_{RVC}| > r_{RVB} \tag{6}$$

Equations 4 and 5 give two separate discount rates since discount rate for costs is lower and the decrease in basic value of the discount rate s_i for costs is higher that the adequate increase for benefits. We argue that the proposed formulas resolve simultaneously:

- the issue of ethical attitudes of contemporary people to future generations, by adjusting opportunity cost given by g by a certain value of inequality aversion η defined as an ethical attitude indicator.
- the need of careful treatment of future costs, i.e. environmental resources, due to the fact that society shows a tendency for risk aversion both for costs and benefits.
- the issue of putting more weight to losses than gains due to irreversible damages and growing scarcity of environment.
- Restructuring social discount rate under uncertainty and intergenerational perspective.

4 Intergenerational Framework in Discounting: Individual, Social and Extended-Social Perspective

While discussing the results, one must turn attention to the assumption of separate risk attitudes between individuals and the society that is rooted in the criticism of utilitarianistic approach. Perman et al. (2003) highlight that individuals exist simultaneously as consumers and citizens. That is also the view presented by Sen (1987), who argues that there is essential and irreducible 'duality' in a person's considerations: "Indeed, the person himself or herself may have reasons for pursuing goals other than personal well-being or individual self-interest". He describes it as the "agency aspect" of a person, which can have some other goals than utilitarianistic well-being maximization. Taking this angle, we may further support the assumption of changing Kahneman and Tversky's (1979) "S" shape individual utility function with risk-aversion toward gains and risk-seeking toward losses as a basis that can be potentially rejected when taking social point of view, particularly in intergenerational framework, where individual perspective is cut-down to one-generation life expectancy only. This discrepancy is also noticed by Dasgupta (2008), who argues that discount rate based on discounted utility model concept suffers from a serious weakness: "(…) the formula treats differences between an individual's felicities in two periods of time in the same way as it treats differences between the felicities of two individuals in those same two periods of time. (…) It can be argued, however, that for someone to ask oneself, 'how much should I save for my children?' involves ethics that are different from those pertinent when that same person asks, 'how should I spread out my consumption over time?'(…)".

The question that should be also considered is whether the same result as proposed by Eqs. 4 and 5: positive risk premium for benefits and negative risk premium for costs, can be achieved by applying "the precautionary effect" for the Ramsey formula (cf. Gollier and Mahul 2017), which lowers the overall value of the discount rate.

We argue that there are two reasons why it cannot illustrate *harm aversion* the way as it is put forward in the paper. Firstly, it does not assume separate treatment of costs and benefits, so reduction in rate of discount due to risk inclusion, applies both for positive and negative outcomes. Secondly, the extension of the Ramsey formula is justified by the very uncertainty over the effects (consumption rate of growth or "scenarios" in Weitzman approach), not the attitude to risk itself. Therefore, we argue that uncertainty itself can be perceived a stable factor, irrespective to intra- or intergenerational perspective and the inclusion of uncertainty into the discount rate should be treated as a separate issue, due to the fact that it does not reflects individual or social risk aversion, but the variability of investment outcomes.

Furthermore, as the proposal in the paper eventually leads to applying two various discount rates, it must be contrasted with some other solutions to apply double discount rates, which emerge in case of environmental goods. It must be highlighted that such proposals do not on rest on risk aversion discrepancy in gains and losses, but they relate to the role of environment in natural and man-made resource mix. Kula and Evans (2011) as well as Weikard and Zhu (2005) indicate that the increasing scarcity in case of environmental goods should possess tremendous importance, surpassing both economic growth and diminishing marginal utility of consumption. They argue that economic growth actually undermines natural environment, and on that ground, they justify the proposal of separate discounting of environmental impacts from other costs and benefits. Another argument for separate environmental good discounting is given by Pearce and Markandya (1989), which refer to technological development and marginal productivity of capital as a source of higher relative value of environment (cf. Fisher 2003). In the light of those arguments, separate signs of both risk premia as well as magnitude effects put forward in this paper, could be applied as an extension of discount rates including the relative valuation effect, with environmental losses facing lower discount rates, than environmental gains, while man-made capital would be treated with higher discount rates for both domains.

We argue therefore that the reconstruction of social discount rate put forward in this paper can be perceived as an alternative or an extension to existing procedures, highlighting the specificity of intergenerational social framework from individual one along with differences in risk-aversion perception.

The theoretical proposal of separate discounting presented in the paper may have some implications for empirical research. Particularly, it may improve the appraisal process, particularly in case of Cost-Benefit Analysis. Majority of physical effects in economic appraisal are valued irrespectively of whether they emerge on cost of benefit side and predominant approach is to include their net value in the final analysis. In case of public goods, where contingent valuation is involved, the study may be designed from the very start to evaluate willingness to pay for gains or willingness to accept compensation for losses and then differentiating between risk premiums is not necessary as they are already included in the value of the effect. However, on a regular basis, where some secondary sources are used for valuation (cf. Guide to cost-benefit analysis of investment projects, economic appraisal tool for cohesion policy 2014–2020 2014), using the proposed intergenerational SDR may replace costly process of estimating WTP or WTA separately.

Limitations of the results should be raised as well. We may refer here first of all to the need to verify the proposed solution empirically, i.e. in respect to testing whether preferences toward intergenerational allocations are different from intragenerational in respect to risk perception. Heilmann (2013) and Ok and Masatlioglu (2007) suggest designing a questionnaire asking people about their uncertainty about the future and what is its magnitude in the discount factor which makes future flows value less at present. One must be also aware of other anomalies that may influence the intertemporal preferences. Peccoro and Nijkamp (2012) list i.e. differences in valuations between small and large changes or whether the benefits happen sooner or later than expected. Furthermore, some controversies about double discounting itself are raised (cf. Arrow et al. 2012) or giving rights to people not yet born (Spash 2002). Other controversies come from Dasgupta (2008), who argues that if consumption decrease, the rate of growth in the Ramsey formula will be negative, and then the rate of discount will turn negative as well. The paper does not reach that far in the investigation, assuming that negative inequality aversion factor is the element that decrease only the positive value of the discount rate.

5 Conclusions

Concerning the issue of reconstructing social discount rate in intergenerational projects' appraisal, on the basis of literature review and analysis done in previous sections, the general conclusions suggest the need of separation (1) between intragenerational and intergenerational time frame due to discontinuity between generations leading to failure of individual perspective for decision making, and (2) between costs and benefits of the project due to opposite signs of risk premia in the discount rate and the differences in valuation between gains and losses of the investment.

The first kind of separation involves the necessity to shift to a social point of view when investments with intergenerational perspective are analyzed. The change to social perspective is however not identical with standard cost-benefits analysis maximizing aggregated individual welfares. *The extended social approach*, the term introduced in the paper to highlight this difference, involves searching for optimum not between contemporaries, but between *generations*, and transforming reasons for change of money value in time. As a consequence of non-coexistence of the investing generation and future beneficiaries, both: pure time preference and classically defined risk aversion, cannot serve as justification for discounting of future costs and benefits. Then, the opportunity cost is the only reason for discounting that does not need redefining. However, a redefined risk aversion, which is transformed in intergenerational perspective into inequality aversion, makes the Ramsey equation risk free rate with inequality aversion reflecting ethical stance of contemporaries towards future people.

The second sort of division—between benefits and costs—assumes that the decision maker accepts "precautionary principle". It implies that for intergenerational time frame it is possible to accept risk-aversion attitude both for gains and losses

(*harm aversion*), contrary to intragenerational individual perspective, where people tend to show risk-loving preference in case of losses. Furthermore, based on higher valuations of losses, estimated by willingness to accept compensation, than for gains, measured by willingness to pay, it seems reasonable to assume higher level of absolute value of risk premium in discount rate value for costs (with negative sign) than for benefits (positive sign) due to higher changes in utility for losses than for gains.

The issue of discounting coupled with uncertainty for intergenerational time frame is far too complicated to be analyzed profoundly and completely in the paper. The findings do not offer any comprehensive solution to the problem, but may add to the discussion on the issue of intergenerational allocation decision making and intergenerational justice.

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