Present Bias in Renewable Resources Management Reduces Agent's Welfare

Persichina, Marco

Department of Economics and Management – University of Pisa

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Marco Persichina[*]

Abstract:

This study investigates the effects generated by myopic and present-biased preferences in the context of resource harvesting, specifically on the impact that the present bias has on the agent's welfare when the agent is engaged in an intertemporal harvesting activity from a stock of renewable resources. The harvesting activity, in this context, poses a conflict between the long-run benefit of the agent and the short-run desire. The paper assumes there is evidence of the existence of a dual system of response to short and long-term stimuli. Thus, the study shows and argues that in the decision-making that involves intertemporal choices in renewable resources management, the naive behavior, strongly influenced by the emotional-affective system, leads to a reduction in the lifetime utility enjoyed by the individual because of the present bias.

Keywords: Present bias, naive agent, intertemporal resource management, dual system discounting, agent's welfare, instant utility.

JEL Classification: D03, D90, Q20.

[*] Department of Economics and Management – University of Pisa. m.persichina@ec.unipi.it

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1. Introduction

Intertemporal resources management is frequently subjected to risks of inefficiency and mistakes. Often people face difficulties in defining intertemporal choices and consistently allocating consumption over time. Defining consistent decisions over the time implies the adoption of the conventional exponential discount, where the future benefits are discounted at a constant rate. A discount rate that differs from the exponential one generates time-inconsistent plans and myopic behaviors (Strotz, 1956). Unfortunately, people often behave contradictory to the time-consistency assumption. In fact, there is a wide range of studies that underline the existence of non-compliant behaviors to the precepts of time consistency - for a review Loewenstein & Pralec (1992) and Frederick, et al. (2002). Controlled experiments in the laboratory have shown that people exhibit a systematic tendency to discount the near future more than the distant one (Loewenstein & Pralec, 1992). This depends on the impulsive behaviors of people in following the short-run benefit despite its effects in the long run. Furthermore, the intertemporal choices seem to be better represented by hyperbolic discounting rather than by the exponential one (Laibson, 1997), implying that people make short-sighted decisions where costs and benefits are involved. These kinds of behaviors are interpreted as a lack of self-control or present-biased preferences (O'Donoghue & Rabin, 1999; Laibson, 1997).

This study responds to the difficulty of questioning the effects generated by myopic and present-biased preferences in the context of resource harvesting, specifically on the impact that the present bias has on the agent’s welfare. The focus is on the harvesting activities from a stock of renewable resources in which the present bias can be an element of significant impact, particularly when the harvesting activity poses in conflict the long-run benefit with the short-run desire.

In the last few years, some studies have started to explore the application of the non-constant discount rate in resource management (Settle & Shogren, 2004) and the environment (Brekke & Jhoansson-Stenman, 2008; Karp, 2005), discussing some issues related to the present-biased preferences in these contexts — in particular, the dichotomy between the biased agents and rational ones (Winkler, 2006; Hepburn, et al., 2010). However, the effect of present bias on agent welfare in the field of resources management has not yet been presented. For these reasons, this paper will show that a strict relation between the present-biased behavior and the agent’s welfare exists in this context, and it is strictly related to the nature of present-biased behaviors as phenomena that are derived by a dual system of discounting with the agent’s cognitive foundation.

2. A retrospective on time inconsistency and present bias

Standard economic models usually assume that the agent discounts the future at a constant exponential rate. This assumption guarantees the time consistency of the intertemporal choices such that choices planned and derived from the maximization of the present value are still optimal in the future when they are effectively taken. Time consistency is guaranteed by the independence of the discount rate from the time. However, theoretical and experimental studies have widely shown a higher discount rate over the short time and a lower discount rate in the distant one (Frederick *et al.*, 2002; Laibson, 1997). The time dependence of the discount rate could generate preference reversal, which implies that the preference ordering defined at a given time can be reversed in the future. Impulsivity and misevaluations of immediate rewards are included between the behavioral and cognitive origins of the preference reversal (Ainslie, 1992; Shefrin & Thaler, 1988; Benabou & Pycia, 2002). Therefore, preference reversal generates a conflict between long-run preferences and immediate choices, which consequently creates a conflict between the initial intentions of the agent and the choices implemented.

Preference reversal is coherent with the behavior of agents that show diminishing impatience such that the future is discounted with a declining discount rate (Hepburn, et al., 2010). Evidence of this kind of behavior is widely reported (Thaler, 1981; Della Vigna, 2009; Frederick, et al., 2002), and several observations clarify that time affects the choices in a manner such that a violation of the stationary postulate of Koopmans (1960) occurs — a violation that generates time inconsistency because an optimal choice at time t cannot still be optimal when the task is verified at a time that follows t (Strotz, 1956).

Preference reversal, impulsive choices, and impatience in front of immediate rewards can be explicated by the presence of a hyperbolic discount (Ainslie, 2005).[1] It is also usual to define with present bias the baseline behavior that derives from hyperbolic or quasi-hyperbolic discounting: greater impatience in the short run with a declining discount rate for a more distant future.

Present-biased preferences imply that immediate benefits lead the choices despite the long-run interest; therefore, present-biased preferences can lead the agent to myopic decisions. Present biased preferences are widely observed in several frameworks, such as, the low saving rate (Ashraf, et al., 2006; Harris & Laibon, 2001; Laibson, 1997; Laibson, et al., 1998); health contexts (Pol & Cairns, 2002); drug, smoking or buying addictions (Gruber & Koszegi, 2001; Thaler & Shefrin, 1981; Wertenbroch, 1998; Frederick, et al., 2002); and procrastinating behaviors (O'Donoghue & Rabin, 1999; Bernabou & Tirole, 2003). Furthermore, Cropper and Laibson (1998) have analyzed the non-

[1] Or quasi-hyperbolic discount.

Pareto efficiency in the issue of project evaluation when agents have inconsistent plans.

There are some contributions to the literature that show how the non-constant discount interacts with resource management and climate change policy. Settle and Shogren (2004) explored the application of the hyperbolic discount rather than the constant one in the context of natural resource management. Karp (2005) analyzed the role of the hyperbolic discount in a model of global warming, and Brekke and Jhoansson-Stenman (2008) analyzed the contribution of behavioral economics in the field of climate change. The present bias is also not without consequences in terms of externalities. In fact, Winkler (2006) showed that in the presence of hyperbolic discounting, there is a potential conflict between economic efficiency and intergenerational equity in public good investments. Also, in the framework of intergenerational renewable resource harvesting, the present bias generates negative externalities on the welfare of future generations, reducing the resource stock in the presence of other-regarding preferences of the present generation when the naive agent's behavior has no commitment (Persichina, 2016). Moreover, the present bias also affects the agent's decisions in the exploitation of resources in terms of disruption of cooperative behaviors. In fact, the present-biased preferences can trigger a strategy that directs the community to excessively increase the harvesting level even in the presence of cooperative intentions because the behavior of naïve agents can activate a dynamic of cascading defections from the cooperative strategy (Persichina, 2016). Besides, under the hyperbolic discount, the undesired collapse of the natural resources can occur if the agent is naive (Hepburn, et al., 2010).

3. Roots of present bias and the dual system of discounting

An evolutionary origin seems to be involved in the existence of the present bias. In fact, some authors assign the existence of myopic behaviors and present biased preferences to evolutionary pressure (Godwy, et al., 2013); for example, Dasgupta and Maskin (2005) argue that incertitude and waiting costs have contributed to the emerging of present-biased behaviors. Furthermore, there is evidence that the evolutionary components of these behavioral features are widely rooted in human and non-human animals (Ainslie, 1974; Green & Myerson, 1996).[2]

Evidence exists that shows the ability to ordinate the numbers in a correct cardinal order is not an innate ability of humans, confirming these ancestral roots (Godwy, et al., 2013). In fact, studies

[2] In particular, humans show more care about the future consequences of their actions in compassion with other animals (Frederick, et al., 2002). Some primates show a capability to wait patiently in order to obtain rewards that is not present in other species (Rosati, et al., 2007) .

conducted on indigenous populations of Amazonia show that these populations do not have an exactly numeric ordering, although they have a non-verbal numerical sense. Therefore, when they have to define a spatial ordering for increasing quantities, the space interval between the numbers becomes smaller and smaller (Pica, et al., 2004). Conversely, American adults offer a spatial ordering that shows an equidistant space between the numbers; the logarithmic spatial ordering of the Amazonian populations made them similar to kindergarten pupils who only in the second year of school arrive spacing the numbers equidistantly (Stiegler & Booth, 2004).
However, this result may not appear directly related to the intertemporal discounting, but as underlined by Godwy *et al.* (2013), these results effectively suggest that the non-constant discount has deep origins in the human behavior. Some research in the fields of cognitive neuroscience support a non-constant discount rate and find two different routes designed to process the discounting: one for immediate rewards and another for the delayed ones. In particular, two distinct brain areas related to the definition of intertemporal choices are identified (McClure, et al., 2004). The first area, namely the limbic and paralimbic, is an area of the brain that is heavily innervated by the dopaminergic system and is connected to short-term rewards (Breiter & Rosen, 1999; Knutson, et al., 2001; McClure, et al., 2003), while the other area belongs to the frontoparietal region, an area that supports higher cognitive functions (Loewenstein, et al., 2008). Moreover, in the field of cognitive neuroscience, some experiments show the activation of the limbic circuit just before choices that provide an immediate reward (McClure, et al., 2004); similar conclusions have been reached by Hariri *et al.* (2006) and McClure *et al.* (2007).

In this discussion, it is worth mentioning that the limbic system is the seat of reaction processes that are impulsive and emotional (Hariri, et al., 2000; Pattij & Vanderschuren, 2008), and the limbic system — which is the most ancient part of the human brain — also includes the amygdala (Isaacson, 1974) whose functions are significantly correlated with emotional activities (Cardinala, et al., 2002; Hariri, et al., 2002). Conversely, in the presence of choices that reflect deeper consideration for future gains, there is not the prevalent activation of the limbic system, compared to the activation of the areas afferent to the neocortex (McClure, et al., 2004). The neocortex, exclusive to mammals, is the most recently formed brain area from an evolutionary perspective. The neocortex's areas are markedly developed in humans (Rachlin, 1989) and play a role in appropriate, deliberative cognitive activities (Miller & Cohen, 2001; Smith & Jonides, 1999). It is, therefore, possible to assume that consumer choices in an intertemporal context define a dualism between the limbic system — whose responses are characterized by rapid impulsivity and emotion — with a prevalent activation of this system in response to short-term choices, and the deliberative–cognitive system, afferent to areas of the neocortex, which is slower and more weighted.

The joint involvement of the two systems in the decision-making process is further supported by Bechara (2005), Bechara *et al.* (1999), Damasio (1994), and LeDoux (1996). It has defined a distinction between the two systems of response to short and long-term stimuli, where the information about immediate rewards is subjected to the substantial involvement of the impulsive system, while a more appropriate reflective system refers to decisions about long-run rewards. Therefore, it is congruous to assert that the intertemporal decision-making process and the time inconsistency that comes out from this process is driven by the interaction of these two coexistent systems, coherently with the complexity of human nature (Shefrin & Thaler, 1988; Loewenstein, 1996; Metcalfe & Mischel, 1999).

The wide variety of fields and contexts in which the present bias emerges, the evolutionary hypothesis, the psychological foundations, and the systematic manifestations of the phenomena of procrastination and over-consumption, and the presence of impatience, temptation, and lacks in self-control, clearly outline a profile of the economic behavior that resides outside the barriers of the pure rational behavior. Hence, the present bias is a specific peculiarity of decisional heuristics about intertemporal choices in contexts where the long-run plans can be subject to revision over the short run and where the long-run outcomes depend on a continuum of instantaneous or short-run choices. Frequently, resource dilemmas have the characteristics of the context just cited. In fact, resource dilemmas define a situation in which long-run and short choices can come into conflict, exposing the agent to the risks related to the present bias; in particular, in the context of the exploitation of renewable resources.

4. Decreasing in agent's welfare due to the present bias

The harvesting model concerns the exploitation of a stock of renewable resources, $R(t)$. The dynamic of the growth of resources is given by the following equation:

$$R(t+1) - R(t) = f\big(g, R(t)\big)R(t) - h(t), \qquad (1)$$

where $f\big(g, R(t)\big) \geq 0$, with the constant $g > 0$,[3] is the growth rate, and $h(t)$ is the harvested amount at time t such that the stock of resources is reduced over time, $dR/dt < 0$, when the exploitation rate

[3] $R(0) > 0$ implies $f(g, R(0)) > 0$, and $R(t) = 0$ implies $f(g, R(t)) = 0$.

exceeds the natural growth rate, $h(t)/R(t) > f(g,R(t))$.[4] The interval from 0 to T is the lifetime of the agent. In this model, the resources are materials; consequently, it is not possible to have a negative stock of resources:

$$R(t) \geq 0 \quad \forall \ t \in [0,T] \text{ with } R_0 > 0, \tag{2}$$

where R_0 is the initial stock at time 0. The strictly positive initial stock and the growth rate are known by the agent, the amount harvested is not restorable in the stock of renewable resources, such that:

$$h(t) \geq 0 \quad \forall \ t \in [0,T]. \tag{3}$$

Moreover, the agent is subjected to a capacity constraint and a resource constraint. The capacity constraint implies that in each period, the agent cannot harvest an amount of resources greater than h_{max}, a value that is strictly positive and finite, such that, considering the non-restorable condition:

$$0 \leq h(t) \leq h_{max} \quad \forall t \in [0,T] \text{ with } h_{max} > 0. \tag{4}$$

Instead, the resource constraint implies that the agent cannot harvest at time t more than the amount of resource stock available:

$$h(t) \leq R(t) \ \forall t \in [0,T]. \tag{5}$$

In the model, there is not an exchange market, so the agent's welfare depends only on the amount harvested and enjoyed in each time. The utility function of the agent is defined in the usual manner:

$$U = \sum_{t=0}^{T} \delta(t) u\big(h(t)\big), \tag{6}$$

where $u\big(h(t)\big)$ is monotonic and strictly concave on $h(t)$ in the interval $[0, h_{max}]$:

$$u'(h_t) > 0 \quad u''(h_t) < 0. \tag{7}$$

The discount factor $\delta(t)$ represents the degree of impatience of the agents,[5] such that:

$$\frac{\delta(t)}{\delta(t+1)} > 1 \ \forall t \in (0,T), \tag{8}$$

Continuity for the harvesting amount on the interval $[0, h_{max}]$ is assumed. Finally, the system defined excludes the situation where there is no possible reduction of the stock of resources. This

[4] When $\partial f(g,R(t))/\partial R(t) = 0$, the growth rate is a constant exponential one.

[5] The assumptions exclude the case of pleasure in procrastination, $\delta'(t) > 0$, and neutrality in the harvesting time, which implies $\delta'(t) = 0$ with $\frac{\delta(t)}{\delta(t+1)} = 1 \quad \forall t \in (0,T)$.

context is characterized by the impossibility for the agent to avoid total exploitation of the resources before the end of his lifetime if he continuously harvests the amount h_{max} in each period. Defining with $H_i = \{h_i(0), \ldots, h_i(t), \ldots, h_i(T)\}$ a generic harvesting profile inside the set of all the feasible harvesting plans, $H_i \in \{H\}$, given $R_0, g, f\big(g, R(t)\big)$, gives:

$$\nexists\, H_i \in H : \; h_i(t) = h_{max} \; \forall\, t \in [0, T]. \tag{9}$$

Equation (9) implies that in at least one period, $h(t) < h_{max}$. Considering that the agent tends to distribute his consumption over the time, it is assumed that the agent's intertemporal preferences are given such that:

$$H_{opt} = \left\{ h_{opt}(0), \ldots, h_{opt}(t_b), \ldots, h_{opt}(s) \ldots, h_{opt}(T) \;\middle|\; \begin{matrix} 0 < h_{opt}(t_b) < h_{max} \\ \wedge \\ 0 < h_{opt}(s) < h_{max} \end{matrix} \right\}. \tag{10}$$

Therefore, at time 0, the agent will formulate the harvesting plan, avoiding planning harvesting amounts equal to h_{max} in each period until time t_b if this implies zero harvesting in a future period. This is consistent with the dependency of the welfare from the harvested amount at each time, generating utility only in the period in which the amount is harvested. Therefore, at time 0, the agent formulates his optimal harvesting plan:

$$H_{opt} = \{h_{opt}(0), \ldots, h_{opt}(t_b), \ldots, h_{opt}(T)\}. \tag{11}$$

The optimal harvesting plan evaluated in the absence of present bias guarantees time consistency of the future decisions and corresponds to the long-run harvesting plan for the agent evaluated at time 0. In fact, in the standard rational model, the agent can accurately define his exact optimal path of harvesting, keeping his bond with the initial optimal plan formulated at the beginning, and he will do this throughout his life. As described before, this implies that the discount factor must be expressed in an exponential manner that guarantees time consistency; but, present bias makes an exponential discount factor impossible.

An agent shows present-biased preferences at time t when the following hold:

$$\begin{cases} \dfrac{\delta_t}{\delta_{t+1}} > \dfrac{\delta_s}{\delta_{s+1}} \quad \text{with } \; t < s \; \text{ and } \; s \in [1, T] \; \text{ for } t = 0, \\ \dfrac{\delta_t}{\delta_{t+1}} = \dfrac{\delta_s}{\delta_{s+1}} \quad \text{with } \; t < s \; \text{ and } \; t, s \in [1, T] \; \text{ for } t > 0. \end{cases} \tag{12}$$

When the agent's preferences incorporate the properties of the non-constant discount factor just enounced, the process of maximization can lead the agent to a different harvesting plan with respect to that one predicted at time 0, H_{opt}. In this case, the harvesting plan of the agent is defined with the amounts that are derived time after time by the instantaneous maximization of the utility function under the same condition of H_{opt} but with a non-constant discount rate. The resulting plan is labelled as a biased harvesting plan, H_{bias}, and defined as:

$$H_{bias} = \{h_{bias}(0), \ldots, h_{bias}(t_b), \ldots, h_{bias}(T)\}. \quad (13)$$

A discount factor like that one expressed in the equation (12) determines the typical situation of time inconsistency.[6] The consequences are expressed in the following postulate:

Postulate 1: If it is solved at time *t*, $t < t_b$ with $\frac{\delta_{t_b}}{\delta_{t_b+1}} = \frac{\delta_{t_b+1}}{\delta_{t_b+2}}$, the problem of intertemporal optimization in the interval $[t_b, T]$, with an existent unique optimal solution, then:
$H_t = \{E[h(t_b)]_t, \ldots, E[h(t_b+1)]_t, \ldots, E[h(T)]_t\}$, where $E[h(t_b)]_t$ is the expected harvesting amount for time t_b with $E[h(t_b)]_t < R(t_b)$ and $E[h(t_b)]_t < h_{max}$.
Then, if at time t_b, the same optimization problem is solved in the interval $[t_b, T]$ with the optimal solution,
$H_s = \{h(t_b), \ldots, E[h(t_b+1)]_{t_b}, \ldots, E[h(T)]_{t_b}\}$;
if a time $t_b, \frac{\delta_{t_b}}{\delta_{t_b+1}} > \frac{\delta_{t_b+1}}{\delta_{t_b+2}}$ with $\frac{\partial \delta}{\partial t} < 0$, then $h(t_b) > E[h(t_b)]_t$.

So, the amount effectively harvested at time t_b, $h(t_b)$, is greater than the amount predicted for the same period when the optimal strategy was evaluated at time *t*, $t < t_b$.
The implications for the harvesting plan in this model can be expressed in the following proposition:

Proposition 1:
There are two possible harvesting plans that can be derived by the decision making process of the agent, the first one, $H_{opt} = \{h_{opt}(0), \ldots, h_{opt}(t_b), \ldots, h_{opt}(T)\}$, where at time t_b, $\frac{\delta_{t_b}}{\delta_{t_b+1}} = \frac{\delta_{t_b+1}}{\delta_{t_b+2}}$, and the second one, $H_{bias} = \{h_{bias}(0), \ldots, h_{bias}(t_b), \ldots, h_{bias}(T)\}$, where at time t_b, $\frac{\delta_{t_b}}{\delta_{t_b+1}} > \frac{\delta_{t_b+1}}{\delta_{t_b+2}}$. If under the assumption of present bias defined in (12) and given the conditions (9) and (10), the agent develops an expected harvesting amount formulated at time *t*, with $t < t_b$, $0 < h_{opt}(t_b) < h_{max}$,

[6] Time consistency implies $\frac{\delta_t}{\delta_{t+n}} = \frac{\delta_s}{\delta_{s+n}}$ $\forall\, t \in [0, T]$ and $\forall\, s \in [0, T]$. Only when the discounting strictly respects this condition will the agent's evaluation of the optimal strategy in every period *s* between 0 and *T* lead to the same optimal harvesting strategy evaluated in any period *t* in $[0, T]$.

then in the time interval $[0,T]$, there exists at least one period, t_b, such that:

$$h_{bias}(t_b) > h_{opt}(t_b) \text{ with } h_{opt}(t_b) \in H_{opt} \text{ and } h_{bias}(t_b) \in H_{bias}. \quad (14)$$

Thus, the present bias induces the agent to harvest an amount greater than the optimal one evaluated without the bias, prompting the agent outside from the optimal harvesting path. So, by inducing the reevaluation of the amount harvested at time t_b, the present bias generates a differentiation between the two possible harvesting plans of the agent. Now, the question is, does a different harvesting profile determined by the present bias imply a reduction of the agent's welfare, and if so, does it happen because of the present-bias?

The agent faces two different harvesting plans that respond to two different systems of discounting:
- 1 - The plan that responds to the short-run, expressed by H_{bias}, where the amount harvested at each period is affected by the present bias re-evaluating the harvesting plan time after time, and - 2 - the long-run plan, H_{opt}, where the plan of harvesting formulated at time zero excludes the effect of the present bias and is confirmed each time.

To compare the two plans in terms of the agent's welfare, referring to the concept of total utility of the agent is necessary. In particular, it is useful to separate the concept of decision utility from hedonistic pleasure derived by the instant utility enjoyed by the agent (Kahneman & Sugden, 2005). In this sense, the concept of utility is defined following utilitarian philosophers such as Bentham, where utility is logically separated from what choices are made (Read, 2007). The instant utility is the hedonic value of a moment of experience utility (Kahneman & Thaler, 2006), such that the total utility is derived by a temporal profile of instant utilities. Following this approach, a time-neutral weighting of the outcomes is considered (Kahneman, et al., 1997). Hence, the total utility of the period $[0,T]$ is given by the sum of the instant utilities of the period, allowing the total utility to be expressed as π and given by:

$$\pi = \sum_{t=0}^{T} u\big(h(t)\big), \quad (15)$$

such that the agent's welfare is evaluated by the comparison of the different profiles of the total instant utility.

The comparison of the level of total utility between the optimal long-run plan and the biased short-run shows that the agent's utility is greater in the optimal harvesting plan. In fact, the utility derived by the increase in the harvesting at time t_b, determined by the present bias, is inferior to the decreased utility given by the difference between the total amount that will be harvested following the optimal harvesting plan and the amount that will be effectively harvested under the present-bias hypothesis such that:

$$u\big(h_{bias}(t_b)\big) - u\left(h_{opt}(t_b)\right) < \sum_{t=t_b+1}^{T} \left\{u\left(h_{opt}(t)\right) - u\big(h_{bias}(t)\big)\right\}. \tag{16}$$

Therefore, the increased utility derived by a higher amount in the present is less than the decreased utility derived from the amount enjoyed in the future.[7]

Besides, the present bias is the element that generates the reduction of the agent's welfare. In order to show this assentation, it is helpful to use the utility function with present bias preferences that offers the essential peculiarity of the present biased discount.[8] The present biased preferences are then expressed in the following intertemporal utility function:

$$U_t = u\big(h(t)\big) + \beta \sum_{\tau=1}^{T-t} \delta^{\tau} u\big(h(t+\tau)\big), \tag{17}$$

where β, not greater than 1, represents the present bias. When $\beta = 1$ the discounting guarantees time consistency (absence of present bias) with an exponential discount factor, consequently the optimal harvesting plan is determined. It is trivial to show that when β is less than 1, (12) holds.

Hence, $\{H\}$ is defined as the set of all possible harvesting profiles, and a generic profile is defined as $H_i = \{h_i(0), \dots, h_i(t), \dots, h_i(T)\}$ because the harvesting profile derived from the biased harvesting plan, H_{bias}, is a profile inside $\{H\}$ and it is alternative to H_{opt} at time 0 it will be $H_{opt} \succ H_{bias}$ such that:

$$u\left(h_{opt}(0)\right) + \sum_{t=1}^{T} \beta\delta^{t} u\left(h_{opt}(t)\right) > u\big(h_{bias}(0)\big) + \sum_{t=1}^{T} \beta\delta^{t} u\big(h_{bias}(t)\big). \tag{18}$$

Because $u\big(h_{bias}(0)\big) = u\left(h_{opt}(0)\right)$ and because of how it is asserted in the first proposition, there exists at least one time t_b such that $u\big(h_{bias}(t_b)\big) > u\left(h_{opt}(t_b)\right)$, and so assuming that t_b is the first period in which (14) holds, then,

[7] The proof is provided in the appendix.

[8] This form of present biased preferences was originally used by Phelps and Pollak (1968) in the intergenerational context.

$$u(h_{bias}(t)) = u\left(h_{opt}(t)\right) \; \forall \; t < t_b. \tag{19}$$

Consequently, at time 0, $\sum_{t=t_b}^{T} \beta\delta^t u\left(h_{opt}(t)\right) > \sum_{t=t_b}^{T} \beta\delta^t u(h_{bias}(t))$ implies that,

$$u\left(h_{opt}(t_b)\right) + \sum_{t=t_b+1}^{T} \delta^{t-t_b} u\left(h_{opt}(t)\right) > u(h_{bias}(t_b)) + \sum_{t=t_b+1}^{T} \delta^{t-t_b} u(h_{bias}(t)). \tag{20}$$

Because the agent faces an intertemporal decision-making process in which at each time he defines his harvesting amount, at time t_b, he will reevaluate his harvesting profile, choosing an amount $u(h_{bias}(t_b)) > u\left(h_{opt}(t_b)\right)$ because at this time $H_{bias} \succ H_{opt}$. This implies that at time t_b,

$$u(h_{bias}(t_b)) + \sum_{t=t_b+1}^{T} \beta\delta^{t-t_b} u(h_{bias}(t)) > u\left(h_{opt}(t_b)\right) + \sum_{t=t_b+1}^{T} \beta\delta^{t-t_b} u\left(h_{opt}(t)\right). \tag{21}$$

Consequently,

$$\beta < \frac{u(h_{bias}(t_b)) - u\left(h_{opt}(t_b)\right)}{\sum_{t=t_b+1}^{T} \delta^{t-t_b} u\left(h_{opt}(t)\right) - \sum_{t=t_b+1}^{T} \delta^{t-t_b} u(h_{bias}(t))}. \tag{22}$$

Because (20) implies that $\frac{u(h_{bias}(t_b)) - u\left(h_{opt}(t_b)\right)}{\sum_{t=t_b+1}^{T} \delta^{t-t_b} u\left(h_{opt}(t)\right) - \sum_{t=t_b+1}^{T} \delta^{t-t_b} u(h_{bias}(t))} < 1$, (22) can be true only if $\beta < 1$. This shows that the strategy H_{bias}, which leads to a total utility enjoyed that is lower that H_{opt}, can be implemented only if a non-exponential time discount is adopted.

The consequence of the present-bias on the agent's welfare when he faces the tasks of intertemporal harvesting of renewable resources can then be summarized in the following proposition.

Proposition 2: Given the utility function of the agent expressed in (17), with $\beta \leq 1$, two possible harvesting plans can be derived by the decision making process of the agent: the first one, $H_{opt} = \{h_{opt}(0), \ldots, h_{opt}(t_b), \ldots, h_{opt}(T)\}$, in which $\beta = 1$, and the second one, $H_{bias} = \{h_{bias}(0), \ldots, h_{bias}(t_b), \ldots, h_{bias}(T)\}$, in which $\beta < 1$. The adoption of the plan H_{bias} leads the agent to obtain a total utility lower than in the plan evaluated at time 0, H_{opt}, such that,

$$\sum_{t=0}^{T} u(h_{bias}(t)) < \sum_{t=0}^{T} u\left(h_{opt}(t)\right). \tag{23}$$

The strategy H_{bias} can be implemented if an only if the discount factor applied by the agent incorporates the peculiarities of the present bias. Hence, between the short-run biased harvesting plan and the long-run optimal one, it is the second that generates higher welfare for the agent.

5. Conclusion and final remarks

This paper has defined a discount system that is expressed by the coexistence of two discount forms, an emotional, rapid, and impulsive system for responding to short-term stimuli and a reflective system suitable for the long term. This system of intertemporal discounting is consistent with — and is a part of — the complexity of decision-making that characterizes human beings, who respond to the simultaneous existence of a highly integrated decision-making system composed of two main circuits: the affective-emotional, where the emotional component is predominant in the dynamics of decision-making and the cognitive–deliberative, which is delegated to greater mediation in defining what actions to take given the input received. In this system, a conflict between the long-run and the short-run in the decision output can occur. The reason for the involvement of the present bias in this conflict has been presented and discussed. The discount system in which two potential discount patterns coexist — the long-run with the constant discount rate and the short-run with the non-constant discount — generates two different harvesting plans that both arise from the intertemporal preferences of the agent: two mutually excludable harvesting plans — the optimal harvesting path and the biased plan. The paper has shown that the first plan leads to greater welfare for the agent. In fact, in the long-run harvesting plan evaluated under the constant discount rate, the welfare of the individual is defined by the amount harvested in each period, ignoring that the amounts defined time after time are affected by the emotional component of the decision-making system underlying the present-bias. In fact, the optimal long-run harvesting plan is the result of intertemporal choices weighted by the interaction between the cognitive–deliberative system and the emotional-affective one.

Before this investigation, the relationship between the present-bias and the agent's welfare has not been adequately explored in the literature. In fact, studies on specific applications involving the management of renewable resource stocks, when addressing the basic question of behavior and decisions related to harvesting by naive agents, have focused on the effects in terms of resource management efficiency and resource conservation or depletion, implicitly assuming that the agent's choices will always maximize his utility. This implicit assumption, which in fact ignores the impact of the present bias on welfare, derives from not considering the naive biased/not-biased agent dichotomy as an element of an individual agent's system of preferences. In fact, addressing issues on the lifetime welfare of individuals involved in managing renewable resources inevitably involves contraposition that can be defined as a conflict of choices between those that are biased by current emotions and those of well-being. The second kind of choice is defined in the absence of present bias, that is when the system of intertemporal discounting is oriented toward overall well-being. Conversely, present-biased choices lead individuals to a calculation that is very oriented toward the short term and disregards their long-run preferences. This conflict is part of the decision process of the agent with the dichotomy biased/no-biased choices in the process of realization of the agent’s preferences.

This paper makes it possible to assert that in the decision-making that involves intertemporal choices in renewable resources management, the prevalence of naive behavior, strongly influenced by the emotional-affective system, leads to a reduction in the lifetime utility enjoyed by the individual because of the present bias. In fact, the comparison of the two harvesting plans has shown that the utility derived by the increase in the instantaneous utility determined in the present by the present bias, is inferior to the future decrease in utility determined by the adoption of the biased harvesting plan instead of the optimal one. These conclusions pose a serious question about the effective intertemporal maximization of the well-being of the agent when he adopts a present biased harvesting behavior. It should be noted that a harvesting plan derived from present bias could be not sufficient to allow a definition of effective maximization of the individual's overall well-being when he is in a condition in which he cannot cope with the excessive impulsive component in the immediate present.

These results undermine the principle for which an individual, if naïve, will correctly maximize his overall well-being according to his long-run preferences independently from his ability or possibility to commit his behaviors. Hence, the reduced welfare derived from the implementation of a strategy dominated by the impulsivity inherent in present bias, highlights problems that are relevant to maintaining a given level of resources but also shows the need to identify tools that can ensure effective implementation of strategies to neutralize the effects of present bias during the management of renewable resources. In the context in which the agent faces the risk of making decisions on the spur of the present bias, suitable nudges or instruments are required to offer to the agent the possibility to commit his harvesting plan and having the true possibility to maximize his experienced utility in the overall periods of harvesting.

Appendix

Proof of (16):

In order to show this result, a lifetime of 3 periods is considered, such that the total utility is given by:

$\pi = u\big(h(0)\big) + u\big(h(1)\big) + u\big(h(2)\big)$.

The discount is given such that:

$\delta(t) = \begin{cases} 1 & \text{for } t = 0 \\ \beta\delta^t & \text{for } t > 0 \end{cases}$, with $\delta < 1$. It trivial to show that this discount form respond to the discount factor used in the utility function in (17), and guarantees the present-bias peculiarity express in (12).

At time 0, the harvesting plan is defined by:

$H_{opt} = \{h_{opt}(0), h_{opt}(1), h_{opt}(2)\}$,

where $H_{opt} \succ H_i$, $\forall\, H_i \in H$, and where H is the set that includes all the harvesting plans feasible by the agent.

At time 1 the condition given by (14) - $h_{bias}(t_b) > h_{opt}(t_b)$ - is verified. The agent reformulates his harvesting plan for the present and future periods, implementing a different strategy in these periods:

$H_{bias} = \{h_{bias}(1), h_{bias}(2)\}$.

But, H_{bias} is one of all other feasible harvesting plans different from H_{opt}, meaning that at time 0, $H_{opt} \succ H_{bias}$, which implies:

$$u\big(h_{opt}(0)\big) + \beta\delta\, u\big(h_{opt}(1)\big) + \beta\delta^2 u\big(h_{opt}(2)\big) > u\big(h_{opt}(0)\big) + \beta\delta\, u\big(h_{bias}(1)\big) + \beta\delta^2 u\big(h_{bias}(2)\big),$$

thus:

$\beta\delta\, u\big(h_{opt}(1)\big) - \beta\delta\, u\big(h_{bias}(1)\big) > \beta\delta^2\, u\big(h_{bias}(2)\big) - \beta\delta^2\, u\big(h_{opt}(2)\big)$, then,

$\beta\delta\big[u\big(h_{bias}(1)\big) - u\big(h_{opt}(1)\big)\big] < \beta\delta^2\big[u\big(h_{opt}(2)\big) - u\big(h_{bias}(2)\big)\big]$, hence,

$$\frac{1}{\delta} < \frac{\big[u\big(h_{opt}(2)\big) - u\big(h_{bias}(2)\big)\big]}{\big[u\big(h_{bias}(1)\big) - u\big(h_{opt}(1)\big)\big]}.$$

Because $\frac{1}{\delta} > 1$, then $\frac{\big[u\big(h_{opt}(2)\big) - u\big(h_{bias}(2)\big)\big]}{\big[u\big(h_{bias}(1)\big) - u\big(h_{opt}(1)\big)\big]} > 1$. So,

$u\big(h_{opt}(2)\big) - u\big(h_{bias}(2)\big) > u\big(h_{bias}(1)\big) - u\big(h_{opt}(1)\big)$, and finally,

$u(h_{opt}(1)) + u(h_{opt}(2)) > u(h_{bias}(1)) + u(h_{bias}(2))$ such that:

$u(h_{opt}(0)) + u(h_{opt}(1)) + u(h_{opt}(2)) > u(h_{bias}(0)) + u(h_{bias}(1)) + u(h_{bias}(2))$,

where $u(h_{bias}(0)) = u\left(h_{opt}(0)\right)$.

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