## Referee report on Now or never: Environmental protection under hyperbolic discounting

In the current study the author(s) examine the optimal intertemporal investment plan in environmental protection for a society where the agents use hyperbolic discounting. It follows that agents over-weight future outcomes compared to the exponential discounting case. Using three different scenarios for the agents, which the author(s) call, committed, naive and sophisticated, it is shown than under some circumstances the agents may postpone investment for future periods leading to an inefficient outcome. This does not happen when the agents can commit to their initial plan.

Since nowadays we face serious environmental problems, I find the scope of the paper interesting and of practical relevance. However, in its present form the paper is not very 'user-friendly'. The first section, Introduction, is rather well written and seems to do a good job in positioning the paper in relation to other relevant research made in the field. The beginning of section 2, A simple model of environmental protection, is easy to follow, even though it is possible to improve upon it. However, when the discussion comes to the discount factor the analysis is rather confusing to a reader that is not "placed" in this literature. In particular, in p.4  $\delta_o = \sigma_o$  are assumed to equal unity. However, right after it is assumed that the per-period discount factors  $\sigma_{\nu}$  are increasing. Someone may perceive that the discount factor will be greater than unity which is not the case in this paper and would drastically alter the results. I would expect to be explicitly stated that  $\sigma_{\nu}$  is strictly lower than unity, i.e., for  $\nu \geq 1$  then  $\sigma_{\nu} < 1$ . Within the same paragraph it is defined the quasi-hyperbolic discounting without ever defining  $\alpha$  and its role.

In section 3, Ex ante optimal investment plan, the paper, technically, flows smoothly. However, the technical analysis is not followed by the appropriate economic intuition. This feeling keeps until the end of the paper. In particular, propositions in sections 3 and 4 state, among other things, the

conditions under which no investment takes place. There is nowhere in the paper an economic interpretation of these conditions. For example, equations (10) and (11) provide some inequalities. What do these inequalities state? It seems to me that on the left hand side we have the ratio of the marginal cost over marginal benefits from initial investment, while on the right hand side we have a ratio which is a function of the upper level per-period discount factors,  $\beta$ . A comprehensive analysis should suggest that the agent weights these two. In case that the discount factor is high enough, i.e., it tends to unity, then future benefits are really important for the agent at time t=0. Even in the case that the left hand side term is high, the representative agent will indeed invest at t=0. In my view, such an analysis should follow every proposition. At the same time, I think, that it would be informative to compare the conditions for no-investment in the hyperbolic discounting case with the corresponding ones of the exponential discounting case. At the same time, the understanding of the reader throughout the paper would improve if a numerical example is introduced, and after each proposition the conditions are presented explicitly in terms of this example.

In section 4, Ex post implemented investment, are provided the conditions for ex post implemented investment under various states of the agents, committed, naive and sophisticated. It would be easier for the reader to see a formal definition of each status in the beginning of every subsection. Crucial to the analysis is the assumption of strategic substitutability which is related to  $\phi(k^s) < 0$ . Under what conditions this  $(\phi(k^s) < 0)$  holds? And what strategic substitutability economically mean, i.e., why investment in one period reduces investment in the next period? Is it because we have more of the capital good in the economy which reduces the benefits of an investment? There are parts of the paper that try to give an intuitive understanding of the results, in particular on page 13. However, I think it would be possible to write them in a far less technical manner.

Several additional comments can be made that are of minor concern in

relation to the discussion above.

- In p.3 the author(s) assume that environmental protection is non-negative and bounded. A justification of this assumption would make it easier to digest.
- In p.12 it is stated "Moreover, no investment in all periods can still be an....equilibrium." It would be interesting to explore further the possibility of multiple equilibria and their economic interpretation.
- I think that the analysis is more relevant for local pollution problems. Transboundary pollution may be attributed to the international public good problem and it would require a different analysis.
- The examples in the Discussion section should me more clear. Correctly these environmental problems are identified, BUT, this does not mean that these problems are attributed to under-investment. The causality could be different, e.g., the global public good problem (as is denoted in footnote 8) or under-regulation due to strategic purposes. Puller (2006) in JEEM presents a model in a total different setting under which the firms may under-invest such that future regulation will be relaxed. Therefore, I would expect more specific examples such that the causality is correctly identified. For example, you may provide some figures about the level of discount rates over the periods you refer too.
- I see no difference in equations (A.13b) and (A.13c) in the Appendix so there might be a mistake.
- It may be suitable as a future extension to use delay equations in this modelling. This allows the existence of a time lag for the benefits to be realized (see for example Kydland and Prescott 1982 Econometrica).

To sum up, I believe the subject of the paper is interesting and that there are potential recommendations to be made, although, a deeper analysis and economic explanation is necessary.