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Reply to No-regret Pollution Abatement Options: A Correction of Bréchet and Jouvet

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We would like to thank the Editor of Ecological Economics for giving us the opportunity to reply to the comments of Antonin Pottier and Adrien Nguyen-Huu concerning our paper "Environmental management may yield no-regret pollution abatement options", Ecological Economics, 2009.
We are also grateful to Antonin Pottier and Adrien Nguyen-Huu for their comments that underline the importance of this paper. They give us the opportunity to define the aim of the paper and to provide some explanation starting from the intuition of the paper and then going to more technical aspects.

1 Intuitive approach

In this paper we provide a microeconomic rationale for the possible existence of "no-regret pollution abatement options" at the firm level, that is, less pollution with higher profits.

Many studies provide empirical evidence for such options, but most of them at country or sectoral levels, rarely at the firm level. As we wrote in the paper, the fact that most economists feel uncomfortable with the very existence of no-regret options must not be overlooked, for it seems to conflict with the assumption of rational behavior, as recalled in the comment on our paper.
Indeed, within a standard microeconomic framework, a rationale for no-regret options may exist if the environment, or symmetrically pollution, operates as a hidden - and, thus, neglected - productive factor within the production process, along with the usual production factors, capital and labor. By neglecting this productive factor, the firm may bear an opportunity cost. By considering how the environment or pollution interacts with the other production factors, the firm may be able to re-optimize its production process. Actually, the marginal productivity of the production factors must be corrected by the contribution of the environment or pollution in the production process. In other words, labor and capital will be paid at their marginal productivities taking account of the pollution effect on those productivities. Without any regulation (such as taxes or permits, for example), the correction of marginal productivities of labor and capital will increase firm's profit.

The role of the environmental manager is to reveal how pollution operates as a hidden production factor, for it influences the productivity of all the classical production factors. Then, the marginal productivity of labor and capital differs from their market price, and the re-optimization, in the absence of regulation, leads to a profit increase.

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To provide a simple intuition of the framework, let us consider the illustration developed in the book "Green Capital, A new perspective on growth" (by De Perthuis and Jouvet, Columbia University press, 2015, chapter Water, the shepherd and the owner). "A shepherd making a living by producing wool from sheep shearing and washing the raw wool. Suppose the shepherd is relatively efficient at small-scale shearing, with ten shearings and five fleeces an hour. Because washing the wool emits pollutants into the used water, the owner - for any reason - asks the shepherd to shear the sheep and wash the fleeces without using water. As this is more difficult, the shepherd still manages to shear ten sheep, but can only wash two fleeces an hour." Hence a part of the creation of value is thus attributable to the use made of the water and so the productivity of the water resource corresponds to the three missing fleeces.

One of the basic principles of economics is that every factor of production should receive a remuneration proportional to its contribution to total wealth production. The question is, who pays for the water as production factor? Shepherd's wage will be adjusted to his marginal productivity, and as a result it is as though the owner of the sheep were also the owner of the water and perceived the water marginal productivity. This increases its profit compared to the previous situation.

The main lesson from this approach is that part of the production associated with traditional factors of production ultimately depends on the use of the environment, or symmetrically pollution. This is not simply a matter of nomenclature, because as soon as we consider three factors instead of two at a given level of output, we necessarily see a decrease in the respective weights of physical capital and human capital in production, a decrease that is offset by taking into account the environment. The main consequence is that the productivities of the usual two factors need to be revised downwards. Indeed, by accepting that the environment is involved in production, the productivities of physical and human capital are in fact overvalued for a given level of production. The productivity of these factors, and therefore their remuneration, should be corrected, since part of the productivity attributed to conventional factors of production ultimately stems from the degradation of the environment.

2 Technical point of view

The firm produces an homogeneous good with an increasing, concave and homogeneous of degree one production function $F(X)$, where X is the vector of N production factors, $X= \{X_1,...,X_N\}$. Under *laissez-faire* the output level is $\hat{Y}$. This activity results in the emission of a pollutant in quantity $\hat{P}$, pollutant which is neglected by the firm.

The question is: what happens at the firm level when the firm moves from ignorance to awareness about the role of the environment in its production process?
The modeling *à la* Stokey (1998) allows us to answer by comparing the two situations, with and without environmental management. Using the function $\psi(z) = P/F(X)$, continuous differentiable, increasing, convex satisfying $\psi(0)=0$, allows us to define a $(N+1)$ factor production function Φ, homogeneous of degree one, in which pollution appears as an input for production,

$$\Phi(X,P) = \psi^{-1}(P/F(X))F(X) \qquad (1)$$

The overall production function is then given by $Y=G(X,P)=\min\{F(X), \Phi(X,P)\}$.

We denote by μ the Lagrangian multiplier associated to the constraint $P \leq \bar{P}$ and by using the function $\psi(z)$, the Lagrangian writes

$$\mathcal{L} = zF(X) - pX + \mu(\bar{P} - \psi(z)F(X)) \quad (2)$$

The value of X and z solutions of this problem are solutions of the following first-order conditions,

$$(z - \mu\psi(z))F_{Xi}(X) = p_i, \text{ for all } i \in N \quad (3)$$

$$1-\mu\psi'(z) \leq 0, (=0 \text{ if } z < 1) \quad (4)$$

$$\mu(\bar{P} - \psi(z)F(X)) = 0 \quad (5)$$

Obviously μ is not freely chosen by the firm. A key point is that the shadow price μ depends on the constraint level and the relation (4) implies that $d\mu/dz < 0$. This means that the closer z to one, the lower μ. It is natural to assume that the pollution target $\bar{P}$ must not outreach the *laissez-faire* pollution level $\hat{P}$ (the constraint is binding). If not, as said in the comment, firm would choose an upper level of pollution and $z > 1$. Formally, this boils down to assume that $0 < \bar{P} \leq \tilde{P}$. The environmental manager has to identify the technological opportunities that may allow the firm to reach the pollution target. Reaching this target has two effects: first, a decrease of the output level (which decreases profit) and, second, as discussed in the comment of equation (3), a re-optimized profit level with the revised marginal productivities (which increases profit),
$(z-\mu\psi(z))F_{Xi}(X) < F_{Xi}(X)$, *for all i*.
To determine the upper-bound profit increase we have to consider
$\lim_{z^- \to 1} (z-\mu\psi(z)) = (1(z-\mu\psi(1))$.

Thus, the contribution of pollution as a productive factor is embodied through all the other production factors' contribution. We agree with the comment when it says that "there exists a range $[0, \tilde{\mu}]$" is a confusing sentence. Actually, there exists a range $[\bar{P}, \hat{P}]$ of emission target P compatible with a profit increase. Therefore the upper-bound profit increase is given by
$\tilde{\Omega} = \tilde{\mu}\psi(1)F(\tilde{X})$ and the upper-bound of pollution abatement is given by $\bar{z} = 1 - \psi(1)/\psi'(1)$.

3 Conclusion

By recognizing that the environment is a production factor, we show that interaction with polluting factor *may lead* to a profit increase. With their comment Pottier and Nguyen-Huu highlight some confusions or ambiguities in the previous article. It allows us to better explain the main argument of the paper and to clarify the mathematical approach.

References

De Perthuis, Ch, and Jouvet, P-A, Green Capital A new perspective on growth, Columbia

University press, 2015.