

Thank You very much for Your encouraging and stimulating comments.

I agree with Your general comment, which is a faithful summary of the paper's intentions, and I shall therefore limit my answer to the specific points You raise. There is only one minor disagreement, and that is when You write that the study of market interactions is not necessary for the purpose of the paper which is to study the structural role of mass-conservation, etc. *from the point of view of the social planner*. It seems to me that this is a tautology, because it amounts to saying that I adopt the point of view of the social planner, because the purpose of the paper is to study the problem from the point of view of the social planner. As a matter of fact, my motivation is a different one, since the point of view of the social planner allows to study the *real problem of an optimal material state of society*, whereas the study of market interactions is relevant for understanding whether market forces can drive the economy to the neighbourhood of the social optimum or restrain the economy at a far distance from it. Of course, this is extremely important, but this area of study is very well known and well understood, since market failures have been the hobby-horse of economists since decades. For this reason, I thought it was better to focus on the *real problem*, instead of repeating what is already well known on market interactions.

I now turn to Your specific comments.

Dynamic concept of sustainability

I strongly agree with point a) of Your first comment. A stationary state, implying constant stocks, is not sufficient to guarantee sustainability. There are at least two good reasons for this.

The first reason is, as You rightly point out, that nature evolves in historical time and therefore the interaction of the economy with the biosphere may need adaptation as time goes by. It must be added however, that these types of adaptation will have to take place at longer time intervals, since the pace of natural evolution is slow, compared to the rate of change in human societies.

There is an additional reason however for the necessity of rearranging the economy-biosphere interaction in shorter time intervals, and that is, that our idea of sustainability is always conditional upon a given state of eco-systems knowledge. The experience of the past has shown, that threats to sustainability have remained covered for long periods of time and have only been uncovered by eco-systems research at a point in time, when considerable damages to the ecosystem had already been produced. For this reason, society may have to rearrange the interaction between the economy and the environment in shorter time intervals, due to improvements in eco-systems knowledge.

I do not think however that a shift to dynamics would much help to address these issues, as You seem to suggest. The reason is that a dynamic model maximizing welfare through time under mass

conservation constraints must be either based on perfect foresight or, at least, on knowledge about probability distributions over the future evolution of nature and over the future states of eco-systems knowledge, and I do not think, at least for the moment, that this is a very promising perspective.

My conclusion is rather that we should be very modest and cautious when we talk about sustainability and that we should be aware that all of our statements on this matter are conditional upon the present state of natural evolution and of eco-systems knowledge.

Endogenous knowledge

Knowledge is a very complex object of study and I do not think that a single model can possibly cover all of the complex ramifications of this field of research. My concern with knowledge is obviously limited in scope, since I only consider the effects of knowledge on productivity, eco-efficiency and the quality of consumption goods. Only instrumental knowledge therefore, and not knowledge for the sake of it, is covered by the paper, and I am not concerned with “scientific revolutions” but rather with “normal science”. My point is, that “normal” knowledge production uses capital (and other material inputs, not considered in the paper), and is therefore rooted in the material flows between society and the environment, as any other kind of human activity. If it is legitimate to ask questions about the environmental impacts of human activities, why not of science and research? For this reason, I do not think endogeneity of knowledge to be an unreasonable assumption, since possible environmental effects of material flows, set in motion by research, should be compared with benefits deriving from it. Of course, it would be silly to deny the existence of autonomous, non controllable dynamics of knowledge accumulation and to ignore that curiosity and inventiveness of researchers may influence social attitudes on the desirability of knowledge. In particular, if “spontaneous” (do You mean, without the help of computers, laboratories, libraries, etc.?) new ideas improve life without causing additional environmental disruption, there is certainly no reason to object to them.

Knowledge vs. human capital

I think You are right in saying that to use these two expressions synonymously may cause confusion. It would be probably better to delete human capital and write knowledge instead.

Alleged inconsistency of equation (26)

I do not see any inconsistency in equation (26). N is the number of individuals in the population. Each individual supplies one unit of labour per unit of time to the productive system. Therefore $N \times 1$ are total labour services to the economy per unit of time. This is equal to the sum of labour

services supplied per unit of time to each economic sector. Although N is population (a stock), $N \times 1$ is a flow of labour services per unit of time.

It often happens that flows are expressed with formulas containing stocks. For example, K is the capital stock, whereas $\delta_K K$ is the flow of capital depreciation per unit of time.

Utility function

I cannot justify $U_K < 0$ by making reference to the literature, because I am not aware of any paper making this assumption. I can only say that I make this assumption because I think it is meaningful to do so. The reasons are as follows.

Anthropogenic stocks represent materials displaced from their natural location. Although few people would object to the displacement of marble from the mountains of Paros to the body of the Venus of Milos, many would think that the displacement of concrete and steel to build a power plant is an ugly intrusion into the landscape, likely to cause a reduction in welfare. This is not in contradiction with the fact that a power plant is very useful, since it contributes to output and consumption. This positive contribution is accounted for by assuming $U_z > 0$. The task of the planner consists of finding a compromise between the negative and the positive effects of a power plant or other types of capital.

I do not think it is necessary to justify $U_D < 0$ by reference to the literature, since everybody agrees that the existence of pollutants negatively affects welfare.

Maximization problem on p. 16

I do not understand Your comment. This is a maximization problem under constraints. All variables are decision variables. These are: v , r , z , ϑ , η , π , K , D and H . These variables can be freely chosen by the planner, provided they satisfy the constraints, which are (5), (17'), (28'), (22), (23) and (24). The variables are 9, the constraints are 6. There are therefore 3 degrees of freedom. First-order conditions (30), (31) and (32) close the gap. Every choice of variables satisfying the constraints is feasible. Only a choice satisfying the constraints and the first-order conditions is optimal. What is the problem?

I agree with all of the other minor remarks and I shall consider them when revising the paper.