

Knowledge Based Innovations and Sustainable Development: Economic and Policy Insights

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Three main issues are discussed in an integrated way in this paper: weak and strong sustainability as pillars of a macroeconomic interdisciplinary discourse, the role of uncertainty and irreversibility (modelling uncertainty), and finally sustainability policies including mitigation, adaptation and innovation/knowledge-based policies. These three issues will be discussed below.

As a primary step, it's important to state the necessity of sound multi-, inter-, and transdisciplinary thinking when addressing ecological, climate, and resource-based issues from a social sciences point of view. Fatima Vieira¹ defines inter-multi-transdisciplinarity as follows:

I only came to fully understand what multidisciplinary is about when I came across a white paper published by the MIT that explained that the best example of multidisciplinary might be found when a house is being built. To build a house, you need at least an architect and an engineer, but the architect does not want to be an engineer, and the engineer does not want to be an architect: each has got his own methodology. The best image to illustrate multidisciplinary is that of convergence: we have different independent disciplines addressing the same problem, but always from the point of view of their field. The case with interdisciplinarity is different: it combines two or more disciplines, integrating them to a level where you are taken to see that each discipline can affect the research output of the other. Finally, with transdisciplinarity, we are taken one step further, since the different disciplines are so fully integrated that they generate something completely new. Convergence is undoubtedly the most promising methodology that we, at the university, have at hand today, regarding the creation of new knowledge.

A sentence from Mary Shelley's *Frankenstein*, the modern Prometheus, is also worth citing: «A man would make but a very sorry

¹ https://sigarra.up.pt/flup/en/func_geral.formview?p_codigo=215533

chemist if he attended to that department of human knowledge alone. If your wish is to become really a man of science and not merely a petty experimentalist, I should advise you to apply to every branch of natural philosophy, including mathematics» (Mary Shelley, 1818). Shelley also published *The Last Man*, a post-apocalyptic novel which can also be connected to climate-change scenarios that did not yet exist at that time but were possibly foreseeable due to the massive extraction of coal that was destroying the English landscape during the fossil-based Industrial Revolution.

First, the precautionary principle (PP) is strongly linked to the political economy of sustainability. PP is more coherent with a strong rather than a weak version of sustainability (where full or partial substitution between natural and other forms of capital is assumed, meaning that if for example human capital stocks increase more than natural capital losses, the system is on a sustainability track). Weak sustainability does not fully account for critical thresholds that could also be unknown at any given time or connected to both uncertainty and irreversibility. Political economy settings, where environmental policy is integrated with education, innovation, and industrial policies, should receive information on critical thresholds and constraints from other disciplines (exogenous to socio-economic systems).

Second, uncertainty is relevant for sustainability, even when taking the welfare economics theoretical framework into account. Two seminal contributions are worth noting for a sound, informed sustainability policy. The quasi-option value, or the value of waiting (new information on the value of the environment, for example, biodiversity) is a key concept connected to seminal works by Krutilla (1967) and Arrow and Fisher (1974). Given that only environmental costs might be irreversible, when the future (uncertain) value of environmental goods is high, an adapted cost-benefit rule would prescribe waiting to develop after getting more information about real future values. A sort of value of waiting emerges, which is driven by the potential irreversible costs of natural capital stocks that could increase in value in the future. Conservation is then supported to keep this window open. Development can be postponed following a new cost-benefit rule that considers both irreversibility and uncertainty. A normal cost-benefit rule would in some cases fail, leading to development when conservation should be chosen as a strategy. Martin Weitzman proposes instead a complement narrative, which is

driven by the simple intuition that future interest rates are uncertain. The presence of probabilistic states of the world generated a model where a new discount rate is constructed, namely a certainty equivalent discount rate (Weitzman, 1998). In policy terms, this leads (Weitzman, 2001) to declining rather than increasing exponential discounting, with discount rates of 1% for figures between 75 and 300 years from now, and 0% after that period in the very long run. The tragedy of myopic behaviour is mitigated using logic, maths, and models that aim at providing support to policy making. Weitzman's discussion revolves around uncertainty on interest rates, rather than on the complexity of knowing costs and benefits.

Both theories inform policies by integrating sustainability discourses that are strongly affected by uncertainty and cost irreversibility in some or most cases.

The third issue under consideration is the integration of adaptation and mitigation climate policy in an uncertain world historically exposed to non-linear unsmooth patterns due to wars, oil shocks, recessions, and pandemic crises. On the adaptation side, it is worth noting that local predictability of costs and shocks is perhaps lower than in the global dimension: local effects can reach high peaks. On the mitigation side, in terms of environmental policies for mitigation on local and national levels, the EU should deliver financial resources for innovation and knowledge (key in the long run) to enhance territorial resilience and support innovative absorptive capacity. Musolesi et al. (2025) analyse the endogeneity of environmental policy effectiveness with respect to the role of country-based specific investments in R&D. They state that the larger the investments in knowledge are, the stronger the possible role of policy in inducing new green inventions is. Moreover, the higher the combination of any R&D/R%D spillovers, the stronger the capacity of the socio-technical system to absorb the initial cost of the policy, and this is translated into inventions. The economic system's absorptive capacity is the ability to recognize the value of new external "information" (a policy in this case), assimilate it, and apply it to invention ends. This resilience and innovative capability is crucial to respond to uncertain shocks. Technological, social, and human capital investments set the stock of resources that support both mitigation and adaptation through flexibility and resilience. Mitigation policies could

also generate resources for adaptation as well, in a sort of policy mix “circle”.

Increasing the earmarking of revenues, following the solid, old ecological tax reform rationale is one way: clear, transparent earmarking of fiscal resources, including those coming from the auctioning of emission trading allowances² (Borghesi et al. 2016; Soberon et al. 2025). It is worth noting that the key choice between fiscal instruments (carbon taxes, levies, and charges on pollution at the local level) finds a complement in the political economy decision about the possible use of green tax/auction revenues. Labour-oriented goals can be defined in specific ecological tax reforms following the Jacques Delors European Commission white book from the 1990s: cutting labour costs for the unskilled workforce and funding training are ways to achieve environmental and labour double dividends. Other options are fuelling eco-innovations and inventions, and creating and/or sustaining the stock of knowledge for growth and sustainable development (Musolesi et al. 2025, EEA, 2019). The relative potential advantage of economic instruments with respect to command and control policies like technological standards is then threefold: static efficiency linked to the Pigouvian microeconomic theory based on externality correction; dynamic efficiency related to economics and management approaches (first among others the Porter hypothesis, that is, well-designed policies can stimulate innovation and competitiveness); and the use of revenues to compensate losses and trigger specific policy realms like education and/or innovation (Diaz Lopez et al. 2023).

In summary, uncertainty and irreversibility must be fully integrated in economic valuation, project appraisal, and policy making to unveil the true cost of development versus conservation options. Conservation might be related to future relevant socio-economic benefits; it is not a mere environmental issue.

To tackle the important challenge of global warming – which involves providing a global, intertemporal public good with uneven costs across regions – both private and public resources need to be found. On the public policy side, earmarking procedures should be enhanced,

² <https://fsr.eui.eu/publications/?handle=1814/60237>

also by using sound and effective policy communication strategies. Levies, charges, taxes, and auctions of allowances generate revenues that should fund knowledge and innovations, thereby fostering invention and resilience.

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