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Impact assessment culture in the European Union. Time for something new?

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ABSTRACT

Current approaches and cultures for the economic evaluations of environmental and health policies may suffer from excessive reliance on a standard neoclassic economic toolbox that neglects alternative perspectives. This may prematurely limit the spectrum of available policy options. Here we show how the inclusion of neglected currents of thought such as non-Ricardian economics, bioeconomics and a set of qualitative-quantitative methods from post-normal science leads to richer perspectives for a more inclusive uses of quantitative evidence, and opens the analysis to more possible futures. We also present some case studies in the energy, water, health and climate domains that highlight the point in a practical context for a more policy-oriented audience. We situate our analysis in the context of recent calls in the EU for the inclusion of more perspectives from the social sciences and the humanities in environmental assessment works.

In memory of the ecological economist Herman E. Daly

1. Introduction

There is, among sociologists and scholars of science and technology studies (STS), a vein of critique of the cultural stance underpinning the present EU impact assessment culture, see Stirling (2022) for a recent review. The cultural elements addressed by this critique are a tendency to scientism, the adherence to the so-called 'deficit model' of public engagement – whereby scepticism toward science and technology is due to a lack of scientific literacy, and the presupposition that scientific understanding should automatically predominate as public meaning (Wynne, 2014). In this culture, the concept of calculable risk dominates the discourse, making uncertainty disappear along with the social determinants of what constitutes a risk[1] (Scoones and Stirling, 2020; Stirling, 2023). Sociologists of quantification have targeted these instances of evidence-based policy as instrumental to New Public Management (NPM) objectives. NPM is seen as functional to neoliberal policy aimed to reduce the presence of the state and the extent of social

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[1] We refer here at the distinction between risk – assumed computable, and unquantifiable uncertainty (Knight, 2005).

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protection, as discussed by Salais (2022) in relation to employments and by De Leonardis (2022) in relation to inequality.

The reductionism in the framing of complex issues has deep roots and motivations, some of which have to do with institutional features of the EU: the single market needs a centralized, hence standardized,[2] risk assessment approach, and the EU has a generally pro-industry (e.g. biotech) growth agenda (van Zwanenberg, 2020). Another institutional concern is the fear of opening the road to endless deconstruction of planned policies and to regulations that are more expensive. All this reinforces the reductionist tendencies already mentioned (van Zwanenberg, 2020).

There is hence a perceived need to overcome these tendencies and lock-ins, which are identified by STS scholars even in the writing of the various EU research work-programmes (Rayner, 2012). In that sense, the Horizon Europe program (2021–2027) has issued calls to investigate limitations (including short-termism and the insufficient attention to socio-economic inequalities or inclusiveness) of mainstream economic theory and models used for impact assessment, and asked to improve existing practices by including perspectives from sociology, political sciences or the humanities (European Commission, 2021a). This effort is in line with the European Commission (EC) ambition to lead the use of evidence for policy in the framework of its 'Better Regulation' initiative (European Commission, 2021b, 2021a), and is part and parcel of the specific legislative process in the European Union. The leading role of the EC in the use of evidence for policy is endorsed by the Organization for Economic Cooperation and Development (OECD, 2018).

There are reasons why the EC also needs (beside technically or statistically robust evidence) what is known as social robustness (Gibbons, 1999). This kind of robustness is achieved when the evidence brought in support to policy has been tested against all stakeholders that are likely to have an interest, material or normative, on the issue being discussed. This implies that no interest has been neglected or marginalized. The European Commission, which enjoys the power of initiative in legislation, and makes exemplary use of impact assessment methodologies, is in acute need of this robustness. EC legislative proposals are often the subject of societal controversies: genetically modified organisms, pesticides, classification of forest biomass as renewable energy, the inclusion of nuclear in the taxonomy of green energies, are just a few old and new examples. While the impact assessments on any legislative proposal must be revised and cleared by the EC Regulatory Scrutiny Board, EC texts are subject to negotiation with Parliament and Council. The final text is likely different from the original one but the original impact assessment is normally not revised. A recent discussion of this context, where better coordination is called for, can be found in European Commission (2021b).

The different epistemologies presented here aim to counteract the excess certainty often associated with existing economic impact assessments (Stirling, 2022, 2023). Terms and methodologies such as 'expected utility', 'decision theory', 'life cycle assessment', 'ecosystem services', 'externality assessment', 'impact analysis', 'sound scientific decisions' and 'evidence-based policy' are often deployed to deliver answers with high levels of precision. The resulting impression of accuracy needs to be gauged against possible rhetorical use, especially when these methods are mobilized to prove that a given policy or practice are 'safe' or 'best' (Stirling, 2019). Looking at an issue using a broader spectrum of tools may broaden the space of the policy options (Saltelli et al., 2020b; van Zwanenberg, 2020), providing an escape route from tunnel-vision and technological determinism.

One problem with the present culture of purported evidence-based policy is that it wishes to treat conflicted issues, where none of the involved parties is neutral, with techniques routinely presented as neutral. No methods, technique or lens is, however, neutral (Saltelli et al., 2020b). For instance, the concept of unemployment can be dramatically affected by the way it is quantified (Salais, 2022), and the same holds for the concept of inequality (De Leonardis, 2022).

The door of economic quantification needs to be open to the humanities and the social sciences (i.e., art, literature, philosophy, history, sociology, law and politics). These fields have an important bearing on how we assess the quality of evidence, including evidence feeding into economic assessments of ecologic and social wellbeing. For instance, the history of cost-benefit analysis from the nineteenth century to present day helps us to understand its power as well as its limits (Porter, 1995). The emphasis on quantification of economic outcomes can be seen as instantiation of the Cartesian dream of a society ruled by judicious use of mathematics (Davies and Hersh, 1986; Pereira and Funtowicz, 2015). An historical perspective also reveals that the Italian and the German schools of economic thought predominated over their English counterparts for many years before being overshadowed by the latter (Reinert, 2016; Reinert and Reinert, 2019). As discussed below, this shift had momentous historical consequences. In ecology, authors such as Rachel Carson, Lewis Mumford, Langdon Winner, Ivan Illich and Ernest F. Schumacher have contributed to shape the ecological movement of today with works halfway between literature and science.

Limiting the impact assessment to the methods and culture of neoclassic economics in a context of neoliberal policies may foreclose important policy options (Drechsler and Fuchs, 2023). In general the emphasis on the individual tends to diminish the importance of social policies. To make an example, when employing the technique of nudging (Sunstein, 2020) the individual is gently pushed to adopt behaviours that are considered 'socially desirable' by the proponent of the method, such as subscribing a health insurance. This implies that the responsibility is with the individual, not with the state. Privatizing public utilities based on consideration of costs and benefit again absolve the state from enacting policies to protect public goods. The neoclassic emphasis of what has been called the mathematization of economics (Drechsler, 2000; Reinert, 2000; Mirowski, 2013; Romer, 2015), with the use, e.g., of dynamic stochastic general equilibrium models of the economy, creates dangerous oversights such as that of the last recession (Pierce, 2008; Mirowski, 2013); A crisis that has an element of responsibility in the mathematics of the credit crunch (Salmon, 2009; Wilmott and Orrell, 2017). Taking Ricardo's theorem as a dogma (see next section), and trade as beneficial even among countries at different stages of development, may lock the developing countries in poverty, and overlook industrial policies that would accelerate development. Neoclassic economics furthermore creates 'invisibilities' (e.g., women labour) which prevent the adoption of policies of care, essential at any time and foremost at time of crises.

The new lenses we propose here should especially be harnessed in the presence of political conflict or contestation: the excluded will appeal to alternative worldviews in order to have their voice heard, and the lenses presented here offer the opportunity for these hearings. The adoption of these lenses may expand the original problem framing, and if more uncertainty and ambiguities are revealed in the process, these do not necessarily get in the way of political negotiation. Instead, they create the space and the scope for these negotiations to take place.

Our analytical lenses present elements of a counter-culture, potentially fruitful for the design and economic evaluation of environmental and health impact assessment policies in the European Union. The lenses are non-Ricardian economics, bioeconomics and a set of approaches originated in the context of post-normal science (global uncertainty and sensitivity analysis, sensitivity auditing, NUSAP and quantitative storytelling). We show here that the lenses are relevant, and that their inclusion leads to a more responsible quantification, to a better acknowledgment of uncertainties and to the opening of the analysis to a richer spectrum of possible policy options.

[2] Though we do not have here the space to treat standardization in the context of a neoliberal agenda a useful source about the 'marketization' of ethical concerns is Thévenot (2022). The tendency of EU agencies to standardize processes for impact assessment via what is defined as 'protocolization' is discussed by Lemus and Kovacic (2022).

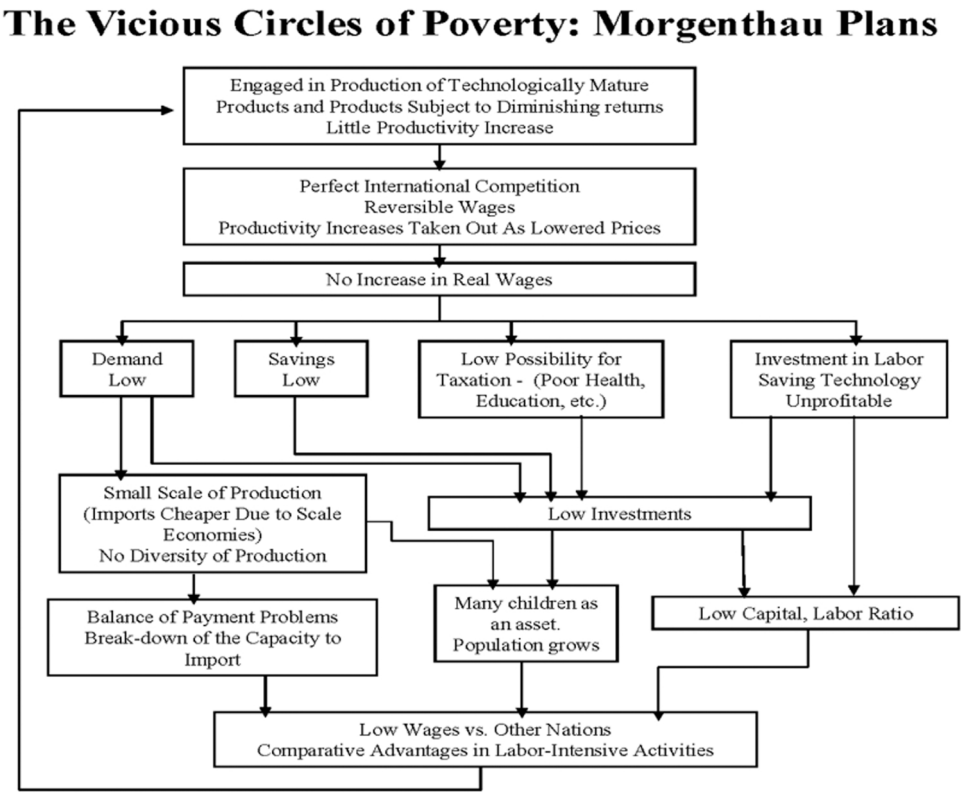

Fig. 1. The vicious circle of poverty.
Adapted from Reinert (1980).

Our focus is on impact assessment (IA) policies. "An impact assessment is a process comprising a structured analysis of policy problems and corresponding policy responses. It develops policy objectives and alternative policy options and assesses their impacts" (European Commission, 2021a, p. 42). The European Commission makes exemplary use of impact assessment, with a rich repertoire of methods associated with its 'Better Regulation' initiative (European Commission, 2021b, 2021a). To give an idea, the EC Better Regulation toolbox (European Commission, 2021a), mostly devoted to IA, runs over 500 pages.

We motivate our selection of analytical lenses with a double movement: we show how neglecting non-Ricardian economics, bioeconomics and post-normal sciences approaches lead to what philosopher Gunnar Skirbekk (2019) would call 'epistemic challenges', i.e. to instances of 'not-seeing'; and we illustrate the point with case studies, aiming to appeal a policy-oriented audience.

The three lenses share an emphasis on unveiling generated by the status quo in impact assessment. Merging these visions is all the more needed since academic disciplines are united by their disunity – each discipline proudly shielding its methods, journals and terminology, against incursions from other disciplines (Stirling, 2014).

To embrace the suggestions of the present paper probably entails a cultural and political shift away from consolidated practices, a shift that is likely more arduous for international institutions that derive from this culture an important part of their epistemic authority (van Zwanenberg, 2020; Saltelli et al., 2021). What is at stake is not the abandonment of evidence-based policy or of quantification, but better ways to quantify, following for example the lesson offered by the French statactivists (Bruno, Didier and Prévieux, 2014; Samuel, 2022). Failure to realize this cultural change will lead us along the path away from a just society (Supiot, 2017) and toward an 'a-democracy', a political regime that maintains the formal procedures of democracy but impedes citizens from having palpable impact on democratic choices (Salais, 2022, p. 397).

2. The three lenses

Overall, each lens attempts a methodological reversal of how science for policy is done. The foci are:

1. Non-Ricardian economics: international trade system
2. Bioeconomics: over-exploitation of nature
3. Post-normal science: how to deploy science for policy

We will show how the lenses unveil corresponding invisibilities:

1. Non-Ricardian economics: invisibility of qualities, whereby all hours of work are taken to have the same value
2. Bioeconomics: invisibility of nature, whereby natural resources are considered as infinite or infinitely substitutable
3. Post-normal science: invisibility of values, obfuscated by the purported neutrality of quantification

There is common ground among the lenses, as each of them is holistic in its own way. All lenses can be said to share an opposition to neoliberal policies and their methodological apparatus, foremost in the mathematization of science for policy. Bioeconomics and PNS object to the 'work of nature' being considered as an infinite externality. These lenses also share elements of a common genealogy. We review here the main methodological ingredients and policy questions associated with the three lenses.

2.1. Non Ricardian economics

The fact that neoclassical economics treats most environmental factors (such as pollution, biodiversity, and forest preservation) as "externalities", because there are no markets in which their prices can be set, evidences the inadequacy of neoclassical theory for dealing with

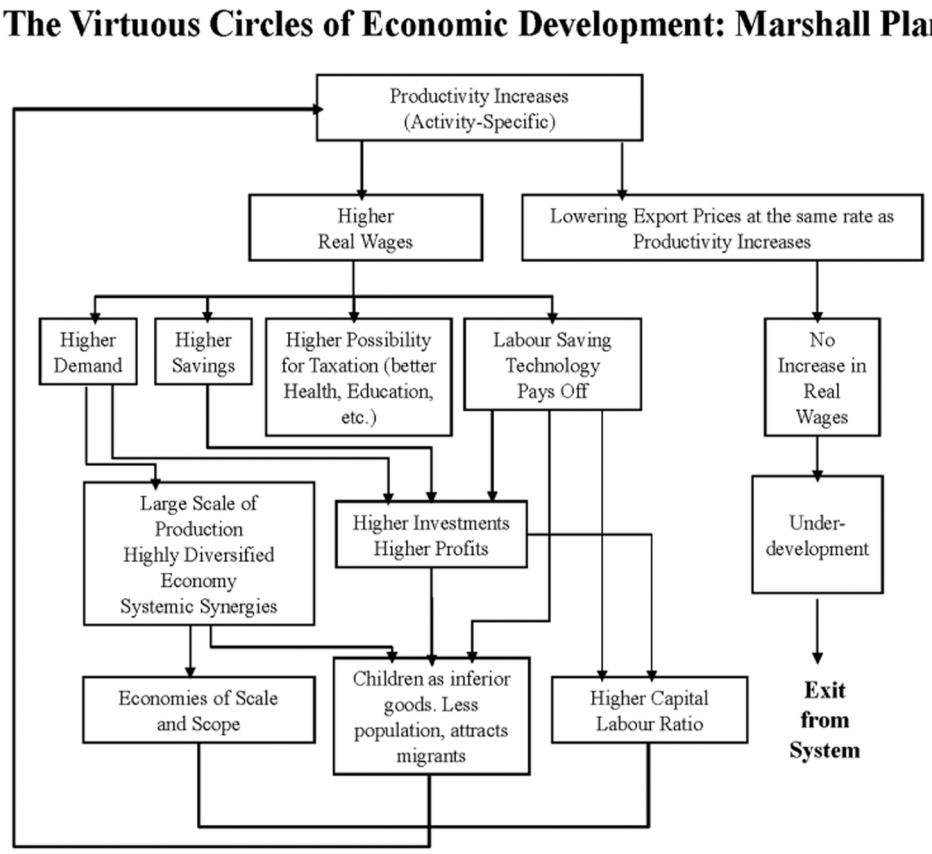

Fig. 2. The virtuous circle of development.
Adapted from Reinert (1980).

economy-environment interactions and effectively enacting conservation strategies. There always was a tension on this subject, as proved by the now famous exchange in the 70′s involving Daly (1997a) (1997b), Stiglitz (1997) and Solow (1997)[3] Also as a result of the last recession, a critique of neoclassical economy has come to life (Macfarlane, 2017), with initiatives such as the Institute of New Economic Thinking (2022) and vocal support from influential economists such as Joseph Stiglitz (2011) or Paul Romer (2015). This is a vast topic that cannot be summarized in the present work. We content ourselves with an important step away from the standard neoclassic economics: the abandonment of the 'equality assumption' at the basis of Ricardian economics; that is, the assumption that all economic activities are equal in producing desirable outcomes. A key qualitative element distinguishing economic activities is if they are subject to increasing or diminishing returns:

Diminishing returns: Economic activities where one factor of production is limited in quality and/or quantity by nature – agriculture, fisheries, mining – will, after a certain point, not yield proportional increases in outcome as investments grow. These factors are also crucial in understanding *sustainability* (Reinert, 1996). In extreme cases, this may lead to technological retrogression (Endresen, 2021).

Increasing returns: Activities where the costs of production decrease as volumes increase (Arthur, 1994).

This difference was the main reason why the infamous Morgenthau plan, applied to Germany after the end of WW II and based on dismantling its industrial capacity, was rapidly abandoned in favour of the Marshall plan to avoid the starvation of Germany (Reinert, 2008).[4] Industrialised countries are so called because they have a high proportion of manufacturing industry, which by definition is subject to increasing returns and permit sustaining a larger population (Figs. 1 and 2).

The distinction between increasing and diminishing returns was still present in the works of Alfred Marshall (1890), founder of neo-classical economics. However, this phenomenon was not compatible with the physics-based equilibrium economics that came to dominate 20th century economics and disappeared from mainstream economics. Important vested interests (Veblen, 1919) are involved here: if the dichotomy of increasing and diminishing returns (a key to explaining poverty) is eliminated from economic theory, then industrialized countries – operating under increasing returns – will be able to collect assumption-based rents from countries that specialize in raw materials prone to the mechanism of diminishing returns.

A contrast between two books in the 1970 s illustrates the relevance of the distinction. 'Limits to Growth' (Meadows, 1972) was criticized in 'Models of Doom' (Cole et al., 1973) for assuming diminishing returns also under conditions where this was not relevant. This is the same problem from which the gloomy predictions of Reverend Malthus arose (Malthus, 1798). Clearly both assumptions are relevant, but each in their respective contexts.

In relation to the need for insights for major European policies in the

[3] The debate - started in 1975–1979 by Georgescu-Roegen in opposition to Solow and Stiglitz - was about to what extent one can substitute capital for natural resources in a growth equation, and what role technology could play to make this substitution more effective. Herman E. Daly, passew away while the present paper was in progress, restarted the debate in 1997 in open opposition to neoclassic economists, iterating Georgescu-Roegen's unanswered critique that one cannot "assume that agents of transformation (funds) can substitute for the resources undergoing transformation (flows)" (Daly, 1997a).

[4] Herbert Hoover noted that the plan would result in up to 25 million Germans unable to feed themselves.

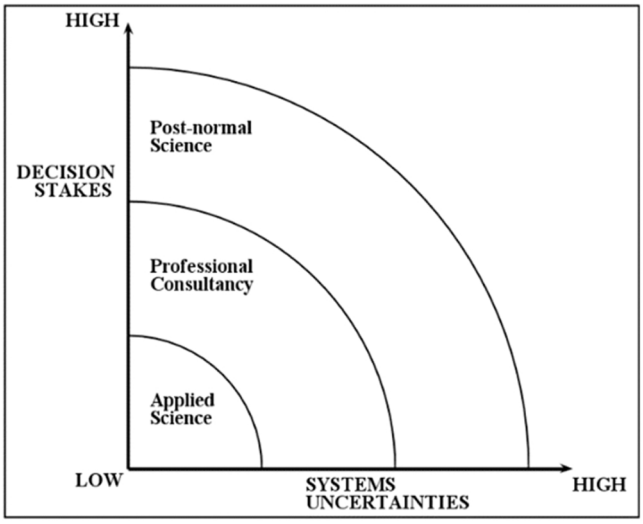

Fig. 3. PNS diagram from (Funtowicz and Ravetz 1993.

Table 1
Methodologies of post-normal science inspiration.

Methodology	Focus of Use	Benefits	Relevant paper
Global uncertainty and sensitivity analysis	Examines model output uncertainty and apportions it onto input parameters and assumptions.	Thoroughly samples the uncertainty space underpinning a given quantification.	(Saltelli et al., 2008; Saltelli, 2019, p. 20129; Puy, 2020;Saltelli, et al., 2020a;Puy et al., 2021)
NUSAP	Provides a notational system for the management and communication of uncertainty.	Explores epistemic uncertainty and the quality of the knowledge at the basis of quantifications.	(Funtowicz and Ravetz, 1990; van der Sluijs et al., 2005; van der Sluijs, 2017)
Sensitivity auditing	Expands sensitivity analysis through a seven point check-list for use in policy-relevant modelling studies.	Accounts for the epistemic dimensions and the framing underpinning quantifications.	(Saltelli et al., 2013; Saltelli and Funtowicz, 2014; Saltelli and Lo Piano, 2017; Lo Piano and Robinson, 2019; Lo Piano et al., 2022, 2023)
Quantitative storytelling (QST)	A plurality of frameworks and worldviews are legitimately upheld by different constituencies and social actors in an interconnected society.	Promoting pluralistic and reflexive research to overcome the silos effect on individual policy domains (e.g., water, energy, and food) and/or expertise.	(Saltelli and Giampietro, 2017; Kuc-Czarnecka, Lo Piano and Saltelli, 2020)

field of environment and climate, consideration of increasing versus diminishing returns may play an important role to adjudicate among alternative policy options given the importance of manufacturing in the context of infrastructural transitions.

2.2. Bioeconomics

Bioeconomics can enrich economic assessments that merely focus on the monetary dimension (Hall et al., 2001; Georgescu-Roegen, 2013) by offering an accounting of the environmental and societal impacts linked to a technology/system. Cost optimisation economic assessments do not necessarily ensure a sound representation of energy systems for policy making by neglecting the importance of the physical accounting of the resources required (materials, labour, land, etc.).

One example is the oil crisis of the seventies, where the crucial role of fossil fuels emerged well beyond what its estimated price could capture. This aspect is also visible in the consequences of the ongoing (at the time of writing) Russian war on Ukraine. Monetary proxies may even be inadequate to estimate natural resource availability. Even when one factors in technical progress, the actual knowledge on resources availability is far from the condition of perfect information, which invalidates economic assessments based on this assumption (Reynolds, 1999).

The chemist Frederick Soddy was the first to propose the perspective of the physical nature of economics by acknowledging its thermodynamic limits (Daly, 1986). That is, the inevitable reliance on harvesting low entropy matter/energy gradients to power up human activities within the overall economic enterprise and return high entropy (wasted) matter-energy gradients back to the environment.

Georgescu-Roegen expanded on this perspective by acknowledging the irreversibility of this entropic process on which the economic enterprise is based. Additionally, he pinpointed another crucial aspect in bioeconomics analysis: the rate at which matter-energy gradients can be harvested from their sources also affects their actual availability (Georgescu-Roegen, 2013).

Georgescu-Roegen dealt with these physical dimensions and limits in economic systems by proposing the 'flows and funds' model. These two core elements define the identity (funds) and the activity (flows) of the system represented. This theoretical standpoint allows for a robust biophysical accounting of the metabolic pattern of socio-ecological systems in terms of the flows of matter and energy between the system and its components, as well as with the external environment (Mayumi, 2020). Flow/fund rates offer a richer accounting in assessing the sustainability of a system by expressing the harvesting (or sinking) rate in relation with the actual capabilities of the system in terms of the available funds and non-renewable stocks.

The resources allocated for the reproduction of the funds that characterise the system constitute the actual requirements of a system to sustain and reproduce itself. This overall analytical lens can be used to assess the physical/economic/technological limitations of the societal systems taken into account and scrutinise their proposed development patterns.

Bioeconomics may usefully investigate the flows exchanged between the technosphere and the biosphere, occasionally detecting implausible 'decoupling' narratives that risk leading to irresponsible management of expectations, e.g., in relation to the achievable circularity of the economy (Giampietro and Funtowicz, 2020).

2.3. Post-normal science and PNS-inspired methodologies

Post-normal science (PNS) has established itself as a viable and useful bridge between concepts arising from ecology, sociology and philosophy with the practices of health, social and natural sciences as deployed for the solution of pressing problems. PNS mantra points to situations where facts are uncertain, values in dispute, stakes high and decisions urgent (Funtowicz and Ravetz, 1993, 1994).

The genesis of PNS owes to several authors and disciplines, from the ecology of Rachel Carson (1962) to the risk sociology of Ulrich Beck (1992); from popular epidemiology (as the case of Love Canal[5]) to the classical works of philosophy of science, including those of Kuhn and Feyerabend, see Ravetz and Edgley (1984) for a discussion.

PNS distinguishes itself from normal science, and from the practice of consultancy, in the presence of conflicted issues (Gluckman, 2014) (Fig. 3),. Practitioners consider PNS a movement for the

[5] A milestone in epidemiology done by the victims (also known as housewife epidemiology) is the work of Gibbs and Levine (1982) on Love Canal, where in the early 80's a community had to tackle a severe case of environmental contamination.

Table 2
The proposed case studies and the analytical lenses to be adopted.

Case studies	Issues to be addressed	Analytical lenses
Climate, energy, and Sámi herders	Externalisation vs. reinternalization of energy production systems	• Global uncertainty and sensitivity analysis • NUSAP • QST • Non-Ricardian economics • Biophysical economics
Climate and Water security	Increasing irrigation efficiency by promoting sprinkler and drip irrigation as key water-saving technologies	• Global uncertainty and sensitivity analysis • Sensitivity auditing • QST
Biodiversity and pollinator decline	The threat posed by the decline of bees and other pollinators	• QST • PNS • Global uncertainty and sensitivity analysis
Lessons learned from COVID-19	The effect of the COVID-19 on the European Green Growth plan	• NUSAP • Sensitivity auditing • QST • Biophysical economics

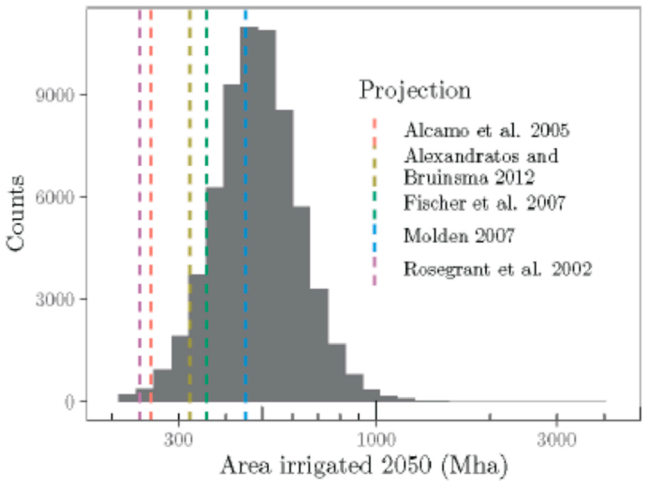

Fig. 4. Inpredicting the need of irrigated land at the year 2050 an uncertainty analysis (grey histogram) reveals that the range of possible outcomes is larger and less conservative than official estimates (dashed lines). Count on the ordinate axis refers to the number of simulations in each bin out of the total number of simulations (~65,000 Monte Carlo runs).
Adapted from Puy et al. (2021).

democratization of expertise (Carrozza, 2015). Warning against the artificial separation of facts and values at the science-policy interface and the need to approach problem-solving by use of 'extended peer communities' are some of PNS' distinctive features. In this context, investigative journalism, whistle-blowers, and lay citizens with a stake or an interest in the issue being debated contribute to the deliberative process. Here we apply four PNS-based methodological approaches (Annex 1 and Table 1). Four illustrative cases.

In this section we show how our proposed approach produces novel insights to help tackle three of the most pressing climatic, environmental and biodiversity challenges the EU will have to face within the next decade. Firstly, the need to promote an adequate use of water for crop production in order to feed an ever-increasing population in a context of climate change. With irrigation agriculture currently being the sector that consumes the most freshwater resources and produces almost half of all food consumed worldwide, failure to properly address this issue will trigger a cascade of noxious effects at several socio-environmental levels. Secondly, and interlinked with the previous challenge, the need to protect pollinators to ensure crop pollination and food security. This requires developing more suitable approaches to regulate the entrance of pesticides in the market. Thirdly, the urgency to curb GreenHouse Gas emissions (GHGs) entails a number of trade-offs across incommensurable dimensions and contrasting scales, whose acknowledgement requires the combination of analytical lenses proposed here. All these challenges are looked at in the context created by the COVID-19 pandemic under the lenses of different economic and epistemological stances (Table 2).

2.4. First case: Climate, energy, and Sámi herders

The European Union has set ambitious climate goals for the forthcoming decades in the attempt to mitigate climate change and contain GHGs. Issues of clean energy system operation and controlled energy demand are central to these emission targets and as such, social and technological transitions are often at the forefront of energy policy agendas. However, concerns exist on how global, regional and national policies can align when faced with global vs. local environmental pressures.

The issue of reductionism in the EU energy policy making is that solutions to climate change are often placed as a problem/challenge of swapping fossil fuel based energy generation for renewable generation, with technology innovation and associated efficiency gains. This policy making is reductionist in relation to climate change seeing the sources of emission as the constituent parts and so describing solution and policy in these terms. Or rather reducing the environmental issues of energy to climate forcing alone - hence renewable energy (RE) generation and a small component of reduction through efficiency. This ignores causal linkages with social and environmental structures.

Renewable generation and efficiency are indeed vital, however, the issues and solutions are more complex as the policies and implemented solutions create social, cultural, and environmental problems of their own. These problems are not necessarily trivial and can have consequences on the ability to meet the critical target of 'climate neutrality' by 2050.

A neoclassical framing on growth and innovation seemingly underpins much of the Commission's policy language, with an evident push for innovation in energy demanding technology through digitalisation and a fairly static framing of society and technology use/need of this technology. "Economic growth through innovation" are in the Renewable Energy Directive (European Parliament and Council, 2018). It also states, when favouring the market for RE sources, that "positive impact on regional and local development opportunities, export prospects, social cohesion and employment opportunities" must be taken into account. It remains unclear whether social cohesion captures the issues of vulnerable communities fully.

Therefore, we focus here on a case study on the re-internalisation vs externalisation of the production of innovative products and services (including batteries for storage and electric vehicles, data centres, green manufacturing, etc.) and the required power system to sustain them. This poses the dichotomy of whether these manufacturing capacity and renewable power generation capacity should be locally installed, with the re-localisation of environmental impacts and local economic benefits, against their thorough externalisation. This decision making includes the choice of a system powered by an interconnected super-grid against a local energy island (Ribbe and Kattnig, 2020).

This problem arises for instance in the long proposed context of grid interconnection between Scandinavian countries and Iceland. Negative effects have been documented on the migratory patterns of reindeers in the Northern part of Scandinavian countries, with harmful spill overs on the Sámi population living in these areas, as acknowledged by a court decision (Euronews, 2021). Further impacts on reindeers are also caused by the increasing traffic volume and railway infrastructure connected to increased mineral extraction and steel manufacturing (Kater, 2019; Kater et al., 2021). Externalising these activities to, say, Iceland, a nearby country with its own autonomous electricity system, would avoid these local environmental and social impacts. However, under these circumstances, installation of extra hydro and geothermal power capacity in areas prone to more sizeable environmental impacts would be required in Iceland (National Energy Authority of Iceland, 2021) in order to sustain the increased energy demand. How are the competing social and environmental impacts of the two local perspectives brought together under an international framing of an energy system? The matter is also relevant to the European emission trading scheme (Breitschopf and Zheng, 2020). Problems of local environmental impact associated with 'renewable energy solutions' can still threaten some of the very things being put under threat from climate change. The Sámi region will face larger climate shifts (according to projections) than many other parts of the globe, but the impact on herd migration from building wind farms and supporting infrastructure in the region mean that solutions can be similarly impactful to these vulnerable (particularly sensitive) regions/communities.

One can imagine entrusting the decision to a model or suite of models, co-designed with the relevant stakeholders, and to develop a 'pressure to decision index' (Saltelli et al., 2000) which orient the choice versus one or another of the options. This index, which comes in the form of a distribution of possible values as a result of global uncertainty and sensitivity analysis, could be used for a participatory analysis session to see if (with allowance made for the extant uncertainties) adequate clarity in the analysis exists to rank the options in a way that is accepted by the stakeholders. The robustness of the quantitative figures underpinning the model favouring one option or the other can be assessed through the NUSAP scheme along with the model output produced through uncertainty and sensitivity analyses. The overall use of the model and its fitness to decision making in the specific policy context can be assessed through sensitivity auditing.

Different quantitative story telling becomes possible, that highlight the existence of trade-offs unavoidable in a democratic deliberative process, and can contribute to making decisions as per the priorities and the analyses set by the different international and local stakeholders involved. An important issue may be represented by critical biophysical limits. These may emerge when looking at the flow/fund ratios for the resources harvested and the sink capacity of the local environment, to be assessed against the revenues one can expect from the industrial activities, and whether that would truly and overall lead to a regime of increasing returns. On another level, even the situation of Sámi reindeer herders needs a plurality of viewpoints to be fully appreciated. As noted in Tyler et al. (2007), loss of habitat, economic predation and legal frameworks "potentially dwarf the putative effects of projected climate change on reindeer pastoralism."

The experience described in Tyler et al. (2007) is illuminating:

> *The validity and legitimacy of reducing a complicated system to something simple and, therefore, amenable to assessment was wholly dependent on the participation at the outset of herders themselves. It is they, rather than outsiders, who can best decide what factors, or what suites of factors, influence reindeer pastoralism: nobody, save herders themselves, can legitimately make the selection. Despite its orthodox format, therefore, the resulting conceptual model, developed through an interdisciplinary and intercultural effort […] represented an integration of empirical data and herders' knowledge.*

We are not suggesting that the distribution of values of the pressure to decision index just discussed adjudicates the energy grid case: ultimately the choice among the option needs to be the result of a political process that may use the index as a negotiation tool. The element highlighted here is that the evidence pros or cons of the various policy options is collected in a way that includes the largest spectrum of perspectives, as to avoid glaring blind spots and hidden losers, in a context where the involvement of minority ethnic groups such as the Sámi put to the centre-stage the perspective of inclusive governance that is proper of deliberative democracy.

Overall, the problem of energy and climate change must be seen more widely than a 'clean energy generation' transition. It is also an issue of local environmental impacts, energy and climate change inequalities, and demand reduction, that lead to new configurations of social organisation, new problems/challenges. The Sámi case suggests either these sorts of issues are not well rehearsed in policy settings or that the weighting towards a particular 'solution' is so great (i.e. leading to reductionism) that cultural and local environmental problems (and push-back from affected communities) will arise. If there were a greater emphasis given to the local impact in thinking about policy for energy and climate change mitigation, perhaps very different policy options could have been discussed or formed.

2.5. Second case: Climate and water security

The development of initiatives to ensure the viability of irrigation agriculture under climate change has been a concern of the European Union since the promotion of the Water Framework Directive in 2000, which led to the Blueprint to Safeguard European Water resources in 2012 (European Environment Agency, 2012). The widespread adoption of sprinkler and drip irrigation is regarded as a key measure towards that goal, especially in Southern European regions, and has been endorsed both by model-based assessments and cost-benefit analysis (Görlach et al., 2006; Flörke, 2011).

Recent work suggests that the potential impact of irrigation in the water cycle can be much more serious than previously thought. The Blueprint assumes that European irrigated areas in 2050 will extend over 30 Million ha (Mha) in the most extreme scenario (Flörke, 2011). Yet when uncertainties are systematically incorporated in the simulations, the range extends to 15–40 Mha, with the right tail of the distribution pushing to 63 Mha (Puy et al., 2020). Similarly, Global Hydrological Models that calculate irrigation water withdrawals at a planetary scale might be missing uncertainties spanning two orders of magnitude at the grid cell level, the minimum geographical unit in which these models simulate water demands (Puy et al., 2022). European policies should hence be redrafted to contemplate extreme scenarios, a shift that inevitably requires opening up the range of economic lenses adopted to tackle climate-driven water scarcity.

To date, neo-liberal approaches seem to dominate the framing of water problems, in Europe and beyond. For instance, the Blueprint suggests the creation of financial instruments to encourage farmers to adopt sprinkler or drip irrigation, since the costs derived from this modernization process may exceed the productive capacity of irrigated areas (Lallana et al., 2001). Israel has favoured the construction of desalination plants by signing concession agreements with the highest bidder. In 2015–2017, 40% of all water used for irrigation was

desalinated (Russo and Kurtzman, 2019). The most conspicuous example of privatization as a way to cope with the water crisis is the World Bank promotion of loans and agreements with European Water companies since 1980, which took place in countries such as India or Nigeria.

These market solutions risk bonding irrigators to financial corporations or technology developers, boosting energy costs and environmental degradation (by dumping chemicals used in the desalination process back into the sea) or making countries dependent on "foreign'" redistribution policies and private companies, a sort of "welfare colonialism" that hinders long-term structural change (Reinert, 2006). They also hamper the successful development of alternative bottom-up initiatives, such as farmer-led irrigation (farmers leading and financing the establishment, development and/or expansion of irrigation agriculture using low-cost technologies and deciding the terms of their involvement with agents operating at the macro scale). Farmer-led irrigation in sub-Saharan Africa has raised income, alleviated poverty and increased resilience to weather variability and climatic shocks (Lefore et al., 2019), with just a tangential involvement of states or large-scale private investments. Although not without problems or potential drawbacks such as environmental degradation or inequity (Mdee and Harrison, 2019), farmer-led irrigation can implement tailored solutions to local water-related challenges and be as water-efficient as any modernist-based initiative. In international development studies, farmer-led irrigation is increasingly seen as a phenomenon prone to provide insights for the development of policies at the national or continental level (Veldwisch et al., 2019).

Overall, the issue of irrigation and water management suffers from a lack of diversity and suppression of uncertainties (Puy et al., 2020; 2021; 2022; 2022). Some neglected vaguenesses, such as those related with irrigation efficiency (e.g., the ratio of the water consumed by the crop to that diverted from the water source to the field), appear to have a much higher impact on the estimation of irrigation water withdrawals than the uncertainties related with climate change, which have comparatively received much more scientific and press attention (Puy et al., 2022).

2.6. Third case: Biodiversity and pollinators decline

Overall, 87 out of the 124 leading global food crops (c. 35% of the world food production volume) depend on insect pollination (Klein et al., 2007), and several other ecosystem functions and services (biological pest control, soil formation, decomposition) are also contributed by insects. Yet there is strong evidence that the Earth's entomofauna is collapsing (van der Sluijs, 2020). The problem - first catching the world's attention with Rachel Carson's 'Silent Spring' (Carson, 1962) - is so serious as to have been labelled "insectaggedon" and is considered potentially more catastrophic than climate change (Monbiot, 2017).

One of the main contributors to the decline of pollinators is the large scale use of neonicotinoids in insecticides, biocides and veterinary medicine. Following evidence of harm to bees, Europe banned in 2018 three out of six authorised neonicotinoids for use in plant protection. However, substitution with other neonicotinoids and large-scale use in greenhouses and use as biocide and veterinary medicine continued.

A major limitation of current European policies is the procedure for allowing pesticides on the market, governed by Regulation 1107/2009 and based on the following stages (Robinson et al., 2018): (i) industry submits a dossier for authorisation of a substance, with tests and safety studies; (ii) the dossier is reviewed by a Member State, which elaborates a draft assessment report (DAR); (iii) other Member States comment on the DAR and the European Food Safety Authority decides on whether the substance meets the approved criteria.

Looking at the case with PNS lenses it can be noted that it represents a good example of how a model of evidence-based policy grounded on an allegedly neutral and factual assessment of the evidence becomes conflicted due to a tangled set of interests. The conflict here does not simply concern individual studies, but the methodologies adopted, the role of vested interests (Veblen, 1919) and lobby groups, the legitimacy of the institutions entrusted with control and regulation, and the policy objectives/economic assumptions (Robinson et al., 2018; Saltelli et al., 2022). The lessons from the sociology of risk (Beck, 1992) about industry capture and appropriation of evidence (in cases such as tobacco and sugar) is instructive to chart the existing risks.

The adoption of non market-based approaches to this case allows the identification of lock-ins and path dependencies, and of a process to overcome them (Maxim and van der Sluijs, 2010; van der Sluijs et al., 2013; van der Sluijs, 2021; Saltelli et al., 2022). van der Sluijs et al. (2021) highlight that entomologists and other key-knowledge holders have a unique societal responsibility to meet the challenges of insect collapse. They need to step up to counter-act the social production of ignorance that enabled the authorisation of harmful pesticides into the market and obstructed timely action on early warnings. They need to increase the policy relevance of their research, help adequately diagnose the problem, and help develop timely structural solutions and policy options. In a similar vein, Drivdal and van der Sluijs (2021) call for a much stronger role for the precautionary principle in pesticide authorisation and pollinator conservation. These authors denounce the practice of invoking precaution in a context of manufactured scientific uncertainty.

Note also that decline in wild pollinators increases the gender gap in nutrition between men, children and women. Although this at present is an issue for third world countries (Ellis et al., 2015) its implications for EU aid policies should not be discounted.

In order to offer another example of what policy option remains neglected by *status quo* assessment culture is a crop insurance programme where growers may purchase insurance, instead of prophylactic use of soil insecticides that harm pollinators, to provide financial compensation when yield losses can be attributed to pests. Furlan and Kreutzweiser (2015) demonstrated that such an insurance scheme is indeed more feasible and cheaper for growers than prophylactic protection with neonicotinoids.

The authors also note that in cases of socially constructed ignorance, strategic controversy and corporate capture of regulatory science that is typical for the neonicotinoid case, a transdisciplinary approach inspired by post-normal science should be taken. Entomologists should join with social scientists, legal scholars, legislators and policymakers to form an extended peer community that jointly addresses the broader human dimensions of pollinator decline and pesticide policies and co-produce adequate policy options for insect conservation (van der Sluijs et al., 2021).

2.7. Fourth case: Lessons learned from COVID-19

The relevance of the pandemic to the new normal within which the European Green Growth plan needs to take place cannot be underestimated. COVID-19 represents a "crisis within a crisis" and a situation of unprecedented, overlapping and mutually reinforcing inequalities. With COVID-19, the European Union suspended the stability pact and ushered the Next Generation Recovery fund (European Commission, 2022), which represents a major shift in its political economy approach, with direct monetary transfer among countries as in a true federative entity. Not even the climate emergency by itself could seriously put tax collection and tackling tax avoidance on the international agenda, or prompt the International Monetary Fund (IMF) to suggest the creation of a one-off wealth or corporate tax. The present G20 initiative for a "minimum tax" for large companies to take place in 2023 is another important initiative of COVID-19 times. The pandemic also allows state and industrial policy to come back on the agenda – a "return of the state" (Alteri et al., 2021) advocated by non-aligned economists (Mazzucato, 2020).

Scholars trained in the PNS tradition (Funtowicz and Ravetz, 1993, 1994) point to COVID-19 as a classic post normal case (Waltner-Toews et al., 2020). A PNS reading suggests that never as with the present

pandemics have numbers, and the attendant activities of measuring and modelling, taken centre-stage. Yet these numbers, often delivered by academics and media alike with extraordinary precision, rely on a rich repertoire of assumptions, including forms of bias, that can significantly skew both the numbers per se and the trust we repose in them. Modelling has made it to the headlines and become enmeshed in socio-political conflicts, with some authors speaking of 'models as public troubles' (Rhodes and Lancaster, 2020; Saltelli et al., 2020a; Saltelli and Di Fiore, 2023).

Policy prescription may need recourse to cost-benefit analysis and related concepts, such as the value of a statistical life (VSL) used in Thunstrom et al. (2020) to conclude that social distancing in the US will lead to a net benefit of about $5.2 trillion. Yet these hyper precise cost-benefit analyses of the pandemic clash with implication which policy cannot ignore: are we looking at *all* numbers? Are we looking at the *right* numbers?

To be noted, market-based solutions taken in the past have, by subsequent events, been brought into question. Reducing the health expenditures suggested by OECD countries (OECD, 2015), or reducing expenditures for forest supervision in the pursuit of austerity or small government logic (Wang et al., 2021) has come at a price in terms of human casualties and burned trees.

For many observers, the pandemic has been a lost chance to reassess the value of care (of children, diseased, the elderly) which is historically mostly provided by women. The devastation brought by COVID-19 has been increased by the inequality that the pandemic has accelerated, and the unacceptable inequity in the availability of vaccines. For Jayati Ghosh, the pandemic has increased economic polarization in income, as well as in access to health infrastructures and cures. The pandemic and the related inadequate policy response led to increased social polarization between protected and unprotected workers, majority and minority groups, and women across all social groups, with losers suffering a disproportionate impact from the pandemic (Ghosh, 2022).

To fully take stock of the impact of the pandemic for policy-making design and implementation, one should not forget also the physical impacts of the measures put in place. These include, for instance, the reduced energy demand and mobility emissions entailed by lockdowns (Carmon et al., 2020; Jiang et al., 2021; Marsden et al., 2021), or the increased plastic use entailed by response and prevention measures in terms of tests, masks, etc. (Benson, 2021; Patrício Silva et al., 2021). In a nutshell, how the biophysical flow/fund of the societal machinery readjusted upon the changing of the overall circumstances. These dimensions need to be accounted for when conceptualising policies on flexible work and safety protocols in order to capture the full spectrum of their physical impacts.

3. Lessons learned and way ahead

The lenses discussed in the preceding sections (non-Ricardian economics, bioeconomics and post-normal sciences approaches) expand the space of admissible analytical frames and permit to fight for this space when it is denied. Characteristics as humility in the production of evidence and a combination of reciprocal respect and circumspection in the needed policy dialogue are elements of this epistemology, which can be seen as a realism checklist. Applied to an environmental impact assessment it would include questions such as:

- Is the impact assessment biased? Since no policy can be neutral, neither can the associated impact or risk assessment if it does not identify winners and losers of the various policy options.
- Was the perspective of the most vulnerable groups used as a yardstick to test the true robustness of the policy? Were women's specific needs and vision identified or considered?
- Since any analysis is predicated on a reduction of complexity, foremost when a conceptual or formal model needs to be developed, who did the reduction? How was the reduction quality controlled? What alternative reductions were considered? Who or what was excluded?
- Did the analysis privilege future planetary threats, while neglecting present and well documented challenges due to local, legal or governance contexts of exclusion or inequality?
- To what extent does the analysis rely on technological silver bullet and unproved technologies meant to colonize the future? Does the analysis support an irresponsible management of expectations?

We see as a positive sign that the EC research work programme acknowledges the need to introduce social sciences and humanities into technical or ecological research. This dialogue among the major families of science is in our view an important necessary condition for change to happen (Crowe, 1969), a sort of lever to open the lid of the reductionists' boxes. That said, formidable obstacles and opposing drivers are at play to make the situation of power and knowledge asymmetry even worse than it presently is, and where science is often mobilized on the side of private interests (Saltelli et al., 2022). Contrasting a technocratic orthodoxy is not impossible if people and institutions are mobilized. The already mentioned movement of the statactivists, 'fighting a number with a number' with the mobilization of trade unions, media and offices of official statistics, offer several interesting examples (Bruno, Didier and Prévieux, 2014; Samuel, 2022).

4. Concluding remarks

> *South Africa's minister of trade and industry Rob Davies […] attested that a root problem in his ministry is the education of staff, whose training is dominated by one standard paradigm – neoclassical economics. Calling for position papers and briefs on myriad of pressing matters, Minister Davis lamented the lack of rival framework to compete with the efficient-market hypothesis and inform debates. He emphasized the need to encourage heterodox views. For good governance, be it in the state or corporate sphere, the task is to see complex problems from a variety of angles* (Mittelman, 2017).

The South African minister of trade and industry efficiently synthesizes the theme of the present work: an oversupply of one way of knowing to the detriment of several possible others.

A conclusion of the present work is that different kinds of short-sightedness affect different disciplines or communities of stakeholders, and that it is only by canvassing a broad spectrum of views that a genuine learning process can be put in place. Nietzsche (2014) admonished that the only objectivity is that which comes from pooling different visions: 'more eyes, different eyes'. For Feyerabend (1975), civic learning would be favoured by exposing the contradiction and controversy of the experts from different disciplines. Dewey (1938) insisted that the multiplication of problems induced by technological progress on humans and their environment called for a process of social discovery. Even for Amartya Sen "the idea of objectivity requires explicit acceptance and extensive use of variability of observations with the position of the observer" (Mennicken and Salais, 2022, p. 17).

This kind of objectivity is often only possible by drawing on local sources of knowledge, made possible by the extended peer communities described here. In this respect, an interesting quote to close the present work comes from Tyler et al. (2007):

> *However, herders' knowledge of the impact of something so relatively specific as climate variation on their way of life is based on an understanding founded on generations of experience accumulated and conserved in husbandry practice and herders' specialized vocabulary. Herders integrate bodies of knowledge gathered over time spans that far exceed significant periods of climate change. It would not be possible, using the traditional methods of the natural sciences, to gather comparable bodies of knowledge by direct observation at less than exorbitant cost.*

CRediT authorship contribution statement

Andrea Saltelli, conception, fourth test case, coordination, Marta Kuc-Czarnecka, Magdalena Olczyk all test cases, Arnald Puy, second test case, PNS, bioeconomics, Samuele Lo Piano, Máté János Lőrincz, Stefán Thor Smith, fist test case, PNS, Bioeconomics, Jeroen van der Sluijs third test case and PNS, Erik Reinert non-Ricardian economics and all test cases, All authors contributed to write up and revisions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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Annex 1, PNS inspired methodologies

Global quantitative uncertainty and sensitivity analysis

Uncertainty and sensitivity analysis[6] have been in use for several decades (Saltelli, Tarantola and Campolongo, 2000; Saltelli et al., 2008, 2019; Saltelli et al., 2020a), although many modelling fields seem reluctant to integrate them as part of the model quality check (Saltelli, 2019; Saltelli et al., 2019; Saltelli et al., 2020a; Lo Piano and Benini, 2022; Saltelli and Di Fiore, 2023). Their use may lead to interesting surprises as to what drives the uncertainty in a mathematical prediction (Puy, Lo Piano and Saltelli, 2020; Puy et al., 2021; Lo Piano and Benini, 2022; Puy, Sheikholeslami et al., 2022). In a recent work global sensitivity analysis is used to gauge model complexity (Puy, Beneventano et al., 2022). See Fig. 4 for an example of uncertainty quantification in irrigation.

NUSAP

NUSAP (Funtowicz and Ravetz, 1990; van der Sluijs et al., 2005; van der Sluijs, 2017), a notational system for the analysis and communication of uncertainty in science for policy, takes inspiration from sociology of science and PNS. It is based on five qualifiers: Numeral, Unit, Spread, Assessment and Pedigree. While the first three correspond to the usual scientific practices, where e.g. one says 3 g $\pm$ 1, the last two inform about the characteristics of the number production process, its scientific status, and about the involved actors. NUSAP is thus designed for a participatory approach to the construction and evaluation of models and knowledge quality, one where engagement of a wide range of knowlegde holders and stakeholders – the already mentioned extended peer communities - is considered essential in knowledge quality appraisal. Examples of extended peer involvement in the modelling process can be found in environmental sciences and in mathematical modelling proper, and has led to the coining of the term "participatory modelling". NUSAP is recommended in several Impact assessment guidelines, such as those published recently from SAPEA (Science Advice for Policy by European Academies, 2019).

Sensitivity auditing

Sensitivity auditing, also inspired by sociology of science, has points of similarity with NUSAP. It specifically addresses the quality of mathematical or statistical models. Its seven rules (Saltelli et al., 2013; Saltelli and Funtowicz, 2014) are: (i) check against the rhetorical use of the model; (ii) adopt an 'assumption hunting' attitude; (iii) detect artificial deflation or inflation of uncertainty; (iv) find sensitive assumptions before they find you; (v) allow interested parties to make sense of, and possibly replicate, your results; (vi) check the framing against alternative worldviews; and (vii) perform a thorough sensitivity analysis.

These points loosely cover the same ground as the five recommendations of Saltelli et al. (2020a). Sensitivity auditing is recommended in several impact assessment guidelines, e.g. SAPEA 2019 (SAPEA, Science Advice for Policy by European Academies, 2019) above and European Commission (European Commission, 2021a). Recent examples of sensitivity auditing can be found in the analysis of sustainable food production (Saltelli and Lo Piano, 2017), nutrition and public health (Lo Piano and Robinson, 2019) and irrigation modelling (Puy, Lankford et al., 2022). Recent reviews are in (Lo Piano et al., 2022, 2023).

Quantitative storytelling (QST)

Quantitative storytelling assumes that in an interconnected society more frameworks and worldviews are legitimately upheld by different constituencies and social actors. QST proceeds via *negativa* (Saltelli and Giampietro, 2017), trying to remove from the spectrum of the policy options those that patently violate existing constraints in:

- Feasibility (can a society afford a given policy in terms of external constraints, e.g. existing biophysical resources? Are there enough minerals for the full electrification of a given sector/country?);
- Viability (can society afford it in the context of our internal constraints, governance, socioeconomic and technological arrangements? E.g. does the characteristics of a country's secondary sector permit a given policy option?);
- Desirability (will the relevant constituency accept it? E.g. taxing fuel to reduce emissions sounds rational but voters tend to reject it).

These three checks can be nested. They can be used in assessments co-developed with stakeholders.

[6] The reader may be surprised to learn that quantitative methods such as global quantitative uncertainty and sensitivity analysis, whose use is fundamental in any number based analysis (econometric, mathematical modelling, statistical inference and indicators…) are to some extend inspired by PNS. And yet this is clearly spelled in the first chapter of the most cited sensitivity analysis handbook (Saltelli et al., 2008), pp 4–5. The reference to PNS in this handbook is to note that quantitative evidence may feed into controversial ecological or sociological problems, where these quantitative methods may be helpful to 'defog the mathematics of uncertainty' (Funtowicz and Ravetz, 1990).

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