Integrating Nature into Macroeconomic Models

Workshop Meeting Note, 23rd January 2026

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Summary for policymakers

On 23rd January 2026, 35 experts from across economics, ecology, finance, and policy institutions came together for a workshop on "Integrating Nature into Macroeconomic Models". The central problem they sought to address was that macroeconomic models – commonly used in fiscal, economic and financial decisions by governments, Central Banks, IFIs and credit ratings agencies - were **built for a world in which nature was assumed to be abundant and stable**. As a result, most macroeconomic models either ignore nature altogether or treat it as an external issue, addressed through parallel indicators or satellite accounts that sit outside core economic decision-making. **This creates a structural problem. When nature is invisible in macroeconomic frameworks: economic growth based on ecosystem degradation is ultimately self-defeating, fiscal and financial risks are understated, and investment in nature is systematically undervalued.** At a time of accelerating biodiversity loss, climate impacts, and rising fiscal stress, this gap is economically consequential and needs to be addressed.

Participants broadly agreed on five points:

- **Nature is economically foundational:** Ecosystems underpin productivity, resilience, and long-term growth. Degrading them is economically equivalent to running down capital assets.
- **Nature-related risks can be macro-critical**: In some countries this is already evident (e.g. small island states, ecosystem-dependent economies). In others, risks emerge through infrastructure bottlenecks, volatility, and fiscal exposure.
- **GDP alone is not sufficient**: GDP measures economic flows, not changes in the underlying asset base. It rises even as societal wealth declines if growth is driven by depletion of natural capital.
- **No single model can do everything:** Different users (finance ministries, IFIs, central banks, investors) need different tools. The solution is not one "perfect" model, but a plural, well-designed toolkit and a set of shared principles for the integration of nature.
- **The challenge is integration, not measurement:** Natural capital accounting and ecosystem metrics are relatively mature. There are gaps in data and understanding, but the main challenge is that they are not yet embedded in the macroeconomic analyses that drive decisions on growth, debt, and investment.

The meeting identified several practical ways to integrate nature into macroeconomic thinking, depending on the decision being made:

- **Growth and productivity:** ecosystem degradation can reduce long-term growth by lowering productivity and labour capacity.
- **Fiscal risk:** loss of natural buffers increases disaster costs, public spending volatility, and debt vulnerability.
- **Financial stability**: nature loss can amplify tail risks and systemic shocks.

- **Investment decisions:** accounting for avoided losses, impacts and resilience benefits can strengthen the economic case for investing in nature.

Importantly, integration does not mean rebuilding macro models from scratch. In many cases, it means feeding nature-related information into existing baselines, scenarios, and stress tests.

Nature is not just something to protect; it is an asset base that economies depend on. The meeting strongly rejected narratives that frame protecting nature purely as a constraint on growth. Instead, participants emphasised that protecting and restoring nature can lead to higher-quality and more durable growth, reduced volatility and fiscal risk, improved resilience and equity, and better long-term economic performance.

Participants agreed on a practical way forward: focus on high-impact entry points such as debt sustainability analysis, macro-fiscal frameworks, stress testing, and investment appraisal; pilot integration in a small number of countries to demonstrate value; translate existing natural capital accounts into decision-relevant signals; produce both policy-facing and academic outputs to support uptake alongside well-crafted capacity building and training.

The overarching message is clear: macroeconomic systems that remain blind to nature risk mispricing growth, stability, and resilience. Integrating nature into macroeconomic decision-making is no longer optional – it is a prerequisite for sound economic policy in the decades ahead.

In summary, this meeting demonstrated that integrating nature into macroeconomic analysis is both feasible and necessary in many contexts. While no single model can capture all ecological dynamics, targeted integration through key transmission channels can materially improve assessments of growth, fiscal sustainability, and risk. For policymakers, the implication is clear: failing to account for nature risks overstating economic resilience and understating the value of preventive investment. Incorporating natural capital into macroeconomic decision-making can support more robust, forward-looking economic strategies.

"Nature entered macroeconomic models of growth and development in the 1970s, but in an inessential form. The thought was that human ingenuity could overcome Nature's scarcity over time, and ultimately allow humanity to be free of Nature's constraints"

Sir Professor Patha Dasgupta, Dasgupta Review

1. Introduction and framing of the workshop

Why this problem matters now

Across the opening session and repeatedly throughout the day, participants returned to a shared diagnosis: **macroeconomic systems remain fundamentally nature-blind at precisely the moment when nature-related risks and opportunities have become macro-relevant.** This timing mismatch was seen as central to why the topic is now urgent.

Several speakers argued that macroeconomic frameworks were largely built during periods when natural capital appeared abundant relative to economic activity. As a result, nature is either: excluded entirely from macroeconomic models, or treated through parallel systems – such as satellite accounts, indicators, or dashboards that sit outside core macroeconomic decision processes.

Participants stressed that this architecture now embeds systematic distortions into policy, finance, and investment decisions. GDP-centric systems make nature loss economically invisible, allow depletion of natural assets to be misinterpreted as growth, and therefore misprice both risks and opportunities.

A key tension running through the discussion was whether the solution lies in fully integrating nature into core macroeconomic systems, continuing to rely on parallel systems, or deliberately doing both, with clarity about roles and limitations. While views differed, there was broad agreement that the current configuration – where nature accounting exists but rarely shapes macro decisions – is no longer tenable.

Participants articulated a core diagnosis that framed much of the subsequent debate:

- Macroeconomic models continue to prioritise GDP, aggregate output, and short- to medium-term stability, often assuming environmental conditions as exogenous or stable.
- Natural capital accounting and ecosystem indicators, while increasingly sophisticated, remain largely disconnected from macroeconomic baselines, fiscal rules, and risk assessments.

This separation was seen as producing a dual failure. On one hand, macro models embed incentives that reward short-term extraction and undervalue resilience. On the other hand, natural capital accounts struggle to influence decisions because they are not embedded in the analytical machinery that governs growth projections, debt sustainability, or fiscal space.

The meeting found strong consensus on these issues and a **strong leaning toward a hybrid approach:** using parallel systems to make nature visible and legible, while also integrating nature selectively into macroeconomic models where it materially affects growth, risk, resilience and investment decisions.

Opening remarks: nature as capital and the foundations of macroeconomics

The workshop opened with remarks by Sir Professor Partha Dasgupta, which set both the intellectual tone and the normative stakes for the discussion that followed. Dasgupta framed the integration of nature into macroeconomics not as an optional extension, but as a correction to a foundational misspecification of the economy's asset base in current macroeconomic thinking.

He emphasised that standard macroeconomic models implicitly treat nature either as a free input or as a background condition that does not bind. Historically, this assumption may have been defensible in periods when natural capital was abundant relative to the scale of economic activity. However, Dasgupta argued that this is no longer the case. Accelerating biodiversity loss, ecosystem degradation, and climate-nature interactions mean that economic production and wellbeing will be increasingly curtailed.

Box: Nature in a Macroeconomic Model by Professor Sir Partha Dasgupta

Humans relate to the rest of Nature in two ways: *we are embedded in Nature and we harvest from her*. The Common International Classification of Ecosystem Services – built on the pioneering work of the Millennium Ecosystem Assessment (MEA, 2005) – can be used to distinguish the two.

1. Classification of Nature's Goods and Services

Provisioning Goods: They are goods we harvest or extract from ecosystems. Their natural regeneration is a flow (as in, so many additional tons of mass of organic material per year), whereas the goods themselves are stocks (as in, so many tons of biomass: period). Provisioning goods include food, fresh water, timber, fuel (dung, wood, twigs, and leaves), fibre (grasses, cotton, wool, silk), soil and gravel as building material, biochemicals and pharmaceuticals (medicines, food additives), genetic resources (genes and genetic information used for plant breeding and biotechnology), and ornamental resources (skins, shells, stones, flowers).Provisioning goods are Nature's 'produce' – their regeneration over a period is Nature's 'yield.' With human ingenuity provisioning goods are transformed into the final products that, when aggregated using market prices, read as gross domestic product, or GDP.

Maintenance and Regulating Services: they are services that maintain and regulate ecosystem processes, including maintaining the gaseous composition of the atmosphere, regulating local and global climate (temperature, precipitation, winds and currents), controlling erosion (retaining soil and preventing landslides), regulating the flow of water (the timing and magnitude of runoff, flooding, and aquifer recharge), purifying water and decomposing waste, regulating diseases (controlling the abundance of pathogens such as cholera and disease vectors such as mosquitoes), controlling crop/livestock pests and diseases, pollinating plants, and offering protection against storms (forests and woodlands on land, mangroves and coral reefs on coasts), recycling nutrients, and maintaining the ability of primary producers to photosynthesize.

Cultural Services offer non-material benefits, including spiritual experiences and an identification with religious values. (It is perhaps more appropriate to trace these experiences and values to Nature, rather than ecosystems, because the latter is a term of recent origin.) The diversity of life has in part shaped the diversity of cultures. Moreover, various systems of thought attach spiritual and religious significance to flora and fauna. People also find aesthetic value in Nature, which gives expression in private gardens and public parks and protected areas. Ecosystems influence social relationships - social capital in coastal fishing villages take a different form from social capital in nomadic herding and agricultural societies – and local ecosystems offer people a sense of place, a cultural landscape.

Although cultural services are supremely important for humankind, the first two are more fundamental, for they are independent of the human presence. Provisioning goods and maintenance and regulating services evolved and formed the character of the biosphere even before hominids, never mind humans, existed. That is why I focus on them here.

Maintenance and regulating services act upon stocks of natural capital and replenish them. By replenishment, or regeneration, we mean *net* regeneration: 'births' minus 'deaths.' In a fishery, for example, there is renewal even when births equal deaths, that is, when net regeneration is zero. Fungi are involved in decomposing dead material and our waste products, enabling ecosystems to regenerate; birds and insects pollinate, helping to create new life; and so on. These processes involve energy flows and material transfers, which contribute to the production of maintenance and regulating services. There is mutual feedback between provisioning goods and maintenance and regulating services. The difference between *drawing upon* Nature for provisioning goods and *depending on* Nature for maintenance and regulating services is all-important here.

These, informal, remarks motivate the model that follows:

2. A Formal Macroeconomic Model (Dasgupta, 2021, 2024)

There are four broad classes of goods that macroeconomic models ought to possess: human capital (H), produced capital (K), natural capital (S), and knowledge and technology/institutions (A). Let R be the rate at which natural capital is harvested. We now construct a bare-bones model of the human economy (extensions suggest themselves):

Let Nature's regeneration rate be $G(S)$. As the biosphere is bounded, G is a bounded function of S. An augmented quadratic form is simple and usable:

$$G(S) = rS\left(1 - \frac{S}{S^*}\right)\left(\frac{S-L}{S^*}\right) \qquad r, S^*, L, (S^*-L) > 0 \qquad (1)$$

In eq.(1), S^* is a stable equilibrium of the natural system, and L is an unstable threshold: Thus, S declines to 0 if $S < S^*$, and gravitates to S^* if it exceeds S^*.

Imagine now that economy-wide output, Y, can be expressed as a function

$$Y = J(S,A)F(K,H,R) \qquad (2)$$

In eq. (2), J is an increasing function of S and A, and F is in an increasing function of K, H, and R. It will be noticed that the appearance of S in the J-function represents the idea that the human economy is embedded in Nature, while the appearance of R in the F-function captures the fact that we humans harvest Nature for our purposes.

For brevity, we display the dynamic characteristics of K and S, meaning that we hold H and A taken to be fixed. We denote time by t and assume it to be continuous.

Let C denote aggregate consumption. Then the economy can be modelled as the dynamical system

$$dS(t)/dt = G(S(t)) - R(t) \qquad (3)$$

$$dK(t))/dt = Y(t) - C(t) \quad (4)$$

$$Y(t) = J(S(t),A)F(K(t),H,R(t)) \quad (5)$$

In the dynamical system described by eq. (1) and (3)-(5), K and S are state variables, whereas as R and C are control variables. Positive economics would ask us to study the system under specific behavioural rules regarding the control variables. Alternatively, we could study an optimising system, in which the control variables are chosen by a decision maker in the light of his/her objectives.

Central to his argument was **the treatment of nature as capital**. Ecosystems are productive assets that generate flows of services – such as water regulation, pollination, climate regulation, and coastal protection – over time. Degradation of these assets is therefore economically analogous to the depreciation of physical capital. Ignoring this depreciation leads to systematically overstated measures of economic performance and masks the true cost of growth strategies that rely on asset liquidation.

Dasgupta placed particular emphasis on the stock–flow distinction. GDP is a measure of flows of marketed economic activity, not a measure of changes in the underlying asset base. When economic growth is achieved by running down natural capital stocks, GDP can rise even as societal wealth – comprehensive wealth – declines. From this perspective, GDP-centred macroeconomic analysis is silent on sustainability and intergenerational welfare.

A further pillar of his remarks concerned non-linearity and irreversibility. Ecological systems are characterised by thresholds, tipping points, and feedbacks. Once certain thresholds are crossed, ecosystems may undergo regime shifts that fundamentally alter their capacity to deliver services. The participants discussed how these dynamics imply that marginal analysis – the dominant mode of reasoning in macroeconomics – can dramatically understate risks, particularly when probabilities are low but consequences are large and persistent.

Finally, Dasgupta stressed that macroeconomic models embed ethical assumptions, whether explicitly or implicitly. By ignoring natural capital depreciation, models effectively privilege present consumption over future wellbeing. He argued that such ethical choices should be made explicit and subject to scrutiny, rather than hidden within technical assumptions.

He concluded by posing a challenge that recurred throughout the meeting: are macroeconomic models primarily tools for short-run forecasting under assumed stability, or are they frameworks for assessing long-run economic viability in a world where nature is a binding constraint? The answer to this question, he suggested, should guide how economists approach model design and use.

The opening remarks catalysed a detailed discussion of the structure and interpretation of the schematic model that Dasgupta presented, with particular focus on (i) regenerative dynamics of natural capital, (ii) tipping points and thresholds, and (iii) discounting.

Nature as a regenerative stock

Dasgupta introduced a highly aggregated representation of natural capital as a regenerative stock, S, evolving according to a regeneration function minus human extraction/harvest. He

stressed the deliberate level of aggregation and invited participants to treat S as a composite of renewable natural assets to focus attention on the core dynamics.

A key conceptual move in his explanation was that nature must enter macroeconomics in two places: (1) as a harvestable resource (the conventional framing), and (2) as the enabling environment within which the economy operates – i.e., as a determinant of the feasibility and productivity of economic activity. This framing connected directly to later workshop discussions on nature as a driver of total factor productivity and systemic resilience.

Thresholds and tipping points

Dasgupta used the regeneration function to illustrate two qualitatively different points: a stable steady state (S) and an unstable threshold (L). L was described as a critical threshold below which the system becomes "done for" (an absorbing collapse state), whereas S is stable under sufficiently constrained human intervention. In the phase-diagram interpretation, L is unstable and S* stable; extraction choices determine whether trajectories drift toward recovery or collapse.

This prompted a broader discussion about how macro models represent ecological tipping points: whether tipping points are assumed known and anticipated, whether they are uncertain, and how behaviour and policy might change under uncertainty about their location.

Discounting, stewardship, and competing objectives

A substantial portion of the discussion centred on the discount rate. Dasgupta argued that discounting can be a "trigger story" for many things that go wrong: valuing the present too highly relative to the future can drive extraction paths that erode the natural capital stock and potentially push the system past the unstable threshold.

Participants interrogated discounting along several dimensions:

- the planner interpretation in which the discount rate governs the steady state toward which the system converges;
- distinctions between a pure rate of time preference and consumption discounting linked to expected future consumption paths;
- ethical concerns, drawing on forestry debates where mechanical application of discounting rules was viewed as undermining stewardship;
- the provocation that restoration or "repair" dynamics might imply very low or even negative effective discounting over relevant horizons.

A further clarifying intervention noted that different disciplines implicitly target different points on the stock spectrum: maximum sustainable yield (MSY), conservation targets, or maximum economic yield (which differs from MSY because of discounting). A point of convergence was that these differences matter less than a shared imperative to remain safely away from points of irreversible collapse.

From stylised dynamics to macro modelling choices

Finally, participants stressed that even this stylised model raises core questions macroeconomic modelling must confront explicitly: behavioural foundations that generate extraction paths in decentralised settings, assumptions about substitutability between natural and produced capital, and the extent to which price signals can be relied upon to prevent over-extraction.

These early discussions established a recurring theme: the analytical challenge is not simply to add an "environment variable" to a macro model, but to reconsider deep assumptions about stability, substitutability, and long-run welfare when nature is treated as an essential and potentially fragile asset base.

Key questions and objectives guiding the discussion

Early in the meeting, participants explicitly framed a set of key questions, which served as reference points throughout the day:

1. How should nature be brought into macroeconomic analysis without simply reproducing the limitations of GDP-centric frameworks?
2. When is full integration into macro models necessary, and when are parallel systems more appropriate?
3. Who are the primary audiences for macroeconomic analysis of nature, and what decisions should it change?
4. How can macroeconomic framing move beyond constraint-based narratives toward growth, resilience, and equity?

A recurring intervention was the insistence on clarity about who macroeconomic modelling of nature is for and what outputs matter. Participants repeatedly emphasised that without explicit definition, modelling efforts risk becoming either too abstract or politically irrelevant.

The primary audiences identified were: (1) Ministries of Finance and Planning, concerned with growth, fiscal space, and debt sustainability; (2) governments, investors and local planners looking to inform specific investments, (3) International financial institutions, particularly the IMF and multilateral development banks, operating through surveillance and lending frameworks; (4) Central banks and supervisors, focused on stability and tail risks; (5) Sovereign risk analysts and investors, pricing long-term risk and opportunity. Each of the needs is different and has different implications for how and where to bring nature into models.

Across these audiences, participants stressed that what matters are signals that affect real decision – growth trajectories, fiscal risk, resilience – not environmental reporting for its own sake.

The meeting consistently rejected framing nature as a purely constraining force on economic activity. Instead, participants argued for a positive-sum narrative centred on: (1) higher-quality and more durable growth; (2) reduced macroeconomic volatility; (3) improved long-term fiscal sustainability; (4) distributional and equity considerations.

Several participants noted that constraint-based narratives often fail politically and analytically. In contrast, framing nature as an asset base that supports productivity and resilience aligns more closely with the mandates of finance ministries and economic institutions. This framing was explicitly linked to the case studies discussed later in the meeting, which demonstrated that investment in nature can reduce fiscal risk, improve debt dynamics, and strengthen growth prospects.

Finally, participants emphasised that indicators and accounts are not ends in themselves. The goal is to translate information into decisions that alter policy, investment, and real-economy outcomes.

Several speakers sketched an implicit decision chain: monitoring and information, economically meaningful signals, policy and investment decisions, real-economy change. Failure at any point in

this chain was seen as a central weakness of current approaches. This insight informed later discussions on model design, use cases, and practical integration.

Throughout the framing discussion, participants repeatedly acknowledged the limits of models. Macroeconomic representations of nature were described as necessarily partial, uncertain, and often linear approximations of non-linear systems. Data gaps, distributional effects, and political economy constraints were emphasised. This was not framed as an argument against modelling, but as a call for disciplined pragmatism: tools should be as simple as possible, transparent, and explicitly tied to decisions, while avoiding false precision and one-size-fits-all solutions.

2. Why this is important

2.1 The policy centrality of macroeconomic models

The discussion in the early sessions turned to the practical importance of macroeconomic models in shaping real-world decisions. Participants emphasised that macroeconomic models are not neutral analytical devices; they structure policy debates, define what is considered economically (and politically) feasible, and influence the allocation of financial resources.

Specific applications highlighted included:

- Fiscal policy and budgeting: Medium-term fiscal frameworks rely on macroeconomic projections of growth, revenues, and expenditure needs.
- Debt sustainability analysis (DSA): IMF and World Bank DSAs use growth, interest rate, and shock assumptions derived from macro models to assess sovereign solvency.
- Monetary policy: Central banks depend on macro models to forecast inflation, output gaps, and transmission mechanisms.
- Financial stability and stress testing: Macro-financial models underpin stress tests used to assess the resilience of banking systems and sovereign balance sheets.
- Sovereign risk and credit ratings: Rating agencies draw on macroeconomic assessments to evaluate long-term creditworthiness.
- Project-level analysis: informing specific projects, policies or investment decisions

Because these models structure expectations about future growth, productivity, and risk, omissions at the modelling stage can propagate through policy advice, investment decisions, and market pricing. Several participants argued that the absence of nature from macroeconomic baselines implicitly assumes ecological stability, thereby embedding optimistic growth paths that may not be robust to environmental degradation.

2.2 Implicit assumptions about nature in macro frameworks

Participants argued that most macroeconomic models implicitly assume that the natural environment remains sufficiently stable over the relevant policy horizon. Nature may enter models through exogenous shocks, such as natural disasters, or through narrow sectoral channels, but it is rarely treated as a dynamic asset whose condition evolves endogenously with economic activity.

This implicit assumption has several consequences:

- Growth projections may be systematically over-optimistic if they ignore degradation of productive ecosystems.
- Fiscal risk may be understated if natural buffers that reduce disaster impacts are eroded.
- Structural change induced by ecosystem collapse may be missed entirely.

- The benefits of investment in natural capital are underestimated.

Several participants noted that these assumptions are rarely made explicit, which makes them difficult to challenge in policy debates.

2.3 Baselines, path dependence, and the invisibility of nature loss

A particularly important point is concerned with the role of baselines in macroeconomic analysis. Baseline projections typically assume continuation of past trends, implicitly embedding historical ecological conditions into future expectations. As a result, gradual ecosystem degradation can remain invisible until it manifests as a shock. This is compounded by hysteresis behaviours displayed by many ecosystems with tipping points, whereby a shock due to ecosystem collapse lags behind the degradation and making nature's recovery from the shock much more challenging.

Participants highlighted that this creates a form of path dependence in policy analysis: once nature is excluded from the baseline, it becomes difficult to justify policy interventions aimed at protecting or restoring ecosystems on macroeconomic grounds. Nature-related policies may then appear as discretionary add-ons rather than as measures to protect the economic core.

This observation reinforced the argument that integrating nature into macro models is not merely about better risk assessment, but about reshaping the analytical baselines against which policy choices are evaluated.

3. Macro-criticality of nature-related risks

3.1 Why macro-criticality became the organising question

Following the opening conceptual discussion, the meeting turned explicitly to the question of macro-criticality, which quickly emerged as the central organising concept linking theory, modelling choices, and institutional relevance. Participants repeatedly returned to macro-criticality as the hinge between academic analysis and policy uptake: unless nature-related risks can be shown to be macro-critical, they will remain peripheral to the macroeconomic frameworks used by finance ministries, central banks, and international financial institutions.

Several participants noted that macro-criticality is not a purely analytical concept but an institutional filter. In IMF surveillance, World Bank diagnostics, and credit ratings, issues deemed macro-critical enter core analysis; those that are not will remain contextual or descriptive. As a result, the stakes of defining and evidencing macro-criticality are high.

3.2 Institutional definitions and ambiguities

The IMF's working definition of macro-criticality – factors that materially affect macroeconomic stability, growth, fiscal sustainability, or financial resilience – was used as a reference point. However, participants highlighted that this definition is deliberately broad and leaves substantial discretion in application. In practice, macro-criticality is often established implicitly, through precedent and judgement, rather than through formal thresholds.

This ambiguity prompted several clarifying questions during the discussion: Is macro-criticality about expected impacts or tail risks? Over what time horizon must impacts materialise to qualify as macro-critical? Does macro-criticality require economy-wide effects, or can sectoral impacts suffice if they propagate systemically?

These questions framed much of the subsequent debate.

3.3 Nature-related risks against macro-criticality criteria

Participants advanced multiple arguments for why nature-related risks meet macro-criticality criteria under identifiable conditions. These arguments were grouped around four main dimensions.

Growth and productivity effects

Several contributions emphasised that ecosystem degradation can affect not only short-run output but also long-run growth trajectories. Examples included: declining agricultural yields due to soil degradation, water stress, and loss of pollination; reduced labour productivity due to heat stress, pollution, and disease ecology; constraints on energy and manufacturing linked to water availability.

A key point was that these effects are often persistent rather than transitory. When natural capital underpins productive capacity, its degradation shifts the economy onto a lower growth path rather than generating a temporary shock. Participants noted that this distinction is crucial for macro-criticality, as persistent growth effects dominate debt dynamics and fiscal sustainability.

Fiscal impacts and public balance sheets

The discussion highlighted several fiscal channels through which nature-related risks can become macro-critical: increased public expenditure on disaster response and recovery; higher adaptation and infrastructure costs as natural buffers are lost; erosion of revenue bases linked to natural resource rents, tourism, and ecosystem-dependent sectors.

Participants stressed that these fiscal effects interact with debt dynamics. Even modest reductions in trend growth or increases in expenditure volatility can materially worsen debt sustainability assessments, particularly in countries with limited fiscal space.

Conversely, preserving or even restoring natural capital can have positive long-run growth and resilience impacts that compound over time to improve debt sustainability and increase fiscal space.

Volatility, shocks, and tail risks

A recurrent theme was that nature-related risks often manifest as low-probability, high-impact events, such as ecosystem collapses or correlated climate–nature shocks. Participants argued that macro-criticality should not be assessed solely on the basis of expected losses, but should also account for tail risks that can destabilise economies.

Historical examples including the Dust Bowl and large-scale ecosystem regime shifts, e.g. desertification in China since the 1980s, were cited as evidence that nature-related stresses and shocks can have economy-wide consequences. Several participants noted that standard macro models, which focus on marginal deviations around equilibrium, are poorly equipped to capture these dynamics.

Financial sector and sovereign risk transmission

Participants emphasised that nature-related risks can propagate through financial systems. Channels discussed included: (1) increased sovereign risk due to weaker growth and fiscal positions; (2) higher credit risk for banks and corporates exposed to ecosystem-dependent sectors; (3) feedback loops between financial stress and real economic activity.

From this perspective, nature-related risks can become macro-critical even if their initial impacts are sector-specific, provided they transmit through financial channels.

Context specificity and country archetypes

While there was broad agreement that nature-related risks can be macro-critical, participants strongly emphasised context specificity. Macro-criticality depends on economic structure, exposure, and institutional capacity. Several archetypes were discussed:

- Low-income, ecosystem-dependent economies, where agriculture, fisheries, and natural resources dominate output and employment;
- Small island and coastal states, where natural capital provides critical protection against shocks;
- Middle-income economies in transition, where rapid growth is placing pressure on ecosystems;
- Advanced economies, where exposure arises through global value chains and imported nature risks.

This typology reinforced the view that integration of nature into macro models should be prioritised where macro-criticality is most evident, rather than pursued uniformly across all contexts.

3.5 The macro-criticality paradox

A central paradox crystallised during the discussion: if nature-related risks satisfy macro-criticality criteria, why are they largely absent from core macro frameworks such as IMF Debt Sustainability Analyses and baseline growth projections?

Participants offered several explanations: data limitations, lack of modelling conventions, institutional inertia, and the tendency to treat nature as a long-run issue outside standard policy horizons. However, many argued these explanations are increasingly insufficient given the scale, immediacy, and persistence of nature-related risks.

This paradox set the stage for a further, more reflective discussion later in the meeting on whether macro-criticality should be the sole or even primary criterion for integrating nature into macroeconomic models.

3.6 Beyond macro-criticality: broader rationales for integrating nature into macroeconomic models

In a later session, participants explicitly questioned whether the focus on macro-criticality, while necessary for engagement with central banks, the IMF, and prudential authorities, was too narrow to capture the full set of reasons for integrating nature into macroeconomic analysis

Several speakers argued that macro-criticality functions as a gatekeeping concept: it determines what enters core surveillance and stress-testing frameworks, but it does not exhaust the

legitimate use cases for macroeconomic models. From this perspective, insisting that nature be macro-critical before it is modelled risks reproducing the very blind spots the workshop sought to address.

Macroeconomic models as tools for opportunity analysis, not only risk screening

One strand of the discussion emphasised that macroeconomic models are not used solely to identify downside risks. They are also used to: assess growth strategies and development pathways; evaluate public investment priorities; compare alternative policy scenarios; make the economic case for reforms, including cost benefits analyses and policy appraisals.

From this vantage point, integrating nature into macroeconomic models can serve to demonstrate the positive contribution of natural capital to growth, resilience, and fiscal performance, even where degradation does not yet pose an acute macro-critical risk.

Participants argued that if macro models are used only to highlight crises, they systematically undervalue investments in prevention, protection, and restoration. Integrating nature proactively can therefore help shift policy debates from reactive risk management toward strategic investment in natural capital.

The discussion drew explicitly on the Belize case to illustrate this point. In Belize, analysis of coral reefs and mangroves demonstrated that healthy ecosystems significantly reduce hurricane damages and macroeconomic volatility. However, several participants noted that under standard IMF and World Bank frameworks, this protective function appears only indirectly, if at all.

Gross Ecosystem Product (GEP) and growth-oriented use cases

A parallel argument emerged from discussion of China's work on Gross Ecosystem Product (GEP). Participants noted that GEP was developed not primarily as a crisis-management tool, but as a way of reshaping development incentives by making ecosystem service provision visible alongside GDP.

In several Chinese provinces, GEP is used in parallel with GDP to assess performance, with explicit policy objectives to "grow GEP." Participants argued that this illustrates a fundamentally different use case for macro-style metrics: rather than screening for macro-critical risks, GEP-informed analysis is used to guide investment, land-use planning, and inter-regional transfers.

This experience reinforced the view that macroeconomic frameworks can be used to value nature as a driver of economic opportunity, not only as a constraint. Several participants suggested that a narrow focus on macro-criticality may underplay these opportunity-oriented applications, particularly in development contexts.

Reconciling multiple use cases

The discussion converged on the idea that macro-criticality should be understood as a sufficient but not necessary condition for integrating nature into macroeconomic models. For institutions with financial stability mandates, macro-criticality provides a defensible entry point. However, for growth, development, and investment planning, other rationales, such as improving growth quality, resilience, and intergenerational welfare, are equally legitimate.

Participants suggested that clarity about model purpose is essential: the same economy may warrant nature integration for different reasons in different analytical contexts. Recognising this

plurality of use cases was seen as crucial for avoiding an overly restrictive framing that limits innovation and policy relevance.

4. Case studies and empirical applications

4.1 Purpose and role of the case studies

The case studies presented during the workshop played a dual role. First, they provided empirical grounding for the conceptual and modelling discussions in earlier sessions, demonstrating that nature–macro linkages are not hypothetical but observable in real economies. Second, they served as boundary objects between disciplines and institutions, allowing participants to test how different modelling approaches perform when confronted with concrete policy problems.

Participants repeatedly emphasised that the case studies should not be interpreted as templates to be replicated mechanically. Instead, they were presented as illustrative examples highlighting distinct transmission channels, institutional entry points, and modelling challenges.

4.2 Belize: coral reefs, mangroves, and macroeconomic resilience

The Belize case was among the most frequently referenced throughout the meeting and served as a canonical example of how natural capital can be macro-critical through risk buffering and volatility channels. Belize is a small, open economy with high exposure to tropical cyclones and a narrow production base. Presentations described modelling work that combined: ecosystem service valuation of coral reefs and mangroves; hurricane damage functions differentiated by ecosystem condition; macroeconomic projections of GDP, fiscal balance, and debt dynamics. This analysis compared counterfactual scenarios with intact versus degraded ecosystems under identical hurricane intensities.

One participant observed that Belize's macroeconomic resilience to Category 4 hurricanes may be systematically understated when ecosystem services are excluded from baseline analysis. In this context, the value of nature lies not only in averting a debt crisis (macro-criticality), but in improving the economy's long-run growth–volatility trade-off and reducing fiscal risk ex ante.

The results showed that healthy reefs and mangroves substantially reduce expected damage to coastal infrastructure and housing. More importantly for macroeconomics, ecosystem degradation was found to: increase GDP volatility; worsen fiscal balances following shocks; raise the probability of debt distress events.

Participants emphasised that these effects operate through distributional changes rather than large shifts in mean outcomes. Ecosystem loss increases tail risk, which is central to macro-criticality in Small Island Developing States' economies.

This led to the argument that waiting until nature loss becomes macro-critical risks missing the opportunity to use macroeconomic analysis to justify early investment in ecosystem protection. The Belize case was therefore cited as evidence that nature should enter macro models as a contributor to resilience and growth, not only as a source of downside risk.

The Belize case was repeatedly cited as evidence that standard IMF Article IV consultations and DSAs may systematically understate resilience when ecosystem services are excluded. Several participants argued that this creates a bias against ecosystem investment, as the macroeconomic benefits of nature-based solutions are rendered invisible.

4.3 Ghana: natural capital, growth, and debt sustainability

The Ghana case focused on the interaction between land-use change, ecosystem degradation, and macroeconomic performance. Ghana's economy is highly dependent on agriculture and natural resource exports, making it a relevant test case for nature-related macro-criticality.

Results suggested that continued ecosystem degradation could materially lower medium-term growth trajectories, with significant implications for debt dynamics. Participants noted that even small downward revisions to trend growth can substantially worsen debt sustainability assessments.

Participants argued that Ghana exemplifies a class of countries where integrating natural capital into baseline macroeconomic projection, not only stress scenarios, may be warranted. This reinforced the view that DSAs represent a high-impact entry point for nature integration.

4.4 Uganda: forests, hydrology, and macro-fiscal risk

The Uganda case focused on forest landscapes and their role in hydrological regulation, agricultural productivity, and disaster risk. Presentations described how deforestation affects downstream flooding, soil erosion, and rural livelihoods. The analytical approach combined landscape-level ecological analysis with macro-fiscal scenarios, illustrating a modular integration strategy.

Participants highlighted that forest degradation increases both the frequency and severity of floods, leading to: higher public expenditure on disaster response; increased infrastructure repair costs; greater volatility in agricultural output and rural incomes.

The Uganda case was used to demonstrate how detailed ecological analysis can inform macroeconomic scenarios without requiring full ecological–macroeconomic integration. This was cited as a promising pathway for low-income countries with data constraints.

4.5 United Kingdom: nature-related risks in an advanced economy

The UK case was discussed as an illustration of how nature-related risks can be economically material in an advanced economy even when they are not yet conventionally classified as macro-critical. Participants emphasised that in the UK context, nature does not primarily enter macroeconomic analysis through aggregate output collapse, but through cumulative impacts on productivity, prices, fiscal exposure, and risk management. Examples raised in discussion included flooding affecting infrastructure and housing, heat and water stress impacting agricultural output and labour productivity, and degradation of natural floodplains and wetlands increasing reliance on engineered defences and public compensation mechanisms, as well as rising risks of international supply chain shocks.

These impacts are often treated as localised or sectoral, and time-limited, but participants noted that their cumulative effects, through higher insurance costs, rising public expenditure on disaster response and adaptation, and pressures on food prices, can become macro-relevant over time.

The UK case was therefore used to demonstrate that waiting for nature-related risks to become clearly macro-critical may bias decision-making toward reactive rather than preventive policies. Several participants argued that integrating nature into UK macroeconomic analysis should focus on early-warning signals, fiscal risk, and resilience, rather than attempting to model economy-wide collapse scenarios. More broadly, the UK example was used to challenge the perception that nature–macro linkages are primarily a concern for low-income or highly nature-dependent

economies, and to underline the relevance of nature for long-term growth quality and stability in advanced economies.

The UK case was therefore used to illustrate the importance of early integration to support preventive investment.

4.6 France: water stress

The France case was raised in discussion as a salient example of how nature-related risks can become macro-critical in an advanced economy. Participants referred to recent episodes of drought and heat stress, which constrained water-intensive industrial production processes, hydroelectric production and limited the cooling capacity of nuclear power plants. Drought episodes also have consequences on agriculture yields and therefore on food inflation. The analytical framing emphasised water as a systemic input into electricity and industrial production, linking hydrological conditions directly to industrial output, electricity prices, and macroeconomic stability.

The France case illustrated several transmission channels discussed earlier in the meeting:

- Production and input dependency: electricity generation constrained by water availability;
- Price and inflation effects: reduced industrial and agriculture production contributing to higher prices;
- Fiscal and quasi-fiscal impacts: public exposure through state-linked utilities and price stabilisation mechanisms;
- Cross-border spillovers: impacts on electricity trade within the European market.

Participants stressed that these effects are not well captured in standard macroeconomic baselines, which typically assume stable energy supply conditions.

The France case was used to demonstrate that nature-related risks can be macro-critical in advanced economies when they affect core infrastructure systems and industrial production processes. Unlike some other cases discussed, the macro relevance here arises not gradually but episodically, through binding constraints on a system that underpins the wider economy.

Similar to the UK case, participants argued that this example challenges the perception that nature–macro linkages are primarily a concern for developing or ecosystem-dependent economies. It also reinforced the need for macroeconomic models to consider critical-input bottlenecks and non-substitutability in infrastructure systems.

4.7 China: Gross Ecosystem Product (GEP) as an alternative macro metric

China's work on Gross Ecosystem Product (GEP) was presented as an example of a fundamentally different approach to integrating nature into economic decision-making. GEP measures the value of ecosystem services alongside GDP, with explicit policy objectives to increase ecosystem service provision.

Participants noted that GEP is used in some regions to guide land-use planning, inter-regional fiscal transfers, and performance assessment. Unlike crisis-oriented macro tools, GEP is designed to reshape development incentives. The China case reinforced the argument that macroeconomic frameworks can be used not only to manage risks but also to promote nature-positive growth pathways.

4.8 Ecuador: debt-for-nature swaps and fiscal space

The Ecuador case centred on the 2024 terrestrial debt-for-nature swap, which linked debt relief to long-term ecosystem protection commitments. Participants discussed how such instruments interact with macro-fiscal dynamics by reducing debt service burdens and potentially lowering future disaster-related expenditures. This case was used to illustrate how financial innovation can create entry points for integrating nature into macroeconomic and fiscal analysis.

4.9 Cross-cutting lessons from the case studies

Drawing the case studies together, participants identified several common lessons: nature-related risks and opportunities operate through multiple macroeconomic channels; macro-criticality is highly context-specific; different modelling approaches are appropriate for different cases; failure to integrate nature often biases macroeconomic analysis against preventive investment.

These lessons informed subsequent discussions on provocations, synthesis, and next steps.

5. Transmission channels between nature and the macroeconomy

5.1 Why transmission channels became the analytical bridge

Building on the discussion of macro-criticality, participants converged on transmission channels as the key analytical bridge between ecological processes and macroeconomic outcomes. Transmission channels were seen as a pragmatic way to connect complex, non-linear ecological dynamics to the stylised structures of macroeconomic models without requiring full ecological–economic integration.

Several participants noted that transmission channels already play a central role in climate-related macro-financial analysis (e.g. physical and transition risk channels in NGFS work). Extending this logic to nature was viewed as both analytically coherent and institutionally legible. Importantly, a transmission-channel approach allows analysts to be explicit about which mechanisms matter for which policy questions, rather than asserting that nature must be fully modelled everywhere.

5.2 Production and input dependency channels

A first set of channels discussed concerned the direct dependencies of production on ecosystem services. These channels were presented as the most intuitive entry point for macroeconomic models, but also as the most frequently underestimated.

Participants highlighted multiple examples: agriculture's dependence on soil quality, water availability, and pollination; fisheries' reliance on ecosystem structure and regeneration; water-intensive manufacturing and energy systems constrained by hydrological conditions.

Several speakers stressed that these dependencies are often treated as sectoral issues, yet their macroeconomic relevance emerges through aggregation, price transmission, and employment effects. When such dependencies are widespread or correlated, they can materially affect aggregate output and inflation.

Concrete illustrations were drawn from case studies discussed later in the meeting. In **Ghana**, research showed how agricultural productivity and export revenues are tightly coupled to land and ecosystem condition, with implications for medium-term growth and debt trajectories. Similarly,

in Vietnam, participants noted that degradation of mangroves and coastal ecosystems threatens aquaculture and export-oriented fisheries, with knock-on effects for balance-of-payments dynamics.

The France case was discussed as a particularly important example of how nature-related risks can become macro-critical in an advanced economy through critical infrastructure and industrial production dependencies, rather than through traditional environment-sensitive sectors such as agriculture. Participants referred to recent episodes in which heat stress and low river flows constrained water-intensive industrial production processes, hydroelectric production, nuclear plants' cooling capacity and, forcing reductions in electricity generation. In case these episodes would be more recurring and severe, these constraints would have economy-wide implications, including effects on electricity prices, inflation dynamics, and cross-border electricity trade within Europe. The modelling discussion focused on the fact that water availability functions as a non-substitutable input into energy and industrial production in the short to medium run. Standard macroeconomic models typically assume stable energy supply or smooth substitutability between inputs, and therefore struggle to represent such binding constraints. The France example was used to illustrate several broader points:

- nature-related risks can be macro-critical even in high-income economies;
- macro relevance may arise episodically, through infrastructure bottlenecks, rather than gradually;
- equilibrium assumptions and linear responses can substantially understate economic impacts when key systems are constrained.

Participants argued that this case underscores the need for macroeconomic models to explicitly consider critical-input bottlenecks and non-linear supply constraints, particularly where public balance sheets and regulated utilities are involved.

5.3 Labour productivity, health, and human capital

A second cluster of channels related to labour productivity and human capital. Environmental degradation affects labour supply and productivity through heat stress, air and water pollution, and disease ecology.

Participants emphasised that these effects often operate cumulatively and interact with socioeconomic conditions. Reduced labour productivity may not appear dramatic in a single year, but persistent degradation can significantly lower effective labour input and long-run growth.

Examples from Belize were cited, where ecosystem degradation exacerbates vulnerability to hurricanes, leading to repeated disruptions to labour markets, schooling, and health services. The UK example linked increased air pollution and declining public health benefits of nature (as leisure) to reduced labour productivity. Participants argued that these channels are rarely captured in macro models, which typically treat labour supply shocks as temporary. While these impacts may not yet appear macro-critical at the national level, they illustrate how labour–nature channels can become economically salient well before reaching crisis thresholds, especially when compounded with climate change.

Several participants noted that macro models typically capture labour impacts only through demographic change or exogenous productivity shocks. Integrating environment-related productivity effects requires explicit recognition of nature and climate as determinants of effective labour supply.

5.4 Fiscal channels and public balance sheets

The discussion then turned to fiscal transmission channels, which were viewed as particularly salient for debt sustainability analysis and finance ministry decision-making.

Key mechanisms discussed included: increased public expenditure on disaster response as natural buffers are degraded; higher long-term infrastructure and adaptation costs; loss of fiscal revenues linked to ecosystem-dependent sectors (e.g. tourism, natural resource rents).

Participants stressed that fiscal channels often interact with growth effects, amplifying their macroeconomic significance. For countries with limited fiscal space, even moderate increases in expenditure volatility or reductions in revenue can have outsized effects on debt dynamics.

Several case studies were used to illustrate these dynamics.

In **Uganda**, discussion focused on forestry and land-use dynamics and their fiscal implications. Participants described how forest degradation affects hydrological regulation, agricultural productivity, and disaster risk, with knock-on effects for public expenditure on flood response and rural infrastructure repair. The Uganda case was used to illustrate how investments in forest protection and restoration could improve fiscal outcomes over the medium term, even if near-term costs are visible and benefits accrue gradually.

In **Ecuador**, reference was made to the 2024 terrestrial debt-for-nature swap, which explicitly linked fiscal space to long-term investment in ecosystem protection. Participants noted that while such instruments are often discussed as conservation finance, they also operate through fiscal channels by reducing debt service burdens and lowering future disaster-related expenditures.

5.5 Risk buffering, volatility, and tail-risk amplification

A distinct but related set of channels concerned risk buffering and volatility. Healthy ecosystems, such as mangroves, wetlands, coral reefs, forests, and floodplains, act as natural buffers that reduce the frequency and severity of shocks.

The loss of these buffers was discussed as a form of endogenous risk amplification. Rather than simply increasing expected losses, degradation raises volatility and tail risks, which are particularly problematic for macroeconomic stability.

The **Belize** case again featured prominently. Participants discussed modelling exercises that compared macroeconomic outcomes under Category 4 hurricane scenarios with and without intact reef and mangrove systems. Results suggested that ecosystem degradation shifts the entire distribution of outcomes, increasing the likelihood of extreme GDP contractions and fiscal stress events, even if average impacts appear modest.

The discussion also referenced **Uganda**, where degradation of upstream forests and wetlands increases flood risk and agricultural volatility downstream. Participants noted that such risks manifest not only as episodic disasters but also as chronic volatility affecting rural incomes, food prices, and public expenditure planning.

5.6 International trade, value chains, and spillovers

Participants devoted significant attention to international transmission channels, noting that nature-related risks frequently propagate across borders through trade and value chains.

Examples included: imported food inflation due to ecosystem degradation in producer countries; supply-chain disruptions linked to water stress or deforestation; transboundary ecosystem services, such as rainfall regulation, whose degradation has global consequences.

Case studies discussed at the meeting illustrated these dynamics. Work in Colombia and Vietnam highlighted how deforestation and land-use change can alter hydrological cycles, affecting agricultural productivity beyond national borders. Participants noted that such spillovers are rarely captured in country-level macro models, despite their relevance for trade balances and inflation dynamics.

For advanced economies, participants argued that macro-critical exposure to nature-related risks may arise predominantly through imported inputs rather than domestic ecosystem degradation. This reinforced the need to extend macroeconomic analysis beyond national boundaries.

5.7 Financial sector and macro-financial feedbacks

Financial transmission channels were discussed in the context of both risk and amplification. Participants from credit rating agencies and financial stability units highlighted how nature-related risks can affect: sovereign creditworthiness; bank balance sheets; investor behaviour and capital flows.

Illustrations were drawn from Ghana, which suggested that failure to account for ecosystem degradation can lead to systematically optimistic sovereign risk assessments. Participants from credit rating agencies noted that while ratings frameworks increasingly reference environmental risks, integration into core quantitative assessments remains limited.

In Belize, participants noted that improved ecosystem protection could, in principle, reduce sovereign risk premia by lowering the probability of severe fiscal stress following natural disasters. This highlighted the potential for feedback loops between ecosystem investment, financial conditions, and macroeconomic stability.

5.8 Correlation, non-linearity, and systemic interactions

A cross-cutting theme in the discussion was the importance of correlation and non-linearity across transmission channels. Nature-related risks are often correlated spatially (e.g. regional droughts), temporally (persistent degradation), and across sectors.

Participants stressed that macro models calibrated to historical averages may significantly understate risks when multiple channels interact or when systems approach tipping point thresholds. This reinforced earlier critiques of marginal analysis and equilibrium assumptions.

5.9 Implications for modelling practice

The section concluded with a discussion of how transmission channels should inform modelling choices. Participants agreed that: not all channels need to be included in every model; channel selection should depend on policy purpose and country context; transparency about omitted channels is essential.

Transmission channels were thus framed as a modular approach to integration, enabling incremental progress while maintaining analytical clarity.

6. Differentiating macroeconomic models and their purposes

6.1 Why model differentiation became central to the discussion

As the discussion moved from transmission channels to implementation, participants repeatedly stressed that debates about whether and how to integrate nature into macroeconomics often suffer from a category error: macro models are treated as if they are all the same. A central contribution of the meeting was to make explicit that different macroeconomic models serve different purposes, operate at different levels of abstraction, and face different institutional constraints.

Several participants argued that much of the apparent disagreement between disciplines dissolves once model purpose is clarified. Ecologists and complexity-oriented economists often criticise macro models for failing to capture thresholds and non-linearities, while macro practitioners respond that their models are designed for specific policy tasks under time and data constraints. The workshop therefore emphasised the need for a pluralistic modelling ecosystem, rather than a single integrated framework.

6.2 Stylised models: clarifying mechanisms and limits

Stylised or so-called conceptual or 'toy' models were discussed as a critical first tier of analysis. These models deliberately abstract from institutional detail in order to clarify core mechanisms and explore qualitative dynamics.

Participants referred explicitly to the schematic renewable-resource model presented in the opening session (discussed in Section 1), in which natural capital evolves according to a regenerative function with an unstable threshold (L) and a stable steady state (S*). This class of models was seen as particularly valuable for: illustrating how discounting, extraction behaviour, and regeneration interact; demonstrating the possibility of irreversible collapse; showing why marginal analysis around a steady state can be misleading.

Several participants drew parallels with extensions of the DICE model that incorporate tipping points and stochastic thresholds. These models were not presented as policy tools, but as conceptual warnings that inform what policy-relevant models should and should not assume.

Box: Example of stylised model

A key contribution to the meeting was the presentation of a conceptual macro–nature model designed explicitly as a thinking tool rather than a calibrated policy model. The purpose of the framework was to clarify how nature-related processes could enter standard macroeconomic reasoning in a disciplined and transparent way, without immediately requiring full empirical integration or complex ecological modelling. The model treated natural capital as an underlying state variable that affects the economy through a small number of macro-relevant channels, notably:

- trend productivity and potential output,
- exposure and sensitivity to shocks, and
- long-run growth trajectories.

The model focused on exploring how advanced economies import nature-related risks from lower income economies and impose pressures on them. The presenters emphasised that the model's value lay in demonstrating directional effects and interactions, rather than in generating quantitative forecasts. Several participants welcomed this approach as a pragmatic bridge between highly stylised theory and applied surveillance tools such as IMF Article IVs and debt sustainability analysis. The discussion highlighted that such conceptual models can play a critical agenda-setting role: they make explicit where nature enters macroeconomic logic and help discipline subsequent decisions about what must be integrated empirically, and where scenario analysis may suffice.

6.3 Exploratory and research-oriented macro models

A second tier of models discussed were exploratory research models, which sit between stylised theory and applied policy tools. These models typically retain microfoundations and dynamic structure but allow greater flexibility in functional forms, parameterisation, and scenario design.

Examples discussed included: dynamic general equilibrium models with renewable natural capital as a factor of production; growth models where ecosystem services enter total factor productivity; macro-climate models extended to include nature-related damages beyond temperature effects.

One presentation referenced work extending integrated assessment models (IAMs) to represent biodiversity loss and ecosystem services explicitly, noting both the analytical promise and the challenges of calibration and validation. Participants stressed that such models are valuable for exploring orders of magnitude and interactions, even when precise quantification is uncertain.

A recurring point was that exploratory models are essential for stress-testing assumptions embedded in applied models. They can reveal when linear approximations break down, when correlations matter, and when policy conclusions are sensitive to ecological parameters that are otherwise ignored.

6.4 Applied policy models: DSGE, CGE, and debt sustainability frameworks

The discussion then turned to applied macroeconomic models that are embedded in policy institutions. Participants emphasised that these models are constrained by requirements for transparency, replicability, and comparability across countries.

DSGE models

Dynamic stochastic general equilibrium (DSGE) models were discussed primarily in the context of central banking. Participants noted that DSGEs are well suited to analysing short- to medium-term fluctuations and policy transmission, but are poorly equipped to represent non-linear ecological dynamics.

Several central bank practitioners described experiments in introducing nature-related shocks into DSGE frameworks, typically through: productivity shocks; supply constraints; disaster-related capital losses.

While these exercises were seen as useful for first-order insights, participants acknowledged that DSGEs tend to assume mean reversion and equilibrium restoration, which may understate persistent impacts of ecosystem degradation.

CGE models

Computable general equilibrium (CGE) models were discussed as more flexible tools for representing sectoral dependencies on natural capital. Presentations referenced CGE applications that explicitly model land use, water constraints, and ecosystem services in agriculture and energy systems.

Participants noted that CGE models are often used in development and climate policy analysis, including World Bank Country Climate and Development Reports. However, concerns were raised about parameter uncertainty and the tendency of CGEs to assume smooth substitution between inputs, potentially masking hard ecological constraints and to move to equilibrium too rapidly and so underestimate shocks.

Case Study: GTAP-Invest

One contribution presented modelling work based on the GTAP-InVEST framework, a dynamic computable general equilibrium (CGE) model designed to analyse long-run growth, investment dynamics, and structural change. The presentation explored how nature-related factors and environmental constraints could be represented within an existing, policy-relevant global macroeconomic model, rather than through a bespoke ecological–economic framework.

The emphasis of the presentation was on using an established macroeconomic model to test how different assumptions about environmental conditions, resource constraints, or nature-related productivity effects influence investment patterns, sectoral outcomes, and growth trajectories. The presentation highlighted the strengths of GTAP-Invest in tracing economy-wide and cross-sectoral effects over long time horizons, while also acknowledging the limits imposed by its structure and data requirements.

In discussion, participants noted that the GTAP-Invest approach illustrates a pragmatic pathway for integrating nature into macroeconomic analysis: working within models already familiar to policymakers, and extending them incrementally rather than attempting full ecological integration. At the same time, several comments emphasised that CGE-based models such as GTAP-Invest tend to rely on assumptions of smooth adjustment and substitutability, which may under-represent non-linear ecological dynamics or threshold effects.

Debt sustainability analysis (DSA)

Debt sustainability frameworks were discussed as a particularly important but underdeveloped application. Participants from international financial institutions noted that DSAs rely heavily on baseline growth assumptions and stress scenarios, yet rarely incorporate nature-related risks explicitly.

The Ghana and Belize cases were cited as examples where incorporating nature-related growth and volatility effects could materially alter debt trajectories. Participants argued that DSAs represent a high-impact entry point for integrating nature into macroeconomic analysis, given their influence on policy advice and market perceptions.

Hybrid and modular approaches

Several participants advocated for hybrid modelling approaches that combine insights from different model tiers. Examples included: using stylised models to identify relevant thresholds and channels; parameterising applied models using insights from exploratory research; embedding nature-related shocks into existing policy models without full integration.

The Uganda case was referenced as an illustration of this approach, where landscape-level ecological analysis informs macro-fiscal scenarios without requiring a fully integrated ecological–macroeconomic model.

Participants emphasised that modularity enhances credibility: it allows institutions to build on existing tools while progressively expanding their scope.

Model choice, purpose, and institutional mandate

A recurring theme was that no model is universally fit for purpose. Model choice must be guided by: the policy question being asked; the institutional mandate of the user; data availability and uncertainty; the relevant time horizon.

Central banks prioritise simplicity, tractability and comparability to allow integration within the banking sector and assessments across large portfolios of banks and geographies in a consistent way for stress testing and monetary policy applications; development institutions may tolerate greater complexity; research communities can explore more speculative dynamics. Recognising these differences was seen as essential for constructive progress.

Implications for future modelling work

The section concluded with several implications: debates should focus less on whether a model is "right" and more on whether it is appropriate for a given task; stylised models play a crucial agenda-setting role; applied models should be stress-tested against insights from non-linear and threshold-based analyses; transparency about limitations is as important as technical sophistication.

Participants agreed that advancing nature–macro integration requires not a single breakthrough model, but a coordinated evolution of the modelling ecosystem.

7. Provocations, unresolved debates, and points of tension

7.1 Purpose of the provocations

A dedicated portion of the meeting was devoted to surfacing provocations: arguments deliberately framed to challenge prevailing macroeconomic assumptions and to expose unresolved tensions rather than to reach immediate consensus. Participants emphasised that these provocations were a feature, not a flaw, of the meeting: progress in integrating nature into macroeconomics requires confronting foundational assumptions.

This section records the main provocations and debates as they emerged, highlighting where views converged, where disagreement persisted, and why these tensions matter for future research and policy.

7.2 Equilibrium bias versus disruption and regime change

One of the most persistent provocations concerned the equilibrium bias embedded in many macroeconomic models. Several participants argued that standard models are structurally inclined to assume recovery and mean reversion following shocks. This bias was described as increasingly untenable in contexts where ecological degradation can lead to permanent loss of productive capacity.

Drawing on earlier discussions of tipping points, participants noted that ecosystems may cross thresholds beyond which recovery is slow, costly, or impossible. When macro models impose equilibrium by construction, they risk underestimating long-run damages and overstating resilience.

Some participants acknowledged this critique but emphasised that equilibrium assumptions are often necessary to maintain tractability and policy relevance. The tension was not resolved, but there was agreement that equilibrium assumptions should be made explicit and stress-tested against non-equilibrium scenarios.

7.3 Marginal analysis versus systemic and non-marginal risks

A closely related provocation concerned the dominance of marginal analysis in macroeconomics. Several participants argued that nature-related risks are often systemic and non-marginal, particularly when multiple transmission channels interact or when degradation accumulates over time.

Examples discussed included correlated food-system shocks, hydrological disruptions affecting energy systems (as in France), and cascading fiscal impacts following repeated disasters. In such cases, marginal damage functions may fail to capture the scale and persistence of impacts.

Participants debated whether macro models can realistically move beyond marginal analysis without losing analytical coherence. While no consensus emerged on how to operationalise non-marginal/non-linear risks, there was agreement that relying solely on marginal approaches is insufficient for capturing the risks highlighted in the case studies.

7.4 Risk, uncertainty, and ignorance

A further provocation addressed the distinction between risk, uncertainty, and ignorance. Participants noted that many macroeconomic frameworks implicitly assume quantifiable risk, with known probability distributions.

Ecologists and complexity-oriented economists argued that nature-related processes often fall into the realm of deep uncertainty or ignorance, particularly with respect to tipping points and regime shifts. This raises questions about the appropriateness of probabilistic modelling and expected-value optimisation.

Some participants advocated for scenario-based approaches and robustness analysis as more appropriate tools under deep uncertainty. Others cautioned that abandoning probabilistic frameworks entirely would undermine comparability and policy usability. The debate highlighted a fundamental methodological tension that remains unresolved.

7.5 GDP, net measures, natural capital accounting, and GEP

A sustained thread throughout the day concerned where natural capital accounting (NCA) and related frameworks such as Gross Ecosystem Product (GEP) fit within macroeconomic analysis, and why, despite significant technical progress, they have so far had limited influence on core economic decision-making.

Participants were clear that natural capital accounting is among the most mature components of the nature–economics toolkit. International standards such as the UN System of Environmental–Economic Accounting (SEEA) provide well-developed methodologies for measuring ecosystem extent, condition, and service flows, and many countries now produce natural capital accounts on a regular basis.

However, a recurring and strongly expressed concern was that natural capital accounts largely sit alongside, rather than inside, macroeconomic decision frameworks.

Net measures: One participant suggested the adoption of Net Domestic Product rather than Gross Domestic Product (GDP) in more macroeconomic models and decision-making. They stressed that in no other context do we consider gross profit or output rather than net and GDP obscures the costs and can lead to maximisation of present-day consumption over future social welfare. However, others highlighted the challenge of garnering policy maker interest in analysis that did not focus on GDP and challenges of comparability with other analysis. There was wider agreement as a first step GDP could be reported alongside other economic metrics, including net measures, to nudge away from GDP supremacy.

The "satellite account" problem

Several participants described what was termed the satellite account problem: natural capital accounts are produced as supplementary statistics, but they do not feed into the core analytical tools that shape fiscal policy, growth strategies, or risk assessments. As a result, they are often acknowledged rhetorically but ignored operationally.

This was contrasted with national accounts aggregates such as GDP, which are deeply embedded in macroeconomic models, fiscal rules, and institutional mandates. Participants argued that as long as natural capital accounts remain analytically disconnected from these frameworks, their influence on real-world decisions will remain limited.

From measurement to decision relevance

A key provocation was that the challenge facing natural capital accounting is no longer primarily one of measurement, but one of integration. Participants noted that policymakers frequently ask: What do these numbers change in practice?

Several participants argued that without clear links to: growth projections, fiscal balances and debt dynamics, cost–benefit analysis and investment appraisal, and natural capital accounts risk being perceived as descriptive rather than decision-relevant.

Natural capital accounting and macro models

The discussion explored multiple ways in which natural capital accounting could be more tightly integrated into macroeconomic analysis:

- using ecosystem condition accounts to inform assumptions about trend productivity in ecosystem-dependent sectors;
- linking changes in natural capital stocks to adjustments in baseline growth paths;
- using ecosystem service values to parameterise fiscal risk scenarios and avoided-loss calculations;
- integrating depreciation of natural capital into extended measures of net domestic product.

Participants stressed that such integration does not require replacing existing macro models, but rather feeding NCA outputs into the assumptions and parameters that already drive them.

GEP as an alternative integration pathway

The discussion of Gross Ecosystem Product (GEP) was explicitly linked to this integration challenge. Participants noted that GEP differs from natural capital accounting not in its underlying valuation logic, but in how it is used institutionally. In China, GEP has been deployed as a decision metric alongside GDP, influencing land-use planning, intergovernmental transfers, and performance evaluation. Participants argued that this demonstrates how ecosystem service valuation can matter when it is explicitly tied to incentives and accountability, rather than remaining a background statistic. However, participants also cautioned that GEP should not be seen as a universal solution. Questions remain about valuation methods, double counting, and comparability across regions. Nonetheless, GEP was widely seen as an important proof of concept for making nature operationally visible in economic decision-making.

Reframing the role of accounts in macroeconomics

A concluding theme was that natural capital accounts and GEP should be viewed as inputs into macroeconomic reasoning, not as standalone alternatives to macro models. Their value lies in informing baselines, scenarios, and policy appraisal, rather than in replacing GDP or growth models outright.

Several participants suggested that future work should focus less on debating metrics and more on demonstrating concrete decision pathways showing, for example, how ignoring natural capital depreciation biases fiscal decisions, or how incorporating ecosystem services alters investment priorities.

This discussion reinforced a broader message of the meeting: the technical foundations for valuing nature are already well advanced, but their economic impact will remain limited until they are systematically integrated into the analytical frameworks that govern macroeconomic decision-making.

7.6 Substitutability and the limits of price signals

Another point of tension concerned assumptions about substitutability between natural capital and other factors of production. Several participants argued that standard production functions assume a degree of substitutability that is inconsistent with ecological reality.

The France nuclear power example was cited again as evidence that some natural inputs, such as water for cooling, are effectively non-substitutable in the short run. Participants debated whether price signals can be relied upon to prevent over-extraction or whether binding constraints must be modelled explicitly.

7.7 Institutional realism versus conceptual ambition

A final provocation concerned the balance between conceptual ambition and institutional realism. Some participants argued for radical rethinking of macroeconomic models to embed nature fundamentally. Others cautioned that overly ambitious models risk irrelevance if they cannot be used within existing policy processes.

This tension was not resolved, but there was agreement that progress will require work at multiple levels: conceptual innovation, methodological experimentation, and incremental institutional integration.

7.8 Areas of convergence and open questions

Despite the provocations, several areas of convergence emerged: the need to make assumptions explicit; the importance of stress-testing equilibrium models; the value of scenario analysis under deep uncertainty; the inadequacy of GDP-only perspectives. At the same time, open questions remain about how to operationalise non-linearity, uncertainty, and ethical considerations within macroeconomic frameworks.

8. Use cases for macroeconomic modelling of nature and implications for model design

8.1 Why use cases matter

A recurring thread throughout the meeting was that disagreements about how to model nature often stemmed less from substantive differences about economics or ecology, and more from implicit assumptions about use cases. Participants repeatedly emphasised that macroeconomic models are tools designed for particular decisions, audiences, and institutional mandates. Clarifying use cases was therefore seen as a prerequisite for meaningful integration of nature into macroeconomic analysis.

Several participants noted that failure to distinguish use cases leads to unproductive debates – for example, criticising a central bank DSGE model for not capturing ecosystem tipping points, or expecting a natural capital account to directly determine monetary policy. The meeting therefore converged on the need to articulate a typology of use cases and to derive modelling requirements from these. The discussion identified a set of distinct, though overlapping, use cases for macroeconomic modelling of nature:

Financial stability and tail-risk assessment

For central banks and financial supervisors, the primary use case is assessing systemic risk and tail events. In this context, the objective is not precise forecasting of average outcomes, but understanding how nature-related shocks and degradation can: amplify macroeconomic volatility; trigger non-linear responses; propagate through financial systems and therefore constitute a threat to the achievement of the primary and secondary objectives of their mandate (price stability and financial stability).

Participants argued that models used for this purpose must: prioritise tail risks over expected values; allow for persistent or irreversible impacts; be transparent and stress-testable.

This use case favours scenario analysis, stress testing, and modular extensions to existing macro-financial models, rather than fully integrated ecological–economic systems.

Macroeconomic surveillance and debt sustainability

For IFIs, regional development banks, and finance ministries, a central use case is macroeconomic surveillance, including growth projections and debt sustainability analysis.

Here, participants stressed that the key requirement is not modelling all aspects of nature, but identifying when ecosystem degradation or ecosystem services materially affect: baseline growth trajectories; fiscal balances; debt dynamics.

Models serving this use case must: integrate nature into baselines, not only stress scenarios; focus on persistent growth and volatility effects; remain comparable across countries.

This points toward selective integration of nature through transmission channels, informed by natural capital accounts and case-specific evidence.

Fiscal planning and public investment appraisal

Another use case concerns fiscal policy and investment decisions, including medium-term budget frameworks and cost–benefit analysis.

Participants argued that this use case places greater emphasis on: avoided losses and resilience benefits; long-term returns on ecosystem investment; trade-offs between short-term fiscal costs and long-term gains.

For these purposes, models must be capable of comparing counterfactual scenarios with and without ecosystem protection or restoration. Integration of natural capital accounting data and ecosystem service valuation was seen as particularly relevant here.

Development planning and growth strategies

In development contexts, macroeconomic modelling is often used to explore growth pathways and structural transformation. Participants noted that nature enters this use case not primarily as a risk, but as an asset base that can support or constrain long-run development.

This use case places different demands on models: emphasis on opportunity as well as risk; sensitivity to land use, resource dependence, and labour productivity; longer time horizons.

Experiences with Gross Ecosystem Product in China were cited as illustrative of how macro-style metrics can be used to reorient development incentives, even if such approaches are not directly transferable to other institutional contexts.

Subnational and place-based decision-making, including investment

Several participants highlighted that many nature-related decisions occur at subnational or landscape scales, even when macroeconomic implications are national.

For this use case, macroeconomic models must interface with: geospatial and landscape-level analysis; subnational fiscal and planning frameworks; heterogeneous impacts across regions and groups.

This reinforces the need for modular approaches that can translate place-based ecological insights into macro-relevant indicators.

8.2 Implications for model requirements

Across these use cases, the meeting identified several cross-cutting implications for model design.

First, no single model can meet all use cases. Attempting to build a universal model risks producing tools that are neither analytically sound nor institutionally usable.

Second, integration of nature should be purpose-driven. The choice of variables, channels, and time horizons should be dictated by the decision context, not by abstract notions of completeness.

Third, natural capital accounting plays an enabling role across multiple use cases, but only when its outputs are translated into model inputs, baselines, or scenarios.

Fourth, transparency and communication are as important as technical sophistication. Users must understand what is included, what is omitted, and why.

Implications for future work

Participants agreed that future efforts should: explicitly state the intended use case at the outset of any modelling exercise; design models and scenarios to meet that use case; document limitations and boundary conditions clearly; avoid conflating analytical ambition with policy relevance.

This use-case framing was seen as a key step toward aligning economic modelling of nature with the real needs of policymakers, financial institutions, and planners.

9. Synthesis, implications, and agreed next steps

9.1 What the meeting collectively established

First, participants broadly agreed that nature and natural capital are economically foundational, not peripheral. Ecosystems underpin production, resilience, and welfare through multiple channels, and their degradation can materially alter macroeconomic outcomes. The absence of nature from many macroeconomic frameworks therefore constitutes a structural blind spot rather than a minor omission.

Second, there was strong agreement that macro-criticality is context-specific. Nature-related risks are most clearly macro-critical in economies that are highly dependent on ecosystem services or exposed to natural hazards, but they can also become macro-critical in advanced economies through critical infrastructure dependencies (as illustrated by France) or cumulative fiscal and volatility effects (as illustrated by the UK).

Third, participants agreed that transmission channels provide a practical organising framework. Rather than attempting full ecological–macroeconomic integration everywhere, analysts can identify and prioritise the channels most relevant to specific countries, sectors, and policy questions.

Fourth, the meeting established that no single macroeconomic model can serve all purposes. Progress requires a pluralistic modelling ecosystem, ranging from stylised conceptual models to applied policy tools, with clarity about purpose, limitations, and institutional use.

9.2 Implications for macroeconomic analysis and policy practice

The discussions implied several important shifts in how macroeconomic analysis should be conducted and interpreted.

From shocks to trajectories

Participants emphasised the need to move beyond treating nature-related impacts solely as temporary shocks. In many cases, ecosystem degradation affects long-run growth paths, volatility, and resilience. Macroeconomic analysis should therefore consider how nature alters economic trajectories, not just short-term deviations.

From expected losses to risk distributions

A second implication concerned risk assessment. Nature-related risks often operate by increasing volatility and tail risk rather than average losses. Macro frameworks focused exclusively on expected values risk understating the economic significance of ecosystem degradation.

From GDP to broader measures of performance

While GDP remains a central metric in policy institutions, the meeting reinforced the need to complement GDP-based analysis with measures that account for natural capital depreciation and ecosystem service provision. Experiences with inclusive wealth accounting and Gross Ecosystem Product illustrate alternative pathways, even if full integration into macro frameworks remains challenging.

From crisis response to preventive investment

The case studies demonstrated that failing to integrate nature into macroeconomic baselines biases analysis against preventive investment. Incorporating ecosystem services and resilience benefits can help justify early action and shift policy debates toward long-term value creation.

9.3 Agreed priorities for future work

Despite differing perspectives, participants converged on a set of priorities for advancing the integration of nature into macroeconomic models.

1. Clarify criteria for macro-criticality. Develop clearer guidance on when and how nature-related risks should be treated as macro-critical, including consideration of tail risks and long-term growth effects.
2. Advance transmission-channel mapping. Produce practical guidance linking specific ecosystem services to macroeconomic variables across different country archetypes.
3. Prioritise integration of nature into debt sustainability analysis, macro-fiscal frameworks, stress testing and investment plans, where policy leverage is greatest.
4. Develop modular modelling approaches. Encourage approaches that combine ecological analysis with existing macro models without requiring full integration from the outset.
5. Strengthen data and empirical evidence. Invest in data linking ecosystem condition to economic outcomes, including through geospatial analysis and case-study validation.

Attendees

The workshop was attended by 35 experts from across academia, government and international financial institutions, including those experts named below. All attendees contributed in a personal capacity and the views expressed in this document cannot be attributed to individuals or their institutions.

Christopher Adam
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Giles Atkinson
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