ISBN: 978-65-83849-00-7

Aurum EDITORA

CHAPTER 1

REFLEXIVE GOVERNANCE: SCIENCE, TECHNOLOGY, SOCIETY, RISK SOCIETY, AND THE 2030 AGENDA FOR GLOBAL SUSTAINABILITY

https://doi.org/10.63330/aurumpub.010-001

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ABSTRACT

The complexity of contemporary global challenges—marked by unprecedented scientific-technological advances alongside socio-environmental crises—demands a profound understanding of the interactions among science, technology, and society. Although existing literature addresses Risk Society theory and the 2030 Agenda separately, it lacks an integrated, critical analysis exploring how reflexive modernity and manufactured risks impact sustainability governance. This study critically examines the intersections among Science, Technology, and Society (STS) studies, Anthony Giddens's and Ulrich Beck's Risk Society theory, and the 2030 Agenda—proposing an analytical framework for a more reflexive, equitable governance of global challenges. We hypothesize that reflexive modernity, by engendering intrinsic development risks, imposes fundamental obstacles to achieving the Sustainable Development Goals (SDGs). Consequently, a critical approach to science and technology is required to address governance gaps. Employing a qualitative, application-oriented methodology with an explanatory objective, the research centers on a critical, systematic literature review. Its corpus comprises seminal books and high-impact journal articles in STS, Risk Sociology, and Sustainable Development, subjected to qualitative content analysis. Findings indicate that—despite their centrality to the SDGs—science and technology remain ambivalent, simultaneously serving as sources of manufactured risks that the 2030 Agenda, in its current formulation, fails to address structurally. The vagueness of the "Leave No One Behind" principle and the technocratic nature of indicator design limit the Agenda's efficacy and perpetuate inequalities. We conclude that effective global sustainability governance requires a reflexive modernization of the 2030 Agenda itself—incorporating self-critical evaluation, multi-sector participation, and accountability mechanisms to manage inherent development risks. This entails moving beyond purely technocentric solutions toward a more politically and socially engaged approach to science and technology.

Keywords: Science, Technology, and Society; Risk Society; 2030 Agenda; Sustainable Development; Governance.

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INTRODUCTION

The contemporary scenario is characterized by increasing complexity, in which unprecedented scientific and technological advances coexist with multifaceted socio-environmental crises and global challenges. Humanity's pursuit of progress and well-being has profoundly transformed the planet, simultaneously generating uncertainties and threats previously unimaginable. Understanding this dynamic requires an analytical lens that transcends traditional disciplinary approaches and embraces the intrinsic interconnection among knowledge, innovation, and social organization.

In this context, Science, Technology, and Society (STS) studies emerge as a crucial investigative field. This interdisciplinary approach unveils the co-production of scientific-technological knowledge and social organization, rejecting the linear, deterministic view that science and technology are neutral forces simply driving progress. Rather, STS studies demonstrate that science and technology are social products—shaped by values, interests, and cultural contexts—and that, in turn, they shape society. This perspective is essential for understanding how technological innovations, despite promising solutions, can also engender new problems or exacerbate existing ones.

Concurrently, the emergence of "Risk Society," a central concept developed by sociologists Anthony Giddens and Ulrich Beck, offers a framework for comprehending how modernity itself—through its development processes—generates intrinsic uncertainties and threats. Beck argues that industrial society, primarily focused on wealth production, has given rise to a society where risk production—often invisible and global—surpasses the logic of goods production. Giddens, in turn, highlights "manufactured risks," those directly stemming from human knowledge and technology's impact on the natural world, in contrast to exogenous, natural hazards. This conception of modernity as an inherent risk producer is vital for any future-oriented planning effort.

Amidst this panorama of complexity and uncertainty, the United Nations' 2030 Agenda for Sustainable Development—with its 17 Sustainable Development Goals (SDGs)—was established in 2015 as the principal global framework to confront these challenges. The Agenda proposes a universal, integrated, and transformative vision for a more equitable, prosperous, and sustainable future, encompassing social, economic, and environmental dimensions. Its SDGs aim to eradicate poverty, combat hunger, promote quality health and education, ensure gender equality, secure water and sanitation, provide affordable and clean energy, foster decent work and economic growth, build resilient infrastructure and drive innovation, reduce inequalities, create sustainable cities, encourage responsible consumption and production, address climate change, preserve aquatic and terrestrial ecosystems, promote peace, justice, and effective institutions, and strengthen global partnerships.

The intersection of these three pillars—STS studies, Risk Society theory, and the 2030 Agenda—is not merely additive but dialectical, revealing deeper layers of understanding. STS analyses show that

science and technology are not neutral, being imbued with social values and interests. This perspective is crucial for grasping how Risk Society is constructed and how the 2030 Agenda—frequently relying on technological solutions—may inadvertently perpetuate or generate new risks. If science is socially constructed, then proposed technological solutions for the SDGs are not free of values. Risk Society theory reveals that modernity itself produces manufactured risks. Consequently, pursuing sustainability through technology—without critically analyzing risk co-production—can lead to "greenwashing" or solutions that benefit some while marginalizing others, thereby exacerbating the inequalities the 2030 Agenda seeks to eliminate. A profound understanding of these dynamics is essential for formulating governance strategies that are genuinely reflexive and capable of navigating the complexity of contemporary challenges.

In light of the complex intersection among scientific and technological advances, systemic risks, and the global ambition for sustainable development, this article's central question is:

How can insights from Risk Society theory, illuminated by STS studies, inform and critique the implementation of the 2030 Agenda—particularly regarding manufactured risk management and the promotion of more equitable, reflexive governance?

Methodologically, this investigation relies on a qualitative approach, indispensable for deepening comprehension of STS, Risk Society theory, and the 2030 Agenda's complex interrelations. This choice enables exploration of the nuances and intrinsic meanings of these theoretical pillars, aiming not to quantify phenomena but rather to interpret the "why" and "how" of their social and theoretical dynamics.

As applied research with an explanatory objective, the study seeks to employ existing knowledge to develop an analytical framework capable of guiding practical solutions—especially those related to 2030 Agenda implementation and global risk management. Its explanatory aim is to identify the factors driving manufactured risk production and the ambivalent role of science and technology in sustainability—delving into reality beyond mere description.

Procedurally, the research comprises a critical, systematic bibliographic review followed by qualitative, reflexive content analysis. This process facilitates identifying key concepts, formulating hypotheses, and exploring implications for theory and practice, ensuring construction of a critical, propositional argument on these fields' intersections.

THEORETICAL FRAMEWORK

SCIENCE, TECHNOLOGY, AND SOCIETY (STS): FOUNDATIONS

Science, Technology, and Society (STS) studies constitute an interdisciplinary field dedicated to analyzing the intricate interactions among science, technology, and society. This approach transcends the traditional, linear view of scientific-technological progress, which often portrays it as inevitable and

inherently beneficial. Instead, STS studies reveal that science and technology are social constructions—deeply rooted in and shaped by cultural contexts, values, interests, and power structures.

Historically, the inherited conception of science—known as the "traditional view"—postulated science as an autonomous, objective, and neutral endeavor, operating under a purely rational code free from external interference. The scientific method was deemed the intellectual tool guaranteeing the objectivity of scientific products by empirically testing general claims and ensuring theoretical consistency. Scientific development was seen as a cumulative, linear process—a paradigm of human progress.

However, the twentieth century witnessed a robust anti-positivist reaction within academia, propelled by critiques from prominent authors. In his seminal 1962 work, Thomas S. Kuhn introduced irreducibly social concepts to explain how science changes and develops. He argued that understanding science necessitates a detailed study of its actual history, proposing that science advances through periods of "normal science," during which scientists solve "puzzles" guided by a shared theoretical paradigm. Yet, the accumulation of unresolved problems engenders anomalies that may lead to a paradigm crisis—ushering in "extraordinary science" and culminating in a "scientific revolution." During such revolutions, alternative paradigms emerge, sparking disputes and potentially displacing the preceding paradigm. Kuhn underscored that the scientific community—rather than empirical reality alone—determines the criteria for theory acceptance, thereby challenging traditional rationalist analyses of science and emphasizing the social and historical dimensions of scientific knowledge production.

This critique deepened with concepts such as the "theoretical load of observation" and "underdetermination." The former posits that observations rely not only on sensory impressions but also on prior knowledge, expectations, biases, and the observer's internal state—rendering every observation theoretically loaded. The latter suggests that for any given theory or hypothesis explaining a phenomenon, an indefinite set of empirically equivalent yet incompatible alternative theories can be generated. These notions demonstrate that scientific observation and theory are not intrinsically neutral; rather, science actively constructs its representation of reality.

In the 1970s, David Bloor—alongside Barry Barnes and Steve Shapin—formed the Edinburgh School, a research group dedicated to developing a sociology of scientific knowledge. They aimed to analyze science as a social process, emphasizing that non-epistemic values (political, economic, ideological—i.e., "social context") influence the origin, change, and legitimation of scientific theories.

Bloor formulated the "Strong Programme" (1976/1992), which sought to establish principles for a satisfactory (sociological) explanation of scientific knowledge's nature and evolution. This programme stands as an explanatory framework rivaling traditional philosophical approaches such as logical positivism or Popperian views. Its core principles are:

1. **Causality:** Scientific episodes must be explained by focusing on the effective conditions producing beliefs or knowledge states.
2. **Impartiality:** The analysis must remain impartial to truth and falsity, rationality and irrationality, success and failure—providing explanations for both sides of these dichotomies.
3. **Symmetry:** The same types of causal factors must explain both true and false beliefs.
4. **Reflexivity:** Explanatory patterns should apply to the sociology of science itself.

Bloor presented his programme as an empirical study of science, asserting that only through sociology could the peculiarities of the scientific world be adequately explained.

In the early 1980s, Harry Collins at the University of Bath developed a more concrete programme—the Empirical Programme of Relativism (EPOR)—grounded in Bloor's theoretical framework. The EPOR focuses on empirically studying scientific controversies, arguing that these controversies reveal science's interpretative flexibility regarding reality and scientific problems. It highlights the importance of social interaction processes in shaping how reality is perceived and how scientific problems are resolved. The EPOR proceeds in three stages: 1) Demonstrating the interpretative flexibility of experimental results; 2) Uncovering social, rhetorical, and institutional mechanisms that constrain interpretative flexibility and promote controversy closure. 3) Relating these "closure mechanisms" to broader sociocultural and political contexts.

Beyond the Edinburgh School, other critical perspectives significantly enriched STS studies. In Laboratory Life (1979/1986), Bruno Latour and Steve Woolgar argued that science scholars should become anthropologists—entering laboratories to describe scientists' and technologists' daily practices as purely as possible. Their imperative was to "open the black box" of scientific knowledge and detail its contents, emphasizing science's practical, social dimensions.

Philosophical analyses of technology also contributed to the field. Lewis Mumford—aligned with the North American Romantic-naturalist tradition—focused on environmental ecology, urban life harmony, and nature preservation. He argued that machines must be analyzed concerning their psychological and practical origins and evaluated ethically, aesthetically, and technologically. In Technics and Civilization (1934), Mumford explored how machines transformed Western civilization, categorizing technologies as either polytechnic (life- and culture-oriented) or monotectonic (scientific knowledge–based, economically and militarily focused). He contended that modern technology—an exemplar of monotectonic systems—predated the Industrial Revolution, emerging with rigid, hierarchical social organizations he called "megamachines."

José Ortega y Gasset integrated technical studies into his "racio-vitalism" current, proposing an ontological perspective of technology as human acts aimed at satisfying needs by altering nature. He divided technological history into three stages: chance-based techniques, artisanal techniques, and

engineering techniques—distinguished by how humans discovered means to achieve their ends. In The Question Concerning Technology (1954), Martin Heidegger approached technology from an ontological standpoint, linking it to the question of Being. He argued that technology represents a form of "unveiling" that transforms and challenges nature to generate storable, transmissible energy—contrasting modern technology's "enframing" of nature with older techniques that maintained more respectful relationships with the environment. Jacques Ellul deemed technology the most important phenomenon of modernity—arguing that, rather than capital, it is the world's driving force. He defined technology as the totality of methods achieved through rationality, yielding absolute efficiency in all human activities.

Sheila Jasanoff, in her article "Procedural Choices in Regulatory Science" (1995), argued that the traditional model of the science-society relationship is simplistic. Introducing "regulatory science," she highlighted science's new role in providing political action's epistemic basis—distinguishing it from traditional academic science. Regulatory science operates under deep uncertainties, limited knowledge, and time constraints—moving amid uncertain facts, underdeveloped theoretical paradigms, and inconsistent methods—thus giving rise to frequent controversies.

The evolution of STS—ranging from Kuhn's internalism to the Edinburgh School's social constructivism and philosophical critiques of technology—reveals growing skepticism regarding science and technology's inherent neutrality and benevolence. This demystification is fundamental for critically analyzing Risk Society theory and the 2030 Agenda, which often assume an optimistic, instrumental vision of science as a panacea. If science is a socially constructed, nonneutral endeavor, then its proposed "solutions" for Risk Society problems and SDGs carry producers' values and interests. This raises questions about the legitimacy and equity of technology-based interventions—especially when risks are "manufactured" by modernity itself.

RISK SOCIETY: PERSPECTIVES OF ANTHONY GIDDENS AND ULRICH BECK

Anthony Giddens and Ulrich Beck are prominent sociologists who—independently yet convergently—developed Risk Society theory. Both contend that living with risk is an inevitable condition of postmodern society, perpetually facing potential threats to its integrity.

For Ulrich Beck, postmodernity signifies a historical rupture: the transition from an industrial society—focused on wealth production—to a risk society. In this new model, conventional techniques prove inadequate for predicting and controlling risks to human health or the environment. Risks themselves become central to new market productions. Risk society is simultaneously a "science, media, and information" society.

Beck argues that contemporary risks are so severe they transcend socioeconomic class boundaries—affecting both rich and poor indiscriminately. This "democratization and globalization of

risk" redefines social risk individualization, diminishing class distinctions' salience. In advanced modernity, social wealth production goes hand in hand with risk production. Beck asserts that, in risk society, the logic of risk production surpasses wealth production—since risks and wealth are inseparable, more risks are generated than wealth.

Examples include environmental disasters, daily nuclear threats, epidemics, rising armed conflicts, international financial crises, and diffuse crime. Beck characterizes the present era as a "modern medieval age of danger." Risks are ambiguous—dual-natured—demanding weighing opportunities against losses. This ambiguity calls for a new division of labor among science, politics, and economics to curb risk production. For Beck, modernization is not merely a backdrop but the problem itself—exposing individuals to risk regardless of social class. He distinguishes between risk and calamity: while tragedies are bounded in space and time, risk signifies anticipating catastrophe—always a future event that becomes present only through "presentification" or dramatization of global threats.

Despite its contributions, Beck's theory faces criticism. Observers note evolutionism, linearity, and Eurocentrism in his globalization account. He neglects coexistence between class-based and risk-based societies in a globalized world—offering another dimension to risk society. Initially, Beck failed to analyze how poverty and severe risks intertwine, how precarious state control systems amplify risks, or how fragmented democratic cultures appear. Furthermore, he imprecisely discusses implementing his proposals for "subpolitics" or new political forms to address grave risks and for "de-monopolizing scientific knowledge." His political optimism seems inconsistent with his modernity critique.

Anthony Giddens, by contrast, regards globalization as a crucial social phenomenon—defining it as the "intensification of global interdependence and social relations." Globalization transforms the world into a "single world," where actions in one group affect others, and global problems affect individuals—altering everyday life.

Giddens argues that although humans have always confronted risks, contemporary risks are "manufactured"—stemming from human knowledge and technology's impact on the natural world. This contrasts with "external risks" (e.g., droughts, earthquakes) originating in nature. He traces modern risks' emergence to the unforeseen consequences of industrial labor—consequences that classical sociologists did not fully anticipate—particularly the large-scale destructive potential of "productive forces" on the material environment.

The production of new risks contributes to constructing societal fear. Giddens identifies seven ways in which risk is characterized in modernity: 1) Globalization of risk in intensity (e.g., nuclear war); 2) Globalization of risk in contingent events' expansion (e.g., shifts in global labor division); 3) Risk derived from the created environment, or "socialized nature" (e.g., genetically modified foods); 4) Institutionalized environmental risks (e.g., financial markets); 5) Awareness of risk as risk (knowledge

gaps unconverted into certainties by religious or magical knowledges); 6) Well-distributed risk awareness (collective knowledge of dangers by the public); e 7) Awareness of expertise limitations (no expert system can fully predict the consequences of applying experts' principles).

Giddens agrees with Beck that wealth production cannot occur without individual, social, and environmental risks intrinsic to productive activities. Social well-being—as a modern presumption—diminishes, replaced by pervasive risks.

Convergences and Divergences

While Beck's and Giddens's theories present distinct nuances, they share fundamental premises and feature significant divergences.

Convergences:

Reflexive Modernity: Both sociologists agree that modernity is reflexive—meaning contemporary problems are consequences of societal advancement.

Universalization of Risks: Both acknowledge that risks are global, transcending ethnic, social, and geographic boundaries.

Inseparability of Development and Risk: Both contend that contemporary scientific and industrial development accompanies risks neither specifiable nor containable by space and time.

Erosion of Social Well-Being: Both assert that modernity's guarantee of social well-being has eroded—supplanted by pervasive risks.

Divergences:

Source of Risks: Beck sees risk society as emerging from a rupture with primitive industrial society, where scientific and industrial progress chiefly generates social risks—arguing for societal paralysis and the need to measure responsibilities. Giddens posits that manufacturing social risks is inseparable from modern society's constitution—natural, involuntary, reflexive consequences of advanced social knowledge. For Giddens, risks are intrinsic to contemporary societies due to significant technical and scientific complexity.

Nature of Modernity: Beck adopts a more sober view—labeling the era a "civilizational volcano," where risks are simultaneously real and unreal—merging past dangers with calculated threats. Giddens claims the present is purely reflexive due to massive information production and technology use—yielding unpredictable social consequences.

Class Distinction: Beck argues contemporary threats no longer target a specific class—unlike primitive industrial society, where the less fortunate bore disproportionate harm. Giddens's

modernity perspective does not delve into socioeconomic class distinctions or their differential risk impacts.

Accountability: Beck emphasizes the imperative to identify and measure responsibilities to curb social risks. Giddens suggests that, a priori, there is no legal recourse to hold anyone accountable for damage from social risks—nor possibilities for compensating victims.

The distinction between "external" and "manufactured" risks (Giddens) is crucial for the 2030 Agenda. While SDGs address both (e.g., SDG 13 on climate and SDG 9 on infrastructure), persistent manufactured risks—intrinsic to development—imply the Agenda may treat symptoms without tackling modernity's deep-rooted risk production. If environmental and social risks are "manufactured" by human and technological activity (Giddens), Agenda 2030 solutions must go beyond mitigating impacts or promoting new technologies. A fundamental critique of production and consumption models (SDG 12) that generate these risks is required—an omission critics have identified. Thus, sustainability governance must be more than technical; it must be deeply political and reflexive.

THE 2030 AGENDA AND THE SUSTAINABLE DEVELOPMENT GOALS (SDGS): STRUCTURE AND IMPLICATIONS

Adopted by the UN General Assembly in September 2015, the 2030 Agenda for Sustainable Development represents a universal, integrated, and transformative action plan—aiming at global peace and security. Comprised of a Declaration, 17 Sustainable Development Goals (SDGs), and 169 targets, the Agenda seeks to ensure that all nations and peoples everywhere are included and benefit from its realization.

The 17 SDGs span a wide array of global challenges—integrating sustainable development's social, economic, and environmental dimensions. They are interlinked: progress in one SDG may influence advancement or regression in others. For instance, SDG 2 (Zero Hunger and Sustainable Agriculture) is inherently connected to health (malnutrition) and water quality, while SDG 7 (Affordable and Clean Energy) directly impacts health (respiratory issues from air pollution). This interdependence underscores the need for an integrated approach to address health challenges—acknowledging complex interactions among health, poverty, education, environment, economy, and governance.

The SDGs are:

No Poverty: End poverty in all its forms everywhere.

Zero Hunger and Sustainable Agriculture: End hunger, achieve food security, improve nutrition, and promote sustainable agriculture.

Good Health and Well-Being: Ensure healthy lives and promote well-being for all at all ages.

Quality Education: Ensure inclusive, equitable, and quality education, and promote lifelong learning opportunities for all.

Gender Equality: Achieve gender equality and empower all women and girls.

Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all.

Affordable and Clean Energy: Ensure access to reliable, sustainable, modern, and affordable energy for all.

Decent Work and Economic Growth: Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.

Industry, Innovation, and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.

Reduced Inequalities: Reduce inequality within and among countries.

Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient, and sustainable.

Responsible Consumption and Production: Ensure sustainable consumption and production patterns.

Climate Action: Take urgent action to combat climate change and its impacts.

Life Below Water: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

Life on Land: Protect, restore, and promote sustainable use of terrestrial ecosystems; combat desertification; halt and reverse land degradation; halt biodiversity loss.

Peace, Justice, and Strong Institutions: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.

Partnerships for the Goals: Strengthen means of implementation and revitalize the global partnership for sustainable development.

A central principle of the 2030 Agenda is "Leave No One Behind" (LNOB), aiming to ensure all nations, peoples, and segments of society are included—especially vulnerable groups such as children, youth, persons with disabilities, older persons, indigenous peoples, refugees, internally displaced persons, and migrants. The Agenda's Declaration explicitly calls for including refugees. The UNHCR (United Nations High Commissioner for Refugees) works to integrate these populations into national development guidelines and conventional national systems (e.g., health and education).

Despite its ambition and scope, the 2030 Agenda's implementation faces significant challenges and criticisms:

Conceptual Vagueness: Critics highlight conceptual and empirical issues with the LNOB principle due to its vague vocabulary. The lack of an official definition of who counts as "left behind" leads to disputes and imprecision—delegating delimitation responsibility to Member States.

Failure to Question Inequality Sources: The Agenda prioritizes groups at the "end of the line" for distribution of income, goods, and opportunities but does not address structural inequality causes. Thus, although dubbed transformative, it does not commit to tackling institutionalized discrimination perpetuating such inequalities.

Political Disputes in Indicator Definition: Indicator definition—traditionally seen as a technical matter—was permeated by political conflicts among stakeholders (international organizations, private sector, civil society). The Inter-Agency Expert Group on SDG Indicators (IAEG-SDGs) dynamics were guided by technocratic and financial considerations—resulting in indicators that only partially reflect the Agenda's qualitative ambitions.

Absence of Primary Health Care (PHC) Reference: A significant omission in the Agenda's health perspective is the lack of explicit reference to Primary Health Care (PHC)—despite WHO later emphasizing PHC as a driving force for achieving the SDGs.

Unsatisfactory Progress: Doubts exist about countries like Brazil meeting targets by 2030. Reports indicate insufficient progress—highlighting urgency for improved national planning, public sector capacity, digital infrastructure, local governance, and private sector alignment.

Risk of "Greenwashing": The Agenda may serve as a "greenwashing umbrella," yielding little real progress beyond political rhetoric. There is recognition that sustainable development is politically contentious—requiring difficult decisions that inevitably create winners and losers.

Lack of Political Will: Achieving the Agenda depends on genuine political will—demanding bold political decisions to advance sustainability.

Despite its universal, transformative character, the 2030 Agenda faces an inherent contradiction: it proposes global solutions (SDGs) for systemic problems, yet its own critiques reveal reluctance to address structural inequality and risk sources—potentially limiting its efficacy and perpetuating Risk Society dynamics. If the Agenda pledges to "leave no one behind" but does not challenge inequality sources, it may focus more on mitigating Risk Society effects than transforming its root structures. If risks are "manufactured" by modernity (Giddens) and the Agenda does not question development models generating them, it may become a tool for "greenwashing," masking a lack of real progress.

DIALOGUES AND TENSIONS: INTERSECTIONS AMONG STS, RISK SOCIETY, AND THE 2030 AGENDA

Analyzing the intersections of STS studies, Risk Society theory, and the 2030 Agenda uncovers a complex web of dialogues and tensions—vital for a comprehensive understanding of global sustainability challenges.

Reflexive modernization theory—articulated by Beck and Giddens—posits that contemporary problems are consequences of social advancement. This suggests that pursuing SDGs as a form of "more (albeit sustainable) modernity" risks generating new threats or exacerbating existing ones if unaccompanied by deep reflection on foundational premises and methods. Modernity inherently produces risks. Therefore, implementing SDGs—often relying on scientific and technological solutions—must proceed cautiously, avoiding replication of risk-producing mechanisms.

Science and technology are frequently presented as "progress drivers" and deemed essential for attaining SDGs—particularly SDG 9 (Industry, Innovation, and Infrastructure), which underscores innovation and technological transformation for human well-being and environmental harm reduction. They are indispensable for devising new sustainable industrial models, monitoring industrialization's impacts, and developing solutions for issues like climate change and health (e.g., vaccines).

However, Risk Society perspectives and STS critiques reveal science and technology's ambivalence. They serve as primary sources of manufactured risks—industrial pollution, nuclear, chemical, and genetic hazards. Scientific and technological development is not neutral; unregulated application or an exclusive focus on economic growth can inadvertently generate risks or deepen inequalities. By promoting innovation and technological development to achieve sustainability (SDG 9), the 2030 Agenda risks falling into the "reflexive modernization trap," where uncritical technological solutions—absent critical, participatory governance—may spawn new risks or worsen inequities. If modernity intrinsically produces risks (Beck) and technology is a principal manufacturing mechanism (Giddens), then unreflective technological promotion for SDGs can be counterproductive. A technology assessment must transcend technical efficacy—considering long-term social and environmental impacts and equitable benefit-burden distribution. The critical question is not whether to use technology, but how and for whom it is developed and applied.

Jasanoff's "regulatory science" exemplifies this ambivalence—functioning under uncertainty and political pressure—rendering it a field of controversy rather than absolute truth. This demonstrates that exclusive reliance on scientific expertise for SDGs is insufficient: science is "theoretically loaded" and underdetermined. Complex manufactured risks demand science and technology governance for sustainability to be transparent, participatory, and controversy-responsive—integrating diverse

perspectives. This underscores Beck's "subpolitics" and the democratization of decision-making, advocating actor inclusion beyond formal politics.

A robust governance structure is indispensable for SDG implementation. Such governance must involve multiple actors—government, academia, industry, civil society, development partners—in designing and executing Science, Technology, and Innovation (STI) roadmaps for SDGs. This includes institutional structure considerations, cross-sector coordination, clear role and responsibility allocation, and transparency promotion.

The 2030 Agenda's governance operates amid Risk Society's uncertainties—where action consequences are unpredictable and accountability attribution is complex. Yet, this scenario also offers opportunities for more reflexive governance. It is crucial to move beyond purely technocratic approaches—incorporating political and social dimensions into indicator and target design. Furthermore, addressing structural inequality causes—rather than symptoms—is imperative for "Leave No One Behind" to be genuinely effective. Education emerges as an integrating force—fostering critical thinking and civic participation in managing socio-environmental challenges.

Criticisms of the 2030 Agenda—such as LNOB's vagueness and failure to interrogate inequality sources—reveal that purely "top-down" or technocratic governance is inadequate. Manufactured risks' complexity and science and technology's ambivalence necessitate governance that is transparent, participatory, capable of reconciling conflicting interests, and able to mobilize diverse actors. Governance must become a "learning mechanism"—continuously reflexive and adaptive to emerging uncertainties.

THE PRODUCTION OF MANUFACTURED RISKS IN REFLEXIVE MODERNITY AND THEIR IMPACTS ON THE SDGS

Reflexive modernity is characterized by producing risks intrinsic to its development—rather than mere accidents or externalities. This thesis is central to both Ulrich Beck and Anthony Giddens. Beck contends that industrial society—focused on wealth production—has given way to a risk society where risk distribution no longer aligns with traditional social differences. These risks are often invisible, complex, and difficult to attribute—such as environmental disasters, daily nuclear threats, and global epidemics.

Giddens coins "manufactured risks" to describe those directly resulting from human knowledge and technology's impact on nature. Unlike external risks (e.g., droughts, earthquakes), manufactured risks are products of human intervention and technological advancement. Reflexive modernity's "dark side" reveals that unanticipated consequences of industrial labor—and the destructive potential of productive forces—constitute profound dangers. Catastrophe arises not from isolated errors but from systems that amplify human error into incomprehensible destructive power.

This logic of manufactured risk production directly affects the ability to meet various SDGs. For example, SDG 13 (Climate Action) and SDG 15 (Life on Land) are intrinsically impacted by manufactured risks like industrial pollution, large-scale deforestation, and natural resource depletion—all consequences of unsustainable development models. Similarly, SDG 3 (Good Health and Well-Being) is profoundly influenced by risks such as air and water pollution, hazardous chemical use, and epidemic emergence—many directly or indirectly resulting from industrial and technological activity.

Science and technology's ambiguity lies in their simultaneous role as essential for progress and sources of manufactured risks. While indispensable for pursuing SDGs (e.g., SDG 9's emphasis on sustainable industry and infrastructure), they also serve as primary vectors for manufactured risk. The 2030 Agenda—by advocating innovation and technological development—risks succumbing to the reflexive modernization trap: uncritical technological solutions—absent participatory, critical governance—may inadvertently create new risks or exacerbate existing inequalities. If modernity inherently generates risks (Beck) and technology is a main vehicle for manufacturing them (Giddens), unreflective technological advocacy for SDGs can prove counterproductive. It necessitates technology assessment that transcends technical efficacy—accounting for long-term social and environmental impacts and equitable benefit-burden distribution. Fundamentally, the question is not whether to use technology but how and for whom it is designed and deployed—ensuring solutions do not become new problems or reinforce the inequalities the Agenda seeks to mitigate.

THE AMBIVALENT ROLE OF SCIENCE AND TECHNOLOGY IN RISK MANAGEMENT AND SUSTAINABILITY PROMOTION

Science and technology (S&T) occupy an ambivalent position in contemporary society—particularly regarding risk management and global sustainability. On one hand, they are undeniably engines of progress—offering essential tools and knowledge to identify, monitor, and mitigate humanity's challenges. Innovations like clean energy, advanced sanitation systems, vaccines for epidemic control, and early-warning systems for natural disasters exemplify how S&T provide critical solutions for SDGs. Technological transformation and innovation are considered pivotal to enhancing human well-being and reducing environmental harm from economic growth.

On the other hand, unregulated or growth-centric S&T contributes significantly to creating and exacerbating risks. As Risk Society theory highlights, ecological, chemical, nuclear, and genetic hazards are often "manufactured" by industrial and technological activities. This duality—S&T as both problem source and solution provider—epitomizes reflexive modernity's central dilemma.

Sheila Jasanoff's concept of "regulatory science" exemplifies this complexity. Unlike traditional academic science, regulatory science operates amid uncertainty, scarce knowledge, and significant

political and temporal pressures—rendering it a field rife with controversies rather than absolute truths. Recognizing that science is not a neutral entity but is "theoretically loaded" and underdetermined (i.e., observations depend on assumptions, and multiple theories can explain the same phenomenon) is crucial. This perspective challenges exclusive reliance on scientific expertise as the sole path to solving global problems.

Science and technology's ambivalence within Risk Society and the 2030 Agenda demand a paradigm shift in governance. Rather than applying science instrumentally, one must democratize its production and application—acknowledging its limitations and incorporating lay knowledge and public deliberation. If science is "theoretically loaded" and underdetermined, and if manufactured risks are complex and unpredictable, then exclusive reliance on expertise for SDGs is insufficient. Regulatory science's uncertainty requires S&T governance for sustainability to be transparent, participatory, and controversy-capable — integrating diverse viewpoints. This underscores Beck's "subpolitics," advocating for actor participation beyond conventional politics, and the democratization of decision-making — enabling civil society and other stakeholders to shape S&T directions and risk management. Public participation is not merely a democratic ideal but a pragmatic necessity for navigating contemporary risks' complexity and uncertainty.

CHALLENGES AND OPPORTUNITIES IN GOVERNING THE 2030 AGENDA AMID GLOBAL UNCERTAINTIES

Governing the 2030 Agenda for Sustainable Development is a complex endeavor—operating within a Risk Society characterized by inherent uncertainties where action consequences are often unpredictable and accountability assignment is intricate. To implement SDGs effectively, robust mechanisms and structures must be established to foster cross-sector coordination, engage multiple stakeholders, and ensure transparency at all levels. Governance must address global challenges' complexity—requiring interaction among a broad spectrum of actors: government, academia, industry, entrepreneurs, civil society, and development partners.

A key challenge is the tendency toward technocratic approaches that neglect sustainability's political and social dimensions. For instance, SDG indicator definition was fraught with political disputes and financial directives—yielding metrics only partially reflecting the Agenda's qualitative and transformative ambitions. This is evident in the "Leave No One Behind" principle's vagueness—although well-intentioned, it lacks a clear official definition of "left behind," generating implementation imprecision and disputes over inclusion criteria. Moreover, the current 2030 Agenda formulation does not question structural inequality sources—focusing more on symptom mitigation than on tackling exclusion and vulnerability's root causes.

However, this uncertainty also presents opportunities for more reflexive, adaptive governance. Moving beyond purely technical approaches necessitates incorporating political and social dimensions in sustainability policies' design and implementation. Governance must address structural inequality causes, not merely symptoms, for LNOB to be truly effective.

Critiques regarding the 2030 Agenda's failure to question inequality sources and LNOB's vagueness indicate that purely "top-down" or technocratic governance is inadequate. Manufactured risks' complexity and science and technology's ambivalence call for transparent, participatory governance—able to align conflicting interests and mobilize diverse actors. This implies governance as a "learning mechanism," continuously reflexive and adaptive to new uncertainties. In a Risk Society context, governing the 2030 Agenda cannot be a linear, purely technical process; it must be continuous learning and adaptation—recognizing expertise limitations, promoting diverse actor participation, and willing to question development fundamentals.

Education emerges as a crucial integrating force—fostering critical thinking, scientific literacy, and civic participation in managing socio-environmental challenges. By integrating SDGs into curricula and encouraging interdisciplinarity, education can empower individuals to become agents of change—capable of reflecting on their actions and actively participating in socio-political processes for a more sustainable society. Effective 2030 Agenda governance thus requires a holistic approach—combining scientific expertise with public deliberation, accountability, and continuous adaptation in the face of an uncertain future.

DEBATE AND DISCUSSION

INTERPRETATION OF FINDINGS AND THEORETICAL CONTRIBUTIONS

Our critical analysis of STS studies, Risk Society theory, and the 2030 Agenda reveals essential interpretations concerning contemporary global challenges' nature. The principal conclusion is that sustainability transcends a mere environmental or economic issue; it is deeply social and political—intrinsically tied to how society produces knowledge, navigates uncertainty, and distributes risks and benefits.

The research demonstrates that science and technology—though celebrated as progress engines and SDG enablers—are ambivalent. They are not neutral entities but social constructs co-producing both benefits and manufactured risks. This insight challenges the optimistic, instrumental view of S&T often underlying 2030 Agenda implementation. Our analysis indicates that reflexive modernity, by generating intrinsic risks, poses fundamental challenges to SDGs—particularly those reliant on technocentric approaches.

The study's primary theoretical contribution is formulating an analytical framework that transcends fragmented views of global problems. By integrating STS critiques on science's nonneutrality, Risk Society's notion of self-producing dangers, and 2030 Agenda implementation criticisms, we offer a holistic, deeper lens. This integrated framework argues that technical or economic SDG solutions are insufficient unless they address social and political dynamics underlying risk production and unequal impact distribution. The research advances the field by providing a conceptual structure for a more nuanced analysis of theoretical pillars' tensions and synergies—emphasizing the necessity for intrinsically reflexive, socially engaged S&T governance.

CRITICAL CONFRONTATION WITH EXISTING LITERATURE AND STUDY LIMITATIONS

Our findings align with existing literature critiquing simplistic views of scientific-technological progress and 2030 Agenda implementation. STS notions such as "theoretical load of observation" and "underdetermination" reinforce discussions on science's nonneutrality—echoing authors like Kuhn, Bloor, and Collins. Likewise, our interpretation of manufactured risks (Giddens) and Beck's Risk Society thesis resonates with works examining modernization's unintended consequences.

However, our study distinguishes itself by explicitly, critically integrating these pillars with the 2030 Agenda. While many works treat SDGs instrumentally or descriptively, our research deepens critiques—highlighting LNOB's vagueness and the Agenda's failure to interrogate structural inequality sources. Incorporating Jasanoff's regulatory science and Beck's subpolitics critiques adds complexity to understanding S&T governance for sustainability—explaining why proposed solutions may falter amid uncertainty and political dispute.

A primary limitation is the study's exclusively theoretical-bibliographic nature. The absence of empirical primary data on national implementation or case studies precludes direct hypothesis validation in practical scenarios. This research does not aim to quantify phenomena or conduct field hypothesis testing, but rather to build a robust conceptual framework. This limitation is also an asset: it permits a depth of conceptual and theoretical analysis difficult to achieve in empirical studies focused on data collection. Critiquing Beck's "implementation imprecision" of subpolitics and Giddens's scant empirical measurement of reflexivity reveals a theory-practice gap. By acknowledging its theoretical stance, this study establishes a foundation for future empirical research to test our proposed hypotheses and framework in real-world 2030 Agenda contexts—filling this gap and contributing to a more comprehensive, applicable understanding of sustainability challenges.

IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICAL APPLICATIONS

Our findings hold significant implications for researchers in sustainability, governance, and STS fields. Future studies should pursue empirical investigations into SDG implementation—particularly in developing countries—from the Risk Society and STS perspectives. Such research could examine how manufactured risks manifest across various geographic and social contexts, how S&T policies for sustainability are formulated and implemented, and stakeholders' participation and accountability levels.

Another promising avenue is evaluating participatory governance approaches' effectiveness in risk mitigation and equity promotion within SDG implementation. Case studies on "citizen science" initiatives or "constructive technology assessment" (CTA) could yield valuable insights into integrating lay knowledge and diverse social perspectives into S&T decision-making for sustainability. This research underscores the necessity for a reflexive modernization of the 2030 Agenda—going beyond mere metric quantification to include critical self-evaluation and continuous adaptation to development's inherent uncertainties and risks. Critics' observations on the Agenda's failure to question inequality sources and LNOB's vagueness suggest the Agenda may not be sufficiently reflexive for Risk Society challenges. By integrating Beck's and Giddens's theories, we imply the 2030 Agenda must embed self-analysis and adaptability—recognizing its own interventions can generate new risks or perpetuate inequalities. Consequently, future research should assess policy "reflexivity" and practical applications fostering public deliberation and accountability.

Practically, our study's recommendations target policymakers, NGOs, and civil society. Key suggestions include:

Adopting a Reflexive Governance Approach: SDG implementation policies must acknowledge S&T's ambivalence and science's social construction. This entails moving beyond purely technical solutions to incorporate critical analysis of values and interests shaping technological development.

Strengthening Participation and Transparency: Establish robust multi-sector participation and transparency in S&T policy formulation and evaluation for sustainability. This includes creating deliberation forums that integrate scientific expertise with lay knowledge and affected communities' perspectives.

Questioning Sources of Inequality: Implement the 2030 Agenda with a sharper focus on structural inequality sources, not merely symptoms. This requires policies challenging unsustainable production and consumption models—ensuring equitable distribution of development's benefits and burdens.

Investing in Critical Citizenship Education: Reinforce education for sustainable development—equipping citizens to think critically about S&T and engage actively in socio-environmental challenge management.

This study calls for S&T governance that acknowledges its limitations and potential risks—committing genuinely to building a more equitable, sustainable future amid escalating uncertainties.

CONCLUSION

This investigation critically analyzed STS studies, Anthony Giddens's and Ulrich Beck's Risk Society theory, and the 2030 Agenda for Sustainable Development. Our synthesis reaffirms the central argument: modernity, in its advance, not only yields progress but also produces intrinsic risks—risks the 2030 Agenda aims to address but not always in a structurally reflexive manner. Science and technology, although essential for achieving SDGs, prove ambivalent—serving as both solution sources and manufactured risk vectors.

The study's significance lies in contributing to global sustainability governance by demystifying science and technology's neutrality and exposing 2030 Agenda gaps. We demonstrate that reflexive modernity—with its inherent risk production—imposes fundamental challenges to SDG realization; technocentric approaches alone are insufficient. LNOB's vagueness and indicator design's technocratic nature limit the Agenda's effectiveness—perpetuating inequalities by failing to challenge structural roots.

Unlike the detailed interpretations elaborated in the discussion, this conclusion synthesizes the core argument. The study offers a forward-looking perspective—recommending future research and practical strategies. To advance, S&T governance for sustainable development must adopt a more reflexive, participatory stance—continuously evaluating S&T impacts, engaging diverse stakeholders in decision-making, and holding actors accountable for generated risks. Future inquiries should empirically examine SDG implementation through a Risk Society lens across varied contexts—assessing participatory approaches and critical citizenship education's role in fostering truly equitable, resilient sustainability.

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