Exploring the Geopolitical Limits of Responsible Innovation and Technology Assessment

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Abstract

The central argument of this paper is that the frameworks of responsible innovation (RI) and technology assessment (TA) are rooted in an antiquated political and geopolitical paradigm, thus necessitating a conceptual overhaul. This argument is supported by two primary reasons. First, RI and TA are not neutral towards technological innovation; instead, they inherently align with a specific political and geopolitical model: the liberal world order (LWO). This model currently faces significant challenges and crises, which I investigated through a literature review of RI and TA and a subsequent political and geopolitical analysis. Second, the very essence of our technologies has dramatically transformed over the past 20 years. We now live in a world dominated by intricate global engineering systems that are not only political but also geopolitical in nature. These transnational systems influence the decisions and interactions of nations. The current LWO framework struggles to effectively grasp and manage these influential global systems. In addition, this paper presents a reinterpreted version of Rodrik's trilemma. This reformulation was designed to consolidate and expand upon the insights already gained. It revisits the issues identified, emphasising the urgency of revamping both TA and RI, particularly in light of the unique challenges posed by the Anthropocene. As we embark on this reassessment, the invaluable insights from philosophical reflections should not be underestimated.

Keywords: Technology, Innovation. Democracy, Engineering Systems, Rodrik's Trilemma

Introduction

This paper delves into the political and geopolitical underpinnings of responsible innovation (RI), alternatively known as 'responsible research innovation' (RRI), and technology assessment (TA). The core argument is that these methodologies are anchored in a bygone political and geopolitical paradigm[1], the so-called liberal world order (LWO). The aim of this paper is not to underscore the significance of geopolitical influences on technological evolution, as this premise has already been established (Khan et al., 2022; Picado, 2022; Suchkov, 2022), but to illuminate the challenges posed by the decline of a specific geopolitical paradigm in the strategies for overseeing technological advancement.

The focus of this paper can thus be articulated as follows:

- What are the underlying political and geopolitical factors that influence the perception of innovation and its moral and social implications?

- If these foundational beliefs are challenged or invalidated, what modifications should be made to our methodology?

To address these questions, this paper puts forward two hypotheses:

- Our current understanding of innovation and development, along with their associated responsibilities, is deeply embedded in a historical political and geopolitical framework that can be associated with the concept of LWO.
- The existing method of engaging with technological innovation becomes unsustainable over time, particularly as LWO undergoes a profound crisis and new frameworks emerge. This necessitates a re-evaluation and a novel approach to these issues.

RI and TA pre-suppose a specific political and geopolitical paradigm, the LWO, which has been established after the Second World War and is in deep crisis today. This claim is supported by a literature survey on RI and TA and a geopolitical and historical analysis. As I will demonstrate, the LWO has emerged as a political paradigm after the conclusion of the Second World War. It has weathered numerous challenges until the pivotal crisis in 2008, signalling its culmination and end. Thus, the LWO, predominantly shaped during the Cold War era, spanned roughly 60 years and has profoundly impacted the Western world. Over the past 15 years, we have observed the rise of a completely different geopolitical landscape. This new framework is marked by the decline of American supremacy, the ascent of illiberal powers, the surges of populism and technocracy, and the emergence of novel markets. What has been traditionally labelled as 'liberal-democratic solutions' now appears to fall short, as they no longer effectively address the challenges of our world and societies. Without a refreshed political and geopolitical understanding, the notion of 'responsible innovation' may become overly theoretical and lack practical impact. Embracing the concept of co-evolving technology and society, as proposed by Geels (2005), necessitates a thorough geopolitical re-examination of technology in a post-LWO era.

The second foundational argument revolves around the transformation of the essence of technology over the past two decades. In the current era, the world is governed by highly interconnected global engineering systems, also researched and discussed as socio-technical infrastructures in Science and Technology Studies (STS),[2] that hold significant political and geopolitical sway. These entities, operating on a transnational scale, play a pivotal role in shaping the decisions and dynamics between states. They manifest as expansive supply chains and communication networks such as the internet. The distinguishing feature of today's global engineering systems lies in their vast reach, ubiquity, and deep influence on political and social spheres.[3] Beyond their extensive influence, these modern technological networks also symbolise a shift marked by profound conceptual, historical, and philosophical alterations, encapsulated in the term *Anthropocene*. This paper posits that the LWO finds itself ill-equipped to comprehend and govern the intricate and expansive roles of global engineering systems, primarily because the existence of these systems undermines its foundational political principles. Consequently, the ongoing crisis within the LWO and the ascendancy of global engineering systems are intricately linked and mutually reinforcing phenomena.

Finally, I present the claim that these two aspects (i.e. the crisis of the LWO and the rise of global engineering systems) are connected and force the reformulation of Rodrik's (2011) trilemma, which concerns the very essence of contemporary capitalism. Rodrik's trilemma states that it is impossible to achieve all of the following goals at the same time: (1) deep economic globalisation with free circulation of capital, (2) national sovereignty, and (3) democratic politics. According to Rodrik (2011), any government must make a choice between two of these three elements. The crisis of the LWO and the growth of engineering systems have made it even more complex to arrive at a solution.

I must now clarify the nature of this research. First, in this paper, 'liberal world order' does

not mean that the 'liberal' thought has some moral or political superiority over other political predispositions. This paper does actually not intend to provide any moral or political appraisals. Second, in the following sections, I will use the terms *geopolitics* and *geopolitical*. These are quite controversial expressions for many reasons that I will not delve into here (see Kelly, 2006; Dodds et al., 2013). The epistemological status of the notion of 'geopolitics' itself is a much-debated topic for good reasons (see Flint 2021). As for this text, I limit myself to using the expressions 'geopolitics' and 'international affairs' almost synonymously. By employing both terms, I can cover a wider spectrum of discussion that includes both the strategic, geographical dimensions of state interactions (geopolitics) and the diverse aspects of state relations and diplomacy (international affairs). This approach ensures a comprehensive analysis that acknowledges both the physical constraints and the complex, multifaceted nature of global interactions.

Literature survey

The case of RI and TA

Over the past two decades, especially since the nanotechnology debate in the early 2000s, the expressions 'responsible innovation' and 'responsible research and innovation' have become commonplace in discourses and practices aimed at an inclusive, ethical, and transparent management of technological innovations. The discussion of ethics in science, technology, research, and innovation is not new, but the idea and practice of RI has been put forward only recently to incorporate democracy and responsibility into research and innovation policies (Stilgoe and Guston, 2017). According to Von Schomberg, RI is defined as "a transparent interactive process where societal actors and innovators become mutually responsible to each other, viewing the ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products" (Von Schomberg, 2011: 9). The RI approach has been developed primarily in Europe through the efforts of the European Union, rendering it an essential element of its development and funding programs (e.g. Horizon Europe). Conceptually, this approach includes at least four dimensions: anticipation, reflexivity, inclusion, and responsiveness (Owen et al., 2021). Despite this, as Thapa et al. (2019) pointed out, the conceptualisation and operationalisation of RI remain ambiguous to some extent and at risk of being reduced to empty rhetoric. According to Van Lente et al. (2017: 3), RI is primarily an umbrella term "which connects different interests and viewpoints."

It is more complicated to provide a similar definition for TA, not only because TA has a much longer and more complex history (see Banta, 2009; Grunwald, 2019; Knezo, 2005; Sadowski, 2015; Van Eijndhoven, 1997), the roots of which go back to the 1970s (with the first Office of Technology Assessment being founded in 1974 by and for the US Congress), the 1980s (with many new institutions being initiated in Europe) and the 1990s (with EPTA, the European Parliamentary Technology Assessment, founded in 1990), but also because of the many forms of TA (e.g. participatory, health, hermeneutic, or constructive TA).

Generally, TA can be defined as a systematic and multi- / inter- / transdisciplinary process that evaluates the potential societal, economic, environmental, and ethical impacts of a technological innovation or advancement. According to Decker and Ladikas (2004: 14), TA is "a scientific interactive and communicative process which aims to contribute to the formation of public and political opinion on societal aspects of science and technology." In this definition, "particular emphasis is placed on unintended consequences—the non-obvious is to be made visible through interdisciplinary exchange, often involving stakeholders and those affected, and is thus made accessible for evaluation" (Hennen et al., 2023b: 2). TA involves the analysis of the development, implementation, and use of technology to provide informed insights and recommendations to policymakers, stakeholders, and the public. The primary goal of technology assessment is to inform decision-making, foster responsible innovation, and address the complex challenges and implications associated with the introduction and diffusion of new technologies (for an overview, refer to Grunwald, 2009; Vig and Paschen, 2000). In other words, the mission of TA

is "about reflection on technological progress, which should be used to enable a scientifically elaborated knowledge base for political decision-making, and social discourse on questions of shaping futures in an increasingly technology-dependent world" (Hennen et al., 2023b: 2). We can thus identify three dimensions of TA: a) the scientific, b) social, and c) policy dimensions. Connected to these three dimensions are three types of impact: a) raising knowledge, b) forming attitudes and opinions, and c) initiating actions (Hahn and Ladikas, 2019).

Methodology

What are the relationships between RI and TA? I assert that one can reasonably argue that RI is an outgrowth and advancement of TA because it incorporates tools originally developed within TA. On the other hand, Van Lente et al. (2017) proposed that RI serves as a critique of TA, involving a re-evaluation and modification of the objectives and methodologies of TA. This was not intended to question the origins of RI from TA but to provide a different interpretation. In particular, RI critiques TA in two key areas: the treatment of normative aspects and the consideration of stakeholders. According to Van Lente et al. (2017: 5), "[RI's] line of reasoning suggests that TA may overlook ethical complexities and underestimate the importance of guiding the direction of innovation."

The first objective of this research is to identify and analyse the basic political assumptions of these approaches, which I call, with a broader expression taken from Castoriadis (1974), their 'political imaginary'. To do so, I build on a literature survey regarding RI and TA. My literature sample includes 300 papers on RRI and 150 papers on TA that were published between 2017 and 2022. The articles were selected from the EBSCO and Google Scholar databases on the basis of the definitions and dimensions of RRI and TA. The objective of this survey was to conceptually investigate the connection between the two approaches and the so-called participatory democracy, liberal democracy, and public deliberation, as understood in the LWO architecture. NVivo software (2022 edition) was used in both cases for analysis.

I employed both quantitative and qualitative methods in my approach. Frequencies of occurrence of the following terms in the sample were measured: 'democracy', 'democratic', 'democratization', 'liberal', 'liberalism', 'EU (European Union)', and 'UN (United Nations)'. Frequency refers to the group of papers, not to individual papers; the same term can indeed appear several times in the same paper. Based on this methodological premises, I found that the terms 'democracy', 'democratic', and 'democratization' appeared 267, 255, and 245 times, respectively, in papers on RI, and 76, 69, and 85 times in papers on TA. The distributions of the terms 'liberal' and 'liberalism' differed, as they appeared 72 and 73 times, respectively, in papers on RI, and 45 and 38 times in papers on TA. It is also important to note the connection between the concept of democracy and major international institutions such as the EU and UN. References to the EU appeared in 254 papers on RRI and 103 papers on TA. On the other hand, references to the UN appeared 194 times in RI papers and 105 in TA papers.

Table 1 shows the term frequency percentages.[4] This gives us the average number of times each term appears per paper in each group, expressed as a percentage.

Table 1. Term frequencies in percentages.

Term	In RI papers (300)	In TA papers (150)	In the total number of papers (450)
Democracy	89%	50%	76%
Democratic	85%	46%	72%
Democratization	81%	56%	73%
Liberal	24%	30%	26%
Liberalism	24%	25%	24%
EU	84%	68%	79%
UN	64%	70%	66%

Qualitative analysis

As Owen and Pansera (2019: xii) pointed out, the political implications and/or foundations of RI have been little studied in the literature: "If RI aims for a different mode of science, innovation, and society, a different politics, what exactly is this mode, *what exactly is the political imaginary of RI?*" (emphasis added). This is why Owen and Pansera (2019) asserted the importance of a 'second-order reflection' about RI: "Without an understanding of how responsibility is framed, configured, and enacted, there is no 'responsible' in RI" (Owen and Pansera, 2019: 36). Indeed, as Owen and Pansera (2019: xiii) claimed, "RI's focus on science and technology has been at the expense of the very innovation systems within which science and technology development (and the institutions in which these are conducted) is increasingly located, increasingly implicated, increasingly complicit."

The simple analysis of occurrences and connections between terms could be misleading if it is not accompanied by the analysis of some representative texts that provide other useful elements for interpretation. As Yaghmaei and Van de Poel (2013) argued that 'responsible innovation' is not a clear-cut, clearly formulated principle or set of practices. Instead, it consists of a plurality of commitments, strategies, and interactions oriented towards the general objective of technological development aimed at socially desirable ends. The authors defined 'socially desirable' on the basis of UN or EU guidelines or norms. However, the UN and EU are products of the LWO, as they were conceived and designed on the basis of that geopolitical model; this is historical evidence (see, e.g., Acharya and Plesch, 2020; Kentikelenis and Voeten, 2021). Therefore, the crisis of the LWO carries the risk of emptying them of meaning.[5]

Rip (2018) thinks of RI as a model of social innovation that emerged in the late 1990s from the debate on nanotechnologies. Later, it became an umbrella term to indicate a series of approaches used mainly in the European policymakers' context: "RI implies changing roles for the various actors involved in science and technology development and their embedding in society. This is an important aspect of the social innovation of RI" (Rip, 2018: 126). According to Rip (2018: 126), dominant "is the utilitarian ethics perspective: maximise technology's positive contributions and minimise negative consequences. And a neoliberal version of it: it is enough if actors avoid causing harm." Rip (2018) also underlined the important role of the European Commission in developing this approach in research funding programmes. Moreover, Shelley-Egan et al. pointed out that 'responsible innovation' can "be considered to be ubiquitous within the EU's discourse around the governance of emerging technologies, cutting across, for example, subprogrammes within the European Commission's (EC) Horizon 2020 research funding programme" (Shelley-Egan et al., 2018: 1720).

Both the EU and the UN are institutional reactions shaped by the foundational values of the LWO. The purposes of these institutions are to propagate and modify the primary principles of the LWO for diverse global scenarios. Central to their mission is a core belief: the endurance and equilibrium of a specific societal structure hinge on striking the right balance between free markets, multilateralism, and democracy.

What is the relationship between TA and the political system in which TA operates? Hahn et al. (2023) described and highlighted the current and relevant developments of TA across 12 countries. The authors claimed that "the great heterogeneity of different country-specific settings in which TA takes place and is performed globally, cannot hide the fact that on a substantive and methodological level TA faces similar challenges" in all settings (Hahn et al., 2023: 25). On the other hand, "the question of the democratic quality of the political system and the rule of law seems to be a potentially useful predictor of the degree of TA institutionalisation, understood as the existence of fairly stable and formalised organisational structures and procedures within which TA is conducted" (Hahn et al., 2023: 26). Therefore, the authors applied the liberal democracy index of the V-Dem Institute to analyse the state of democracy in the countries under consideration. They concluded that "while any correlation between TA manifestations and scoring on the liberal democracy index should be treated with caution, we can observe that low scores on the index correlate with low

degrees of TA institutionalization, as is the case for India, China, and Russia" (Hahn et al., 2023: 28). In other words, where there is a stronger "liberal democracy, the TA is more institutionalized and stronger" (Hahn et al., 2023: 28). However, the authors also underlined that "the opposite relationship is not supported by our selected cases: a high rating on the liberal democracy index is not uniformly reflected by high degrees of TA institutionalization" (Hahn et al., 2023: 29).

The close tie between TA and liberal democracy is further underscored in recent discussions regarding the potential for a global TA. Hennen et al. (2023b) highlighted that the primary challenge for global TA is adapting the notion of TA as democratic policy guidance, rooted in Western traditions, to developing countries. These nations often differed significantly in cultural and political backgrounds, and typically lacked comparable economic capabilities (Hennen et al., 2023bThe resulting problems to be addressed, according to Hennen et al. (2023b), are numerous: How can we establish a sustainable global TA? What is the most practical and achievable approach to its development? How can TA tools gain traction in non-Western socio-economic and political environments? How can we ensure equitable collaboration among partners with economic disparities?

Let us delve deeper into this matter. Hahn and Ladikas (2019) clearly stated that the Enlightenment and 18th-century liberal traditions are foundational to the S&T policy in Europe. However, when conceptualising a global TA, there is a noticeable tension: the inclination to view TA as a universal method clashes with the necessity to pinpoint a specific environment where TA can operate and evolve. Crucially, TA is not merely a scientific pursuit; its objectives also encompass influencing viewpoints and guiding actions. Consequently, engagement with the social and political realms is indispensable. This means that the political system is essential to develop a good TA infrastructure; that is, TA is impossible in a dictatorship. Hahn and Ladikas (2019: 56) underscored the profound challenges that Eastern European countries confronted in attempting to establish and institutionalise TA after the momentous fall of the 'Iron Curtain'. Another significant remark is that the TA model, as cultivated in the Western world, "does not exist in the Chinese system" (Hahn and Ladikas, 2019: 126). While numerous public entities in China undertake activities reminiscent of TA, they lack the public and stakeholder engagement intrinsic to TA, specifically the component of public debate and deliberation. In China, activities akin to TA are encapsulated within an institutional framework primarily aimed at gauging economic growth, which is significantly different from Western political power structures. A similar argument can be made for Russia (Hahn and Ladikas, 2019: 190).

The problem of the relationship between TA and the political system has been addressed in many ways (Grunwald, 2019; Wong, 2016). Hahn and Ladikas (2019) explicitly asked, "Is TA possible in an illiberal system? Can we translate TA even in a non-democratic context? What are the normative bases of TA? Can non-Western ethical traditions be the foundation in S&T decisions?" These are crucial questions to understand whether a global TA is possible, that is, a TA that can transcend national borders and meet the challenges posed by globalisation. Undoubtedly, freedom of expression and the capacity for open discussion are pivotal to TA.

Furthermore, it is essential to integrate these elements within an economic paradigm that champions free markets and competition. The rationale behind this alignment is that technological innovation and progress, the primary concerns of TA, flourish most effectively in an environment characterized by these economic principles (further details on this relationship are explored later in this article). This consideration leads to a pertinent inquiry: Can TA be effectively implemented within an economic system that diverges from the principles of free market and competition?

Conceptual and operational references to the 'political imaginary' of RI and TA

On the basis of the previous analysis, I argue that there are two types of references to the 'political imaginary' of the liberal democracy model

in the literature on RI and TA. The first reference is purely conceptual in nature. This is evident in Gianni's (2020) definition of responsibility as the foundation of RI: "Being responsible means responding to the guaranteed freedoms as a recognised moral agent of a given society, having the aim of preserving such freedoms and at the same time implementing them through concrete institutional arrangements" (Gianni, 2020: 140). Moreover, the concept of responsible innovation presupposes the ideas of participation, engagement, and deliberation as means of solving collective issues. In this respect, RI and TA incorporate the deliberative democracy and communicative rationality model developed by Rawls (1971) and Habermas (1983) as the conditions of social engagement (Braun and Griessler, 2018; Reber, 2017; Scott, 2023; see also Van Est and Brom, 2012). Greater participation in public deliberation is explicitly demonstrated as the main way to steer social and technological innovation in TA (Hahn and Ladikas, 2019: 56). According to Hennen et al. (2023b), any public discussion weighing the advantages and disadvantages, potential outcomes, and ethical considerations of introducing and using technological advancements can be considered as an informal TA process (see also Rip et al., 1995). The centrality of public debate to liberal democracy was also underscored by Kelsen (2005; see also Tilly, 2007).

On the other hand, the second reference is more operational, as it describes how to translate concepts into norms and policies. This means that democratic deliberation is interpreted and realised in light of European and UN frameworks, and their values and goals (Cavas, 2015; Von Schomberg, 2013). In this respect, the process is reversed: the EU institutions have appropriated the weak conceptual architecture of RI by fully integrating it into their policy-making process (European Commission, 2013, 2014; 2019; European Council, 2009; Kop et al., 2023). Moreover, Hennen et al. (2023a: 234), when proposing models for a global TA, indicated that among the steps to be taken is the strengthening of the role of the UN in TA: "It is evident that the globalTA Network has a lot to gain by working with UNCTAD [the UN TA agency] while the opposite is also true." This means that RI and TA are not only theorisations of a political model but also ways of *doing politics* based on that model.

The main result of the previous quantitative and qualitative analysis is that RI and TA are not neutral approaches; rather, they are based on specific political assumptions about democracy and politics. This thesis intends to develop and improve the claims of Delvenne and Parotte (2018; see also Delvenne et al., 2011; Hennen, 1999), who argued that "TA communities should break with the myth of neutrality to render their political identity explicit and recognize that TA not only *has* politics, but also *is* political" (Delvenne and Parotte, 2018: 1). I claim that from a historical point of view, RI and TA are based on institutions that were born at the end of the Second World War, within a certain international political framework, the LWO. RI and TA can be considered an expression and extension of that political and geopolitical model. In the continuation of this paper, I argue that RI and TA must be updated or superseded, as the LWO model on which they are based is in crisis. In this respect, Lenoir's (2019) thesis that RI is an alternative to neoliberal governance confirms my claim. As we will see, neoliberal governance represents the crisis and end of the LWO.

Crisis of the LWO: A short narrative

TA and RI are generally framed as neutral analytical activities whose goal is to serve society and produce better technology, but this is just a myth. The purpose of TA and RI is to extend democracy and democratisation by implementing methods such as consensus, conferences, citizen summits, future panels, and scenario workshops. However, what is democracy from the perspectives of TA and RI? TA and RI imply a specific concept of democracy: liberal democracy, but what kind of liberal democracy? The one embodied by the LWO.

Over the past two decades, while various economic, political, and social crises have impacted the global arena, the deepest and most foundational has been the challenge to the LWO (Chadha, 2022; Duran, 2019; Lucarelli, 2022; Sinha, 2021; Snower, 2019). Rooted in Enlightenment values, the LWO began to crystallise in the immediate post-war years and solidified after the

Second World War. Spearheaded by the United States and bolstered by the crucial involvement of Western democracies, the LWO evolved and expanded from 1949 to 1989. This expansion manifested in a comprehensive web of international standards and institutions, the promotion of democratic governance within nations, the embrace of free trade, and the endorsement of multilateralism as the preferred mode of state-to-state collaboration and enduring cooperation. According to Gotz (2021), the traits of the LWO encompass the following: (i) a significant degree of security interdependence that promotes cooperation between states; (ii) a comprehensive framework of multilateral organisations that guide emerging powers towards alignment with the prevailing order; (iii) a global capitalist structure; and (iv) a widespread allure of liberal principles and administrative methods. All these traits are, to different extents, challenged by contemporary shifts in global politics. What are the causes of this crisis? What is the political logic behind the LWO?

As Parsi (2022) asserted, the LWO is a model of international relations architecture developed after the Second World War, arising from two distinct needs: the need to limit state sovereignty and therefore avoid new wars (indeed, to make peace economically utmost attractive) through the instrument of a free and internationally open market, and the need to regulate the free market, which, as was evident from the 1929 crisis, is incapable of self-regulation and can heavily undermine democracy (as was the case in the Weimar Republic and the rise of Nazism in Germany). Thus, the pivot of the liberal order was the alliance and balance between state sovereignty and the free market (Harvey, 2005; Ikenberry, 2020a; Reich, 2010). However, this balance is not just an end in itself. The balance between state sovereignty and the free circulation of goods and services, and between the needs of the democratic social order and those of economic competition had, in at least the theoretical intent of the LWO, to benefit, above all, a specific social subject: the middle class. A central aspect of the liberal project was the establishment of a strong middle class by improving the living conditions of a large portion of the working class. This also meant expanding rights, increasing social protection and political inclusion, and reducing economic inequalities.

This certainly does not mean that this system was just or perfect, or that it was 'heaven on earth'. The LWO tolerated or even favoured alliances with completely non-liberal political regimes, such as Franco's Spain, Salazar's Portugal, apartheid South Africa, and other dictatorships or religious fundamentalists around the world. Furthermore, the LWO was based on the US cultural, economic, defensive, and technological dominance, often to the detriment of the European partner. In other words, the balance between state sovereignty and the free market, which are "two powerful forces not necessarily inclined to natural harmony" (Parsi, 2022: 55), has always been fragile.

This international order began to unravel in the late 1960s and early 1970s. There were many causes, but I will limit myself to mentioning only four: the American defeat in the war in Vietnam, the oil shock of 1973, the end of the Bretton Woods agreements, and the implosion of the Soviet Union. According to Parsi (2022: 27), "it was here that the inversion from the original logic of the Liberal World Order also began in favor of the opposing one underpinning the Neoliberal Global Order: no more protecting domestic societies from the threats coming from the international environment, but rather shielding global markets—especially financial ones—from any interference coming from domestic societies." The reply to this change was formulated along three different but converging cultural–ideological lines: neoliberalism, neoconservativism, and ordo-liberalism (Parsi, 2022; Slobodian, 2018). The winning line was above all (but not only) a mixture of neoliberalism and neoconservatism supporting a market logic based on deregulation. This logic theoretically prescribed free competition but in fact protected the concentration of wealth and power. In this way, a transition from the freedom of the market to the 'dictatorship of the market' took place (Parsi, 2022: 66).

The 2008 economic crisis instigated a watershed, putting an end to the balance between sovereignty and the free market; it marked the beginning of the end for the LWO

(Tooze, 2018). In chronological terms, the LWO peaked just after the Second World War and then faced several crises (e.g. the oil crisis in 1973; see Schramm, 2023) until 2008, when its decline began. However, there are other interpretations as well. For Ikenberry (2020b: 133-134), the real end of the LWO was the COVID-19 pandemic: "The moment when the United States and its allies, facing the gravest public health threat and economic catastrophe of the post-war era, could not even agree on a simple communiqué of common cause. … The United States may no longer be the world's sole superpower, but its influence has never been premised on power alone" (see also Ikenberry, 2018, 2022).

The crisis of the LWO originated from the prevalence of the free market over state sovereignty, as demonstrated by the tendency towards deregulation of the financial system in Reagan's administration (Rasmus, 2020). It was accompanied by a profound crisis of democracy itself, with the emergence of what has been termed 'post-democracy' (Crouch, 2004): a system which, while remaining formally democratic, is characterised by estrangement of the masses from politics, the disappearance of the middle class, the emergence of increasingly cohesive oligarchies, and the progressive renunciation of the state to concretely intervene in the lives of citizens. These intertwined phenomena had several consequences such as the rise of power and influence of non-liberal nations like China; the redefinition of the US global strategy; the explosion of new protectionist and nationalistic tendencies; the crisis of international alliances and institutions like the NATO and UN; the growing financialization of the economy and state support for the banking system; the progressive decline in the quality of work with the spread of jobs characterised by insecurity, low wages, poor guarantees, and therefore a tendency towards greater debt; the growth of inequalities and the oligarchic transformation of the political system with a negative impact on the supply of public services (Piketty, 2013); the spread of populist, anti-establishment tendencies (on the nature of populism, see Urbinati, 2020); and the phenomenon of mass migration. Given all these fundamental shifts, "contemporary politics [has become] a game changer for TA institutions" (Delvenne and Parotte, 2018: 2) as well. Moreover, anti-establishment politics comes with serious epistemic effects, questioning the role of scientists and the scientific method, ideologizing debate, and creating conspiracy theories or false truths (Jasanoff and Simmet, 2017).

Now, I want to stress that the crisis of the LWO constituted a crisis of a global political strategy aimed at the harmonisation of two opposite logics. The crucial idea of the LWO, whether in its various liberal-American or European social-democratic versions, lies in finding and perpetuating an equilibrium between the market and democracy in the belief that the shortcomings of each system could be alleviated by the other. This meant finding a synthesis between two inverse logics.

The epoch of global engineering systems

In the past 40 years, owing mainly to the emergence and development of digital technologies, technological systems have become increasingly pervasive, complex, and powerful (see De Weck et al., 2011). Here is a more formal definition:

Engineering systems refer to complex, socio-technical systems that encompass the integration of technical and human components to achieve specific objectives. These systems are characterized by their focus on problem-solving within specific domains, such as transportation, healthcare, or energy. These systems typically require a multidisciplinary approach, bringing together expertise from different engineering disciplines and sometimes including non-engineering disciplines.

I propose to introduce a conceptual distinction between engineering systems and global engineering systems (GESs), composed of many interacting engineering systems. Engineering systems have always existed. However, today, these systems have reached a degree of complexity, ubiquity, and pervasiveness in human life that they have achieved a 'global' scope in both a quantitative (involving many different societies and nations) and qualitative sense (influencing and

determining almost all major aspects of human life). They thus exert political power (Barry, 2001).

Therefore, GESs expand the concept of engineering systems to a worldwide scale, addressing global challenges and opportunities. These systems are not only interdisciplinary but also cross-cultural and international in scope. They involve collaboration across different cultures and nations, necessitating an understanding of diverse perspectives, regulations, and practices.

While engineering systems are primarily focused on solving complex problems within specific domains by integrating technical and human components, GESs extend this approach to tackle global challenges, requiring international cooperation, a focus on sustainability, and an understanding of global interdependencies. An example of GES is GPS, a satellite-based navigation system that provides location and time information globally, under any weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. It is a system of 24+ satellites in orbit, ground stations, and the devices that receive GPS signals. It involves several types of engineering systems: aerospace engineering, computer science, telecommunications, and more. Maintained by the United States government but accessible to anyone with a GPS receiver worldwide; its development and maintenance involve international agreements and cooperation. It is used across various sectors globally, including navigation for transportation, timing mechanisms in financial transactions, and disaster response coordination.

Owing to their power and complexity, GESs are not only political, but also highly geopolitical in the sense that they condition the decisions of national governments and the relationships between states. Another typical example of a GES is the internet, which began as a military application. Today, the internet is no longer simply an engineering system but something much more complex, involving many (maybe all) other socio-technical systems (energy, supply chain, business, etc.) and having social and political effects on a global, multi-sectoral and multi-dimensional scale.[6]

Another relevant example of GES is the International Space Station (ISS). The ISS is a model of international cooperation, a platform for the comprehensive study of the effects of long-term spaceflight on the human body, and a test bed for the technologies required for missions to the Moon, Mars, and beyond. It involves complex engineering and scientific collaboration among several space agencies, including NASA (United States), Roscosmos (Russia), JAXA (Japan), ESA (Europe), and CSA (Canada).

Five features of GESs are especially important here:

1. No one ever designs an entire GES. We only ever design a particular aspect of the system; designing consists of modifications or extensions to some existing element. Therefore, GESs are always a collective work; they are partially designed and evolved (De Weck et al., 2011: 31). Designing GESs "is essentially designing these specific interventions as levers that move the overall system into the direction we want it to go, which usually requires a model and understanding that spans several interventions and their interactions. Interventions can be seen as efforts or action(s) intended to secure a desired outcome or to change an outcome" (Maier et al., 2022: 9).
2. GESs have high internal complexity (i.e. these systems are composed of several elements, services, functions, and many intertwined hierarchical levels of organisation) and external interconnectedness. Furthermore, in these systems, different types of complexity are intertwined; therefore, new methodological approaches are needed to understand these new forms of complexity. We can distinguish at least three 'type sets' of complexity: technical, social, and human, and temporal complexity. I speak of 'type sets' because, for example, in technical complexity, we find many different types of complexity, including computational complexity, mathematical complexity, and complexity regarding design or material construction. The same thing can be said for social complexity, in which we

find administrative and bureaucratic, ethical, political, social, psychological, genetic, and biological complexity, among others.

3. GESs have a global scope in the sense that they are not local; they go beyond a purely national logic limited to state boundaries. On the one hand, they are transnational, crossing national borders and involving different regions and states. On the other hand, they are often managed by private companies or by a cooperation between private companies and public authorities. Thus, GESs are not only the result of long chains of political and strategic decisions but also impose political choices and strategies over time that condition all players involved (states, individuals, organisations, and companies).
4. GESs are designed to last for several generations. Therefore, their design implies a vision of the future. However, future generations are not directly involved in the design process and cannot influence design decisions based on their, possibly own needs, values, and lifestyles.
5. In GESs, innovation cycles (including the conceptualisation, design, development, and marketing of new products and services) become shorter and shorter. This acceleration in innovation is driven by several key factors: 1) rapid advancements in technology, particularly in fields such as information technology, materials science, and automation, have drastically reduced the time required to prototype and produce new engineering solutions; 2) intense global competition motivates companies to stay ahead of the curve; 3) modern consumers have come to expect frequent updates and improvements in products and services, and this drives companies to release new iterations and versions of their offerings more frequently, responding to changing customer demands; 4) agile methodologies and iterative development processes have become prevalent in engineering and product development. The smartphone industry is a prime example of rapidly shortening innovation cycles.

However, it would be too simple to reduce GESs to this definition. In reality, GESs are also the expression of more than just an engineering super-system. They are the expression of a change of epoch and a deeper conceptual, epistemological, and ontological transformation, or what we call the 'Anthropocene'. From this point of view, I would say that the conceptual foundations of RI and TA would need to consider this philosophical transformation much more explicitly and thoroughly.

To defend this claim, I will first specify what I mean by Anthropocene. The general definition of this epoch is based on two basic assumptions: firstly, that "the Earth is now moving out of its current geological epoch, called the Holocene" and that "human activity is largely responsible for this exit from the Holocene, that is, *humankind has become a global geological force in its own right*" (Steffen et al., 2011: 843, emphasis by the author). This means that, secondly, "human activities have become so pervasive and profound that they rival the great forces of Nature and are *pushing the Earth into planetary terra incognita*. The Earth is rapidly moving into a less biologically diverse, less forested, much warmer, and probably wetter and stormier state" (Steffen et al., 2011: 614, emphasis by the author; see also Crutzen, 2002; Crutzen and Brauch, 2016; Crutzen and Stoermer, 2000).

Here, I consider Cera's (2023) thesis that the Anthropocene is a hyper-object characterised by epistemic and ontological instability.[7] The root of this instability lies in the fact that as such, the Anthropocene challenges the boundaries between natural and artificial, nature and culture, nature and society, and hard sciences and humanities, forcing a redefinition of these categories. This is "the definitive overcoming of the traditional clear distinction between nature (*physis, natura*) and culture (*techne, tecnica*), moving towards an osmosis/(con)fusion between the two", and this overcoming "should be considered as transcendental of the anthropogenic hypothesis: the Anthropocene's basic feature, a necessary premise for accessing it" (Cera, 2023: 19). As Australian cultural studies scholar Ben Dibley (2012: 140) claimed, "the Anthropocene is the crease of time." The advent of humans as geological agents "demands ways of thinking these temporalities [the deep time of geology and a rather shorter

history of capital] together" (Dibley, 2012: 140; see also Cera, 2023; Chakrabarty, 2009, 2015, 2016, 2021).

These reflections are pertinent to the analysis of GESs. As I pointed out, GESs are also the expression of a new historical era, specifically the Anthropocene, and must be viewed through this lens to be fully understood.

The cage of Rodrik's trilemma

In this section, I offer a revised version of Rodrik's trilemma that serves both as a summary and an expansion of the earlier sections. I intentionally present this rephrased version in a simplified and formal way, akin to a logical theorem. This reformulated trilemma has a conceptual structure that compels us to acknowledge that the model of technology assessment put forth by RI and TA is not viable, drawing from the content discussed in the previous sections. The three logics of globalisation, state sovereignty, and democracy cannot exist together without at least one of them being compromised. Nevertheless, for a technological innovation and development model such as that suggested by RI and TA, we require the simultaneous presence of all three logics.

Even if we argue that globalisation has changed or is changing, the underlying paradox identified by Rodrik (2011) remains valid. The crisis of LWO demonstrates the fundamental rightness of the trilemma and proves that a balanced and responsible governance (i.e. based on the equilibrium of at least two of the elements of the trilemma) of technology is impossible. However, the emergence of GESs makes the development of a new geopolitically-oriented approach to technology and technological innovation urgent and critical.

Based on an analysis of the 1990 crisis in Argentina, Rodrik (2011: 42) reconstructed a fundamental tension between (hyper) globalization and democracy as "hyperglobalization does require shrinking domestic politics and insulating technocrats from the demands of popular groups." In other words, there was a clash between the international mobility of capital and companies (a basic feature of globalisation), and state sovereignty, which restricts politics to a geographically defined stable area. To justify this thesis, Rodrik pointed out different types of phenomena, such as outsourcing in the world of work; corporate tax competition (i.e. the competition between governments to attract companies and therefore the progressive shifting of the burden of taxes from capital to labour); differences between health and safety standards; and restrictions on industrial policies for the poorest countries (a fact that emerged above all in patent and copyright regulation; Rodrik, 2011: 189–199 for all these aspects).

On the basis of these remarks, Rodrik developed his trilemma. The three actors in the trilemma respond to different, and partly incompatible logics. Foremost, the logic of globalisation is incompatible with both state sovereignty and democracy. Overall, we are left with three options: "If we want hyperglobalization and democracy, we need to give up on the nation state. If we must keep the nation state and want hyperglobalization too, then we must forget about democracy. And if we want to combine democracy with the nation state, then it is bye-bye deep globalization" (Rodrik, 2011: 200). The logic of deep globalisation necessarily implies a weakening or transformation of national policies; the role of the state is reduced to that of the general controller of compliance with some basic conditions. Indeed, the state constitutes a hindrance to deep globalisation and must therefore be curtailed – this is perfectly in line with Rodrik's thesis. Now, what happens if nation-states are reduced and democracy maintained globally? A world democratic order is sought that Rodrik calls the 'global governance option' (Rodrik, 2011: 202). This mode of governance can be imagined as a 'global federalism' based on the worldwide replica of the US model or a milder form of association, such as the EU. Rodrik's thesis is that in this situation, that is, maintaining democracy and deep globalization by reducing nation-states would inevitably lead to a weakening of democracy itself. The reason for such weakening is twofold: a) state institutions would no longer be able to protect democracy, b) the logic of deep globalization is by essence 'disruptive' to democracy in the sense that it tends

to deepen inequalities, while democracy tends to create equality. The handling of the trilemma is the subject of much debate. For Rodrik, there is a need to limit deep globalisation and restore the strength of nation-states. However, other economists argue that the solution must come through strengthening international rules.

The possible scenarios opened by the trilemma can be schematised as follows:

The problem that I want to raise is that we need all these elements *together* (GL + DE + SS) to develop a model of governance conceptualised by RI and TA.

In scenario 1, SS is needed because RI and TA implicitly refer to state sovereignty or international institutions' sovereignty (e.g. the UN or EU and its regulatory context) to regulate technological innovation. This aspect is evident in the literature, as we saw earlier. TA and RI are about anticipating moral choices and taking responsibility for future developments in technology that may affect future generations. In this regard, RI and TA always have a normative background and political objectives. This double normative dimension relates to the public dimension and therefore to the normative sphere of states, or international organisations.

The connection between TA and RI and the normative sphere of states or international organizations becomes particularly clear in instances of TA de-institutionalisation. De-institutionalisation refers to the process where formal structures or established practices of conducting TA within governmental or institutional frameworks become weakened or dismantled. The examples given from the United States and Belgium indicate situations where the formal mechanisms or organizations responsible for evaluating and guiding technological innovation in a responsible manner have been reduced or removed. This process underscores the political and normative dimensions of TA, as the presence or absence of such institutions reflects broader decisions and values within societies about how technology should be governed and for whose benefit (see Delvenne and Parotte, 2018; Van Est and Brom, 2012).

In scenario 2, we need DE because RRI and TA are intrinsically connected to representative democracy and its deliberative rationality. This aspect is evident in Von Schomberg's (2011) study in which RRI was demonstrated to be intrinsically connected to the European decision-making and regulatory structure. As observed earlier, RI and TA are expressions of participatory democracy and a deliberative rationality that is inherently democratic: "With regard to the ethical aspect, deliberation is a requisite in cases of conflict, disagreement or uncertainty, as, for example, when moral intuitions are shaken by new problems, typically surrounding emerging or controversial technologies or when ongoing research brings uncertainty with it" (Reber, 2017: 2). The deep connection between democracy and TA is evident in Grunwald's (2019) work, according to which TA is inherently related with deliberative democracy. According to Grunwald, TA is the expression of the pragmatist and democratic rationality theorised by John Dewey and Jurgen Harbermas. "Technology assessment is not value-neutral but is bound to values of human rights, rights of citizens, division of power, and other crucial issues of a democratic and inclusive society" (Grunwald, 2019: 97). This also means that "among the roots of TA was and still is the concern that scientific and technological advances do not per se support democracy" (Grunwald, 2019).

In scenario 3, we need GL because technological innovation and the free market are intrinsically connected.[8] However, analysing the ways that this connection can be achieved is problematic; the literature is enormous, presenting many theories and theses. Determining the roles of the state and market in innovation is still an open problem (see Mazzucato, 2017).

Table 2. Overview of the proposed reformulation of Rodrik's trilemma

Scenario	Gains	Losses
1	+ GL + DE	- SS
2	+ SS + GL	- DE
3	+ DE + SS	- GL

GL, globalisation; DE, democracy; SS, state sovereignty.

Going back to my main point, I limit myself to maintaining that certain levels of competition, capital, and business circulation are crucial to obtain technological innovation. The essence of this thesis and the problem lies in the concept of 'a certain level'. To regulate technological innovation, the free market must be regulated; otherwise, the risks to society could be enormous. However, regulating the free market requires both democracy and state sovereignty, assuming that state sovereignty without democracy does not interest us. Nonetheless, this is exactly what the trilemma prevents us from doing, and this is also confirmed by the impossibility to build a global governance capable of regulating the markets (see Rodrik, 2011: 67–77).

An objector could reply to this last point by stating that the solution of the trilemma could be to promote moderate growth, that is, a more flexible and light form of globalisation, to keep the three aspects together (DE, GL, and SS). However, this argument does not work. The presence of GESs is an essential feature of deep globalisation. Owing to their nature, these engineering systems inevitably tend to devalue SS and DE; as mentioned earlier, they are transnational and often managed by private companies that have large capitals and are much more dynamic than states. In a world based on the presence and interaction between GESs, SS and DE inevitably tend to decrease. This does not mean that GESs are undemocratic. Instead, this means that they impose a re-conceptualisation of our democratic systems and national sovereignty.

Taking stock of what has been said, I have shown that all three elements (GL + DE + SS) are necessary to develop the model of governance conceptualised by RI and TA. However, these elements cannot be kept together.

Conclusions and future research direction

Based on this argument, I propose two hypotheses. The first is that the design of global engineering systems might be the key to reconciling the three facets of Rodrik's trilemma. Thus, technology should not be viewed merely as a force secondary to economics or politics. Instead, it is better understood as an independent, third force that can be harnessed to counterbalance the first two. The question then is: 'How might we structure our engineering systems to help shape a new world order that ensures freedom, prosperity, independence, and justice for the maximum number of people?' Clearly, this is a query that future research endeavours must explore further.

However, merely pointing out ethical dilemmas and design remedies is an oversimplification. My second hypothesis is that RI and TA demand a profound philosophical re-foundation. This is not just about adapting existing theories but also about pioneering new paths of understanding. This exploratory journey seeks to redefine the essence of RI and TA, examining them through the unique vantage point of the Anthropocene.

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Notes

1 In this paper, I follow Kuhn (1970) in the use of the term 'paradigm'. According to Kuhn, a paradigm encompasses the collective practices that characterize a scientific discipline at a given point in time. It directs the course of research and practice within the field, delineating what constitutes valid research and defining the parameters for scientific inquiry. A paradigm represents the scientific achievements that are broadly acknowledged and serve as benchmarks, offering model problems and solutions for a community of practitioners. It includes not only the prevailing scientific theories but also the methodologies, norms, and standards that are collectively endorsed by the scientific community, guiding their research activities and the interpretation of data. When a paradigm undergoes a crisis or shift, it heralds a profound transformation in the foundational principles and practices of the discipline, a phenomenon Kuhn describes as a scientific revolution. In this paper, I consider LWO as a paradigm for thinking about and developing international relations.

2 The study of infrastructures and expansive technological systems is a theme that, despite its long-standing presence, experienced a phase of diminished prominence within the STS field before witnessing a resurgence. Thomas Hughes's work stands as a seminal contribution to this domain (Hughes, 1983). The 1980s saw considerable engagement with these themes, notably through the anthology edited by Bijker and others in 1987 (Bijker et al., 1987). Susan Leigh Star significantly advanced the discourse on infrastructure through her detailed enumeration of its components, establishing a key resource still referenced today (Star, 1999). The importance of considering global systems is underscored by the pioneering efforts of Paul N. Edwards, with his 2010 book marking a cornerstone (Edwards, 2010). In recent years, a notable segment of the STS community has increasingly focused on the concept of infrastructure, as evidenced by works like Silvast et al. (2013), Monteiro et al. (2014), and Karasti et al. (2016).

3 In my view, the category of socio-technical systems includes that of engineering systems and global engineering systems. Both are increasingly complex socio-technical systems. Additionally, there is a difference between global engineering systems and technological networks (Newman, 2018). Many global engineering systems have the structure of a network (e.g., the internet, electrical or gas networks, transportation networks). However, there is a difference between the two concepts, those of technological network and global engineering system. This difference, in my opinion, lies in the relationship with law and political power. Global engineering systems have a strongly political dimension, in the sense that they redefine the legal and political dimension and have a certain control over this sphere (e.g., the European energy network is composed of many actors, such as nuclear, coal-fired plants, gas, and renewable systems, and all together impose political decisions that are independent of national governments). The technological network does not; it is a conceptual and physical architecture but lacks political value. However, this claim could be contested by using Latour (2005).

4 For each term analyzed, I calculated its frequency by dividing the number of occurrences by the total number of papers in the reference group (either RI or TA). I then multiplied the result by 100 to express it as a percentage. This calculation tells us, on average, how many times the term appears per paper, expressed as a percentage of 1 occurrence per paper. It's a measure of the term's frequency relative to the number of papers, not the number of times it appears in all papers combined.

5 Is it possible to link the LWO crisis to the vagueness of the RRI conceptual statute? "RI and particularly RRI are discourses in the making and are interpretively flexible. It is important to recognize that what responsible innovation purports to be is yet to be settled. These are discourses that are in an active process of discursive translation that is yet to stabilize" (Owen and Pansera, 2019: x).

6 The early history of the Internet traces back to the late 1960s and early 1970s, born from the need for a robust, fault-tolerant communication system during the Cold War era. The Advanced Research Projects Agency Network (ARPANET), funded by the U.S. Department of Defense, was the first operational packet-switching network and is widely considered the precursor to the Internet. Initially designed to allow multiple computers to communicate on a single network, ARPANET's first successful message was sent between computers at UCLA and Stanford Research Institute on October 29, 1969. This groundbreaking network laid the foundation for the development of protocols that would eventually enable the connection of multiple networks into an interconnected network of networks—the Internet. Over time, the introduction of the Transmission Control Protocol/Internet Protocol (TCP/IP) in the early 1980s facilitated this expansion, marking the beginning of the modern Internet era. See Castells (1996), Hafner and Lyon (1998), Abbate (1999), Stokel-Walker (2023).

7 Building on Morton's (2013) perspective, I identified 16 July 1945 as the date of the Trinity test and the commencement of the Anthropocene. However, this epoch's onset is debatable, with others attributing its start to the onset of the Industrial Revolution.

8 Why are they connected, and how? In his seminal book, *The Free-Market Innovation Machine*, Baumol (2002) explored the mechanisms through which free-market economies foster innovation and economic growth. Drawing on a wealth of historical and economic data, Baumol demonstrated that capitalism and competitive markets are unrivaled in their ability to stimulate relentless innovation and hence unprecedented economic growth.