Steering the Course

Negotiating Directions in Alternative Research and Innovation Policies for Transformative Change

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ABSTRACT

This paper explores how inclusive and environmentally focused research and innovation policies challenge dominant models by reshaping directionality and governance for social transformation. It contributes to Critical and Transformative Innovation Studies by addressing key intertwined gaps: the role of agency, the political economy of policy instruments, the politics of continuity, and its territorial grounding. Analytically, it expands a Knowledge Systems approach, promoting a broader, symmetrical view of innovation that values diverse actors, policies, infrastructures, and knowledges. It challenges competitiveness-driven assumptions by exploring how alternative normative directions are negotiated over time. Through two case studies in Argentina—*Yogurito* (a probiotic yogurt to address malnutrition) and the *Paraná River Aquarium* (focused on biodiversity conservation)—the paper traces innovation journeys as a process where multiple actors vie to steer its course. Directionality is framed as both a political process of prioritization and decision making amid competing interests and its negotiated outcome, shaped by actors' visions, knowledge, and policy preferences. The paper also proposes a framework to empirically trace and analyze these evolving pathways. It shows how innovation is steered, which orientations take precedence, and the limits and possibilities of STI as a development driver under enduring structural constraints.

Keywords: Critical Studies of Innovation; Science Technology and Innovation Policy; Transformative Innovation Theory; Mission Oriented Policies; Directionality; Technology Governance.

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INTRODUCTION

Innovation is often heralded as a universal driver of economic growth and a pathway to sustainable, inclusive futures. As Innovation Policy evolved from a theoretical framework to a key policy rationale, it merged diverse policy and technological approaches into a unified, fast-paced "speed politics" (Armitage, 2000) designed to capture markets.

In response to its competitiveness bias, in recent years a "normative turn" (Schlaile *et al.*, 2017) sought to reorient innovation policy toward addressing urgent societal challenges. This shift has generated a proliferation of "X-innovation" frameworks (Gaglio *et al.*, 2019) to amend this bias—from social (Howaldt *et al.*, 2019), sustainable (Boons and Batista Navarro, 2021), inclusive (Heeks *et al.*, 2014), responsible (Owen *et al.*, 2012) to transformative (Schot and Steinmuller, 2018), among others—each reflecting distinct normative goals. These alternative concepts evolved into normative policy models and orientations (Gaglio and Vinck, 2021) offering preferred instruments and infrastructures to steer innovation toward desirable futures (Lascoumes and Le Gales, 2007), while also contributing to the global circulation of institutional models and isomorphic trends (Peck, 2011; Aguiar *et al.*, 2017; Pfotenhauer and Jasanoff, 2017b).

Research shows that policy instruments often take on a life of their own, shifting focus from intended goals to their own operation (Lascoumes and Le Galès, 2007; Ureta, 2023). This inversion of means (i.e. policy instruments) and ends (i.e. policy goals) frequently reveals an implicit competitiveness bias embedded in instrument design, undermining stated social aims (Bortz and Thomas, 2019). Numerous case studies highlight these theoretical and policy shortcomings (Thomas *et al.*, 2017; Ureta, 2023). Despite the persistence of linear models in R&D (Joly, 2010) and the dominance of systemic approaches in policy (Aguiar *et al.*, 2017), empirical evidence shows that interventions often yield isolated, product-oriented outcomes (Thomas *et al.*, 2017; Bortz and Thomas, 2019). Little attention is given to how actors, infrastructures, and processes interact in practice to drive transformative change—reconfiguring systems of production, consumption, and governance to address societal and environmental challenges (Schot and Steinmuller, 2018; De Graaf *et al.*, 2025).

Recent debates have renewed attention on the governance and directionality of innovation—i.e. the normative orientation of sociotechnical change (De Graaff *et al.*, 2025) —driven by academic critiques of innovation's unfulfilled social promises (van Lente, 2012; Pfotenhauer and Jasanoff, 2017b; Godin *et al.*, 2021) and a growing policy trend toward state-led, mission-oriented innovation (Hekkert *et al.*, 2020; Mazzucato, 2021). Yet, while

most analysis focus on systemic directionality, they often overlook the agency shaping transformative goals—that is, direction-setting as a political process and outcome of prioritization and decision making (Majone 1989). This includes who steers, how power asymmetries shape decisions and policy preferences, and how agency is enacted through materialities and infrastructures that influence resource allocation and crystallize policy orientations (Stirling, 2008; Godin *et al.*, 2021; De Graaff *et al.*, 2025). This is particularly evident in the politics of trade-offs between societal and market-driven innovation goals (Grillitsch *et al.*, 2021).

This paper explores how alternative research and innovation (R&I) policies—addressing inclusion and environmental challenges—navigate, contest, and reshape dominant models by negotiating directionality and governance in pursuit of social transformation. By "alternative", we refer to R&I policies that diverge from mainstream industrial or tech-driven approaches, prioritizing goals beyond competitiveness and economic growth (Godin *et al.*, 2021). Through two quasi-experimental case studies in Argentina—the school probiotic yogurt *Yogurito* and the *Paraná River Aquarium*—, the paper examines tensions within local R&I agendas, highlighting conflicts between dominant models and territorially grounded technoscientific practices shaped by local agency.

These cases allow to address key gaps in critical and transformative innovation studies (Grillitsch *et al.*, 2021). First, they make visible the role of agency—who steers directionality and how. Second, while research often emphasized innovations' origin, it overlooked how innovations are sustained, adapted, and negotiated over time (Jackson, 2014; Grillitsch *et al.*, 2021). The cases shed light in the politics of continuity along uncharted innovation journeys (Van de Ven, 2017) and how these intersect with or diverge from mainstream approaches (Dias, 2013).

Third, the cases bring essential territorial sensitivity, often lacking in transformative innovation policy studies, especially regarding regional dynamics in the Global South (Grillitsch and Asheim, 2018). They exemplify early, self-assembled mission-oriented subnational policies—even predating the term's popularization—pursuing bold measurable societal goals through cross-sector innovation and investment for inclusive and sustainable outcomes (Mazzucato, 2021). These cases illuminate how local actors negotiate orientations, market and non-market dynamics, public goods, and services in context-specific ways. They also bring a Latin American perspective largely absent from transformative innovation frameworks and mission-oriented policy studies, not only enriching theory but translating it into practice, revealing lessons from varied regional contexts (Gaglio and Vinck, 2021).

Analytically, this paper calls for a broader view of innovation systems—one that embraces diverse knowledge bases, purposes and directions. Through an iterative dialogue between theory and empirics, we show that directionality is not a fixed endopoint but a continuous negotiation shaped by the shifting interaction of actors, knowledge, policies, and infrastructures. We also show that even when policy goals may remain stable, the paths to achieving them evolve through ongoing micropolitics that reshape both policies and technologies. Using two seemingly virtuous cases of transformative innovation, we also expose the limits of framing STI as a development driver within the structural constraints of the Global South.

1. INNOVATION SYSTEMS, WHERE TO?

1.1. CONTESTING INNOVATION SYSTEMS

Innovation is often tied to values and promises of better futures, accompanied by optimistic claims about its societal benefits (van Lente, 2012). Framed as essential for market competitiveness and economic growth, or even equated to progress itself, it has become an unquestioned policy imperative and the ultimate road to solve pressing societal challenges (Godin *et al.*, 2021; Pfotenhauer and Jasanoff, 2017b; OECD, 2015). Innovation systems theories (Lundvall, 1992; Edquist, 2004) emphasize the role of supportive structures —education, infrastructure, and policy—in fostering innovation, promoting the belief that well-designed systems inherently drive economic success that translates into aspired visions of "common good" (van Lente, 2021).

Since the 1990s, innovation systems approaches shaped both theory and policy, advocating coordination among firms, governments, R&D institutions, and finance to drive growth (Lundvall, 1992). Though developed in high-income countries, it was adopted in Latin America as a forward-looking policy model through international policy agencies and experts, adapted to local contexts (Arocena and Sutz, 2001; Aguiar *et al.*, 2017). As it became more prescriptive, the model emphasized its set of preferred standard tools—from technology transfers, public-private partnerships, technological parks, incubators, to accelerators and start-ups—and privileged actors—firms as the main innovation drivers, connected to universities and R&D institutes, and supported by a growing network of intermediary and support organizations (Suárez and Erbes, 2021).

STI's 21st-century "normative turn" recast its social contract to confront equity and environmental challenges (Lubchenco, 1998; Daimer *et al.*, 2012), with R&D agendas following suit under the 2030 Agenda's call to address distribution, governance, and sus-

tainability (Leach *et al.*, 2018). However, sustained scholarship has shown the unevenness of these expected benefits and limited impact on equity, often treated as a spillover rather than a primary goal (Mazzucato, 2013; Leach *et al.*, 2010). Even efforts to leverage innovation for inclusive and sustainable futures, frequently ignoring regional disparities, ended up reinforcing inequalities (Thomas *et al.*, 2017; Bortz and Thomas, 2019; Suárez and Erbes, 2021).

Amid structural inequalities, the early 2000s saw the rise of "X-innovation" approaches (Gaglio *et al.*, 2019) targeting marginalized populations, especially in the Global South. These ranged from pro-poor market approaches—treating low-income groups as underserved consumers and even growth engines (base-of-the-pyramid, Prahalad, 2010; below-the-radar, Kaplinsky, 2011; frugal innovation, Radjou *et al.*, 2012; or grassroots innovation, Gupta, 2003)—to social problem-solving via individual action, social entrepreneurship, cross-sector collaboration, and engaged university outreach (Edwards-Schachter, 2021). These approaches largely aimed to spur pro-poor innovation, without challenging the structural dynamics of production, consumption, or distribution (Thomas, *et al.*, 2017). In the 2010s, they converged as inclusive innovation (Heeks *et al.*, 2014), blending social and technological efforts through both grassroots and top-down initiatives to advance—rather restricted—aims of inclusiveness and sustainability.

Yet, these initiatives relying on standard innovation tools—like tech transfer, public-private partnerships, entrepreneurship—often produced solutionist fixes misaligned with local needs and broader policy (Thomas *et al.*, 2017; Bortz and Thomas, 2019). This exposed a gap between understanding inclusion as access to goods and deeper demands for structural and epistemic change (Heeks *et al.*, 2014; Bortz and Thomas, 2017; 2022). Policy choices tended to favor the former, overlooking the material, political, and economic dynamics embedded in instruments. As a result, competitiveness-driven tools poorly adapted to inclusive ends, often reinforcing inequality rather than enabling transformative change (Lascoumes and Le Galès, 2007). This calls for rethinking not just tools and infrastructures but the broader political economy of R&I (Tyfield *et al.*, 2017)—who sets directions, controls resources, selects preferred instruments, and defines what inclusive transformation means and how it is actually pursued.

These shortcomings have sharpened debates on innovation "directionality" (Schot and Steinmueller, 2018), revealing weak collective mechanisms for setting priorities and choosing development pathways. While policy and scholar debates have—more often than not—technicized innovation policy as a matter of enhancing instrument choice, finding the "best tool for the job" (Lascoumes and Le Galès, 2007), directionality reveals

as inherently political: trajectories reflect competing interests and power relations that negotiate normative aims—such as competitiveness, sustainability, or inclusion and what they entail (Leach *et al.*, 2010; Schot and Steinmueller, 2018). It comprises both system assessment—how it works and to what ends—with the politics of steering toward desired futures following shared visions, forging consensus on priorities, and cross-level coordination (Joly, 2010; Hekkert *et al.*, 2020).

This renewed emphasis on directionality neither makes STI policy newly "directional" nor lends itself to ratings like lacking/weak/strong (Bulah *et al.*, 2024). Rather, it highlights that all policies—whether curiosity-driven, competitiveness-oriented (with implicit directionality), or mission-driven (with explicit goals)—are negotiated political settlements shaped by unequal power within and beyond the policy arena (Majone, 1989; De Graaff *et al.*, 2025).

Following Van de Ven's (2017) analogy, innovation journeys can thus be imagined as navigating uncharted waters—it entails manouvering through messy, nonlinear paths in converging and diverging currents. Building on Van De Ven's metaphore for increasing "the odds of maneuvering" to reach intended goals (2017, p. 4; Kuhlmann, 2012), we suggest that innovation is not a vessel with a single captain, but one where multiple actors contest the governance wheel, each seeking—explicitly or implicitly—to steer direction through shifting waters.

Analyzing how innovation is steered and toward which goals, or why some directions prevail over others, involves assessing power assymetries, knowledge bases, trajectories, investments, and governance beyond sectoral priorities, linking them to broader sociotechnical change (Geels, 2004). It also requires revisiting the state's role: governments may privilege sectors tied to national interests over broader welfare goals, and direction-setting creates winners and losers (Mazzucato, 2013; 2021). Room to manoeuvre depends on actor legacies, their embedded networks, policy structures, and fragile consensus, as past choices generate lock-ins and dominant designs that narrow future pathways (Stirling, 2009; Bulah *et al.*, 2024).

1.2. KNOWLEDGE SYSTEMS FOR TRANSFORMATIVE CHANGE

The growing innovation studies literature to address societal challenges increasingly centers on systemic transformative change (Schlaile at al., 2017; Schot and Steinmueller, 2018), shifting from early 2000s' narrow focus on inclusion in developing contexts (Heeks *et al.*, 2014) to addressing the global interlinkages of equality and sustainability. This reorientation calls for rethinking categories, visions, and instruments for structural transfor-

mation, while recognizing diverse pathways shaped by local specificities. It emphasizes cross-actor collaboration and the influence of cultural, social, regulatory, and infrastructural factors, stressing the importance of aligning STI policy with broader national strategies.

However, it faces analytical and empirical gaps that open avenues for further research (Grillitsch *et al.*, 2021). First, while *agency* is acknowledged in niche management (Geels, 2004) and user roles (Schot and Steinmueller, 2018), its role in steering transformative change remains underexplored beyond the niche level (Bortz and Thomas, 2022). Though highlighted conceptually (De Graaff *et al.*, 2025), it still lacks empirical depth and specificity. Overlooking actors' effective capacity for action and negotiation, who participates, who holds influence and how they define priorities and policy preferences, limits our understanding of how STI systems are created and transformed in practice and over time.

Second, the role of *policy processes and instruments* remains underexplored, particularly how policy mixes—comprising tools, institutions, rules, and procedures—align with context-specific transformation goals, and how policy preferences are shaped. This calls for selecting tools suited to local needs rather than following global policy trends (e.g., past public-private partnerships, or current missions and entrepreneurship) (Peck, 2011; Aguiar *et al.*, 2017). Instrument choice shapes not only knowledge production but also who is invited to participate and holds influence, reinforcing specific policy preferences and who benefits from it (Lascoumes and Le Galès, 2007). When poorly matched, inclusion-oriented policies can deepen exclusion (Bortz and Thomas, 2019), while context-sensitive mixes can foster inclusion by engaging non-state and informal actors and amplifying marginalized voices and expertise (Bortz and Thomas, 2017).

Third, the knowledge base driving transformation, encompassing not only the knowledge enabling diverse technological pathways, but also the expertise shaping policy and instrument design. This raises questions about expert advice in innovation policy, often confined to a narrow expert community and treated as technical rather than political matter (Aguiar *et al.*, 2017; Ureta, 2023).

Fourth, while recognizing their importance, transformative innovation analyses have often underexplored *local and territorial dynamics*, particularly how policies unfold across geographical contexts (Grillitsch *et al.*, 2019). In many low- and middle-income countries, limited institutional capacity to shape directionality is not always reflected in frameworks from high-income settings. Empirical studies across diverse regions can help adapt and enrich these approaches, especially at the regional level (Suárez and Erbes, 2021).

Finally, while much research focuses on the origins of innovation—privileging design, production, and early adoption amid a broader "predilection for the new" (Jackson, 2014, p. 234)—less attention is paid to maintenance, adaptation, and long-term transformative effects (Laurent, 2021; Grillitsch *et al.*, 2021). The "timeliness of technology" (Jackson, 2014, p. 234) underscores how contingent, often-invisible efforts of repair and upkeep are crucial for making innovations—whether technologies or policy instruments—enduring. Attending to these processes introduces the *politics of continuity*, enriching the temporal narrative of both innovation journeys (our vessel and its disputed path) and institutional structures (the shifting riverbed, its dams, canals and embankments), marked by power struggles, and foregrounds how alternative projects intersect with or diverge from dominant pathways over time.

To address these concerns, we explore the concept of transformative knowledge systems (KS) (Cash, 2003; Cornell *et al.*, 2013; Atela *et al.*, 2021) to shift the focus beyond innovation-led goals toward embracing broader policy and technology choices. This expands the traditional STI framework by including both formal and informal knowledge actors and embracing diverse transformation goals beyond growth and competitiveness —often embedded in "innovation" as a prescriptive near-belief system, with its preferred tools and privileged actors (Godin *et al.*, 2021; Winner, 2018). It highlights a range of often-overlooked components essential for inclusive development, from social and territorial networks, communities, movements, informal institutions, to traditional knowledge.

Knowledge systems (KS) encompass networks of formal and informal actors, practices, and institutions involved in producing, sharing, and using knowledge (Cornell *et al.*, 2013). Emphasizing the networked, relational, negotiated, and contextual nature of knowledge, this approach fosters co-creation between scientists and societal actors (Cash, 2003; Cornell *et al.*, 2013), link diverse ways of knowing and collaboration (Bandola-Gil *et al.*, 2023), and shape flows of credibility and power (Jasanoff, 2004). Co-creation is central to addressing sustainability challenges, requiring open systems that integrate varied knowledge sources and recognize the role of territory, agency, and both market and non-market forces in shaping STI systems (Cornell *et al.*, 2013; Bandola-Gil *et al.*, 2023). Though still evolving, this definition offers a valuable lens to examine how systemic orientations—whether toward competitiveness, inclusion, or sustainability—are negotiated. Making these arrangements visible helps reduce implicit biases and better align[1] diverse knowledge

[1] Misalignment between policies, capacities, and objectives is evident when goals like inclusion or sustainability are unmet, resulting in unintended outcomes—dual economies, exclusion of target groups, or poorly targeted technological solutions. As discussed earlier, many inclusive innovation efforts fell short, with policies and trajectories often contradicting their own stated aims.

(local and generalized, informal and formal, lay and expert, tacit and explicit, traditional and scientific) and capacities (S&T, industrial, political, regulatory, among others) with societal goals, guiding more effective interventions (Frost *et al.*, 2020; Atela *et al.*, 2021).

Building on this definition, and to deepen this analytical lens, we identify five key dimensions for empirical analysis following the intertwinned gaps identified above: (1) *the role of actors and agency*—who participates in transformative change and with what influence over the innovation process; (2) the *knowledge base informing policy and technology design*, as both co-construct transformation, as technological choices—what, for whom, and how—reflect values and power dynamics and co-evolve with policy choices, shaping the direction and inclusiveness of change; (3) *policy processes and instrument mixes*, aligned—or not—with transformation goals; (4) the *politics of continuity*, capturing adaptation and reconfiguration processes; and (5) the *identification of directionalities*. Building on the literature reviewed above, we may distinguish five main directionalities: (i) basic science, shaped by historical research norms (Polanyi *et al.*, 1962; Rip, 1994); (ii) competitiveness and growth, central to innovation systems thinking (Lundvall, 1992; Edquist, 2004); (iii) poverty alleviation, as in inclusive innovation (Gupta, 2003; Kaplinsky, 2011); (iv) sustainable growth, combining green sociotechnical transitions with competitiveness (Kivimaa *et al.*, 2021; Cressman, 2019); and (v) transformative development, integrating sustainability and equality (Thomas and Santos, 2017; Schot and Steinmueller, 2018). Together, these dimensions reveal how actors and knowledge co-produce visions and shape policy preferences, influencing who participates, how change unfolds, and in which direction.

Figures 1 and 2 map the framework as radars charting the diverse "journeys" (Van de Ven, 2017) each vessel may take—whether strictly innovative or not. Figure 1 presents three concentric circles: knowledge bases (inner circle), the actors and institutions that produce and mobilize them (middle), and the policy preferences and choices they shape (outer). The different elements included in the circles emerged inductively, from the evidence collected during the empirical work (see Methods), complemented by the literature review. Directionality—represented by the outward-pointing arrow—captures both the desired orientation these actors through knowledge and policy steer, and the negotiated result of interactions across these layers. Figure 2 builds on this by outlining the five directionalities stylized above (i-v), showing how actors, goals, policy instruments (with their material anchoring), and outcomes are tightly interlinked.

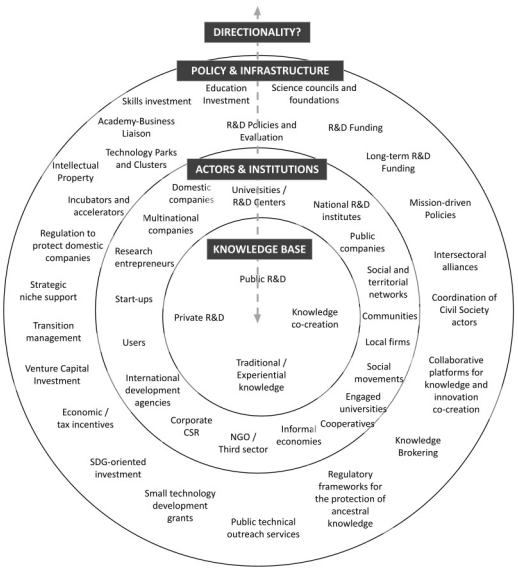

Figure 1. Knowledge System mapping.

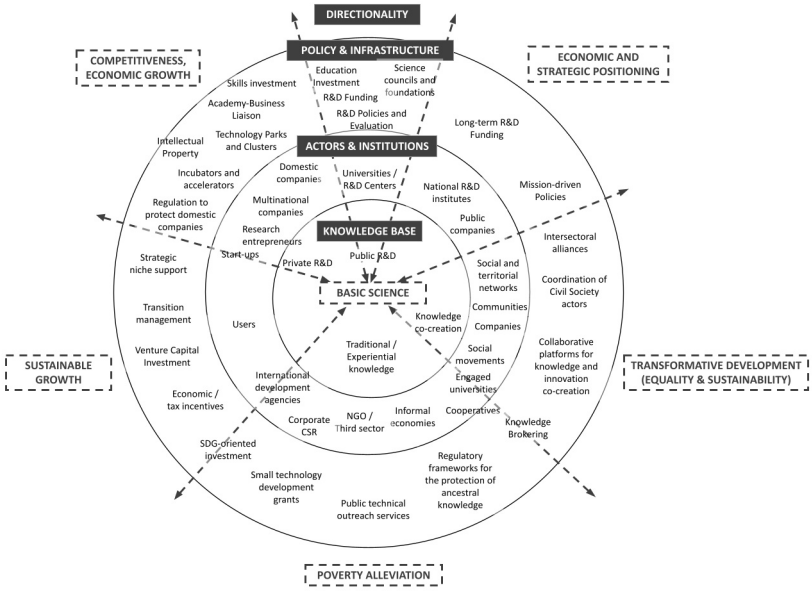

Figure 2. Knowledge systems directionality mapping.

2. METHODS

This study adopts a qualitative, cross-case approach to analyze "innovation journeys" (Van de Ven, 2017) as a way to challenge dominant theories and support alternative conceptualizations (Gaglio and Vinck, 2021). The concept captures the open-ended, uncertain, and negotiated nature of sociotechnical change—marked by detours, shifting goals, and no fixed endpoint. It foregrounds agency as actors navigate evolving institutional contexts, the precise path evolving as travelers gain knowledge and experience (Geels *et al.*, 2008). Originally used to examine how new ideas emerge and evolve within changing organizational settings (Van de Ven *et al.*, 1999; Geels *et al.*, 2008), we extend the concept to trace innovation journeys within broader regional and national knowledge systems.

Case selection draws from a 2013–2017 survey of 66 biotechnology projects addressing social issues in health, food, and environment (Bortz, 2017), followed for a decade. We focus on two long-term initiatives: (1) *Yogurito*, a probiotic yogurt program tackling child malnutrition prompting a local development strategy, and (2) the *Paraná River Aquarium*, a regional center for biodiversity conservation and its sustainable use. Both cases involve diverse actors (scientists, policymakers, producers, civil society), pursue explicit transformative goals, are regionally embedded, have over 20 years of continuity, and yield both marketable and non-marketable innovative outcomes.

We used a constructivist grounded theory approach (Charmaz, 2006; 2016) with an open-ended, iterative design linking data and theory. Data collection included 25 semi-structured interviews across both cases (*Yogurito*: 15 interviews—13 from 2013–2015, 2 in 2024; *Aquarium*: 10—1 in 2013, 6 in 2019, 3 in 2023–2024), identified through snowball sampling. Informal conversations with key informants complemented the interviews. Observations included participatory sessions at guided exhibitions (2015, 2019) and non-participant visits to laboratories and government offices. We also analyzed documents such as project files, policy plans, media, technical reports, academic articles, websites, and CVs. All data were transcribed, coded, and inductively analyzed to connect empirical insights with theory.

The next section reconstructs the innovation journeys of *Yogurito* and the *Paraná River Aquarium*. While deeper case analyses appear elsewhere (Bortz and Thomas, 2017; Bortz, Gázquez and Santos, 2022; Gázquez, 2024), we focus here on key phases marked by directionality shifts. These reflect changes in power dynamics, actor constellations, and evolving uses of policy and infrastructure. Preferences—like technology transfer or multi-actor forums—often emerged from engagement with dominant instruments of the

time. Due to space limits, each phase is presented as a snapshot of critical negotiations between actors, knowledge, and policy.

3. EXPLORING ALTERNATIVE INNOVATION JOURNEYS

3.1. "YOGURITO" SCHOOL YOGURT

The *Yogurito* School Yogurt is a probiotic yogurt developed to prevent diseases linked to child malnutrition in Tucumán, Argentina's smallest province, long struggling with poverty and inequality (Figure 3a). Created by the public R&D institute CERELA (Research Center for Lactobacilli), affiliated to the National Science Council (CONICET), and produced by a local firm with government support, it became a flagship example of inclusive innovation for national STI authorities (Bortz and Thomas, 2017).

Phase 1 (1980s). In 1984, doctors at a children's hospital in Tucumán turned to CERELA to help reduce infant mortality in malnourished children after a severe diarrhea outbreak. Leveraging immunomicrobiology expertise, CERELA scientists developed "Cerela milk," an early innovative probiotic formula using Lactobacillus strains to restore gut flora and improve immunity in malnourished children (Perdigón *et al.*, 1986a; 1986b). The success positioned CERELA as a regional probiotic leader. A joint patent with domestic firm SanCor and Danish food ingredient firm Christian Hansen[2] led to the transfer of this technology in 1988 and the 1995 launch of "Leche Bio" amid an emergent functional food market[3], being considered a great early success of CONICET's recently created technology transfer office (Figure 3b). However, as a commercial product, it diverged from its original public health mission and never reached its intended beneficiaries (Lorenzano, 1995; Bortz *et al.*, 2018). As CERELA's former director expressed this dual perspective:

> "*Leche Bio* is often cited by S&T actors as a successful case of technology transfer: public R&D turned into a mass-market product by a national company (…) [It] brought us great satisfaction, nationally and abroad. It led to a patent between SanCor and CONICET and became a commercial product (…) one with enormous future potential." (Oliver, 1994)

> "Still, it's disheartening. This milk—which treats diarrhea and child malnutrition—has been in the market for seven years and is selling more every day. Yet in Tucumán, it was never officially promoted or used as it should have been in a province with so much poverty…" (*El Siglo*, Jan 24, 2013)

[2] Under the agreement, CERELA received royalties, SanCor held the patent, and Christian Hansen had exclusive rights to sell the probiotic internationally. However, SanCor had to transfer the production and industrial-scale strain multiplication to Christian Hansen's headquarters in Denmark (Gutman and Lavarello, 2014).

[3] Some stakeholders attribute this delay to the time needed to scale from pilot to industrial production, others to the limited domestic demand for functional products, which were still uncommon in the 1980s.

Phase 2 (2003-2007). Argentina's 2001 crisis plunged over half the population into poverty, exposing the deep social exclusion caused by decades of deregulation and market-driven policies. In Tucumán, poverty reached 60%, with malnutrition and public health crises making national headlines. In response, CERELA researchers revisited the idea of a probiotic food for child malnutrition, building on lessons from *Leche Bio*. After two decades of research, they identified *Lactobacillus rhamnosus CRL 1505* as a promising strain to strengthen immunity in malnourished children.

As the crisis eased, and amid a broader expansion of participatory tools in social and development policy in early '2000 (Cornwall and Brock, 2005), the national STI Secretariat (SECyT) launched regional multi-actor forums to tackle local issues. At the Northern Argentina forum, CERELA collaborated with producers, NGOs, and policymakers to co-design a probiotic yogurt for vulnerable children. By 2006, CERELA had completed the laboratory set-up, but testing immune effects required a clinical trial. With support from Tucumán's STI agency (SIDETEC) and the provincial Ministry of Social Development (MSD), CERELA secured SECyT funding (~USD 12,000) to run a clinical pilot—marking the yogurt's first step beyond the lab.

> "Malnutrition on our doorstep made us rethink our role (…) we couldn't just stay locked in the lab." (*El Cronista*, Oct 22, 2009)

> "*Social outreach* was a *debt* we had. That's why, from 2003, we began thinking seriously about transferring science to society." (CERELA director, 2013, interview)

Phase 3 (2007-2008). With SECyT funding, CERELA led a double-blind trial involving 298 children (ages 2–5) in vulnerable peri-urban kitchens in Tucumán. Over 150 people were engaged—MSD officials selected the kitchens based on accessibility and trusted local connections, while nutritionists, kitchen staff, social workers, dairy producers, and provincial health doctors engaged with families and monitored health conditions. The trial also involved reformulating the yogurt based on children's taste preferences. The ferment was manufactured in CERELA's facilities. Trial results showed stronger immune responses (34% vs. 66% in placebo group) (Villena *et al.*, 2012), attracting national media coverage. The current principal investigator recalls:

> "Everyone who heard about it, even in the early clinical studies (…), started to get involved." (…) "We focused on the outskirts—where needs were greatest—and began in community kitchens, since accessing schools was more complex. These kitchens operated in the homes of people living in poverty". (…) "It was a powerful learning experience beyond the science. Working in the field affected us deeply (…) became part of the study's outcomes: not just the increase in IgA (…) or reduced infections, (…) but also creating new eating and hygiene habits, cross-sector coordination, and training for kitchen staff, who adopted better food handling practices. The impact went far beyond our initial scientific goals." (*Yogurito*'s PI, 2024, interview)

Phase 4 (2008-2011). Following the trial's success and widespread media coverage, Tucumán's Ministry of Social Development (MSD) decided to reallocate funds from the *Copa de Leche* ('Milk Cup') school food program to launch *Yogurito*. In 2008, the province invested ~USD 1 million to provide the yogurt three times a week to 56,000 children in public primary schools, scaling to 100,000 in 2009 and 200,000 by 2010, becoming a pillar of provincial food policy (Figure 3c). *Yogurito* became a cornerstone of provincial food policy, steered by the MSD and CERELA, addressing child malnutrition while aiming to revitalize the local dairy sector.

Scaling required coordinated implementation across MSD, CERELA, the Ministries of Education, Health, and Production, local dairy farmers, and a yogurt small manufacturer. It also required organizing production and delivery (milk supply, processing, and expanded ferment output from CERELA), training school staff, and setting up a health monitoring network through primary care centers. A key step was CERELA's pilot plant, funded by reinvested royalties. Drawing lessons from *Leche Bio*, instead of transferring, CERELA kept control of ferment manufacturing, preserving the project's governance to assure the alignment of goals, means and results:

> "Accessibility was emphasized by officials and producers to *distinguish* it from *Leche Bio* a probiotic ferment that *ended up with 'a large company'* and was *sold at high prices*." (*La Gaceta*, 2014)

Collaboration during the 2007–2008 trial led to the 2008 creation of the Intersectoral Board on Health and Nutrition, building on MSD's participatory management experience. Meeting weekly, the Board aligned policies across health, education, production, and social development. Given *Yogurito*'s complexity, public investment and exposure, and CERELA's scientific role, strategic coordination was key. The program drove institutional shifts—reallocating *Copa de Leche* funds, increasing milk demand, reorganizing supply chains, and reorienting CERELA toward industrial-scale probiotic production.

Yogurito allowed CERELA to merge locally driven research with global immunobiotech expertise. The initiative fostered cross-sector collaboration, integrating scientists, policymakers, producers, and educators who navigated technical, industrial, and social challenges beyond their traditional roles. Children's preferences informed product design. As the program became provincial policy, the MSD took the lead and coordination of the program's expanding network. The Intersectoral Board as a co-production site fostered trust, learning, and joint problem-solving, leading to improvements in product design, delivery, and coordination. This collaboration between local actors enabled local adaptations, diversified products (Figure 3d), and expanded probiotic access to remote areas—

e.g., using dehydrated formats to overcome logistical challenges in hot, rural zones with poor infrastructure (Figure 3e)—advancing MSD's province-wide goals and strengthening regional industrial and technological capacities. Local agency, engagement and negotiated decision-making were key:

> "An intersectoral roundtable was set up. (…) *When I say ministries meet, I mean committed people from those ministries who build relationships and persuade others to move forward.* (…) Tucumán already had experience coordinating across sectors, (…) so we replicated that to address health and nutrition. Yogurt was the starting point…" (MSD official, 2013, interview)

> "We worked hard on training—teachers, principals, schools. (…) We had to explain what it was, how to implement it, and its effects. (…) *You have to give people a voice—to explain what we're doing, why, and what we expect.* (…) That's key. *You won't avoid criticism or resistance, but it helps reduce it*." (MSD official, 2013, interview)

Phase 5 (2011-2015). The *Yogurito* program showed results of improved child health, reduced absenteeism, and enhanced school performance (Villena *et al.*, 2012; 2018; González, 2020). For Tucumán's dairy farmers—hit hard by land concentration and 1990s neoliberal reforms—the program was a turning point. Farmers began organizing in 2006, creating the Tucumán Dairy Board and, later, the Trancas Basin Dairy Producers Association (APROLECHE) to meet *Yogurito's* demand. Backed by provincial purchasing power, they coordinated large-scale raw milk supply.

As *Yogurito* expanded, dairy farmers grew into and organized collective actor, shifting from raw milk suppliers to co-managers of production, gaining influence in the decision making process and adding value across the supply chain. This led to the creation of the Tucumán Dairy Technology Hub (2011), enabled dairy sector diversification, and the launch of the local brand *Ñulac* (2014). With support from CERELA and the state, the cluster secured funding to improve milk quality, preserve artisanal knowledge, and boost profitability via quality standards and circular whey reuse. Participation in international fairs aimed to reduce state dependency and promote a self-sustaining, formalized dairy sector, with APROLECHE increasingly shaping local agricultural policy.

Phase 6 (2008-2015). After *Yogurito* became Tucumán's social policy in 2008, and the emblem of national STI policy (Figure 3g), the National Ministry of Social Development decided to scale it nationally, relying on CERELA's expertise, local food policies, and dairy producer mobilization.

> "We presented it [to the national Minister of Social Development] and [banged the table]: '*I want this across the North-East and North-West*. It must *become state policy*. The Ministry will fund the rations—*this is a political decision above all*.'" (STI Ministry official, 2014, interview)

However, national decision making and expansion efforts were halted by local political disputes, leadership turnover, budget limits, and weak local production capacity, stalling *Yogurito*'s journey across other provinces. Despite political will and national STI steering coordination efforts (2008–2015) involving local governments, universities, and cooperatives faltered due to fragile territorial networks and persistent administrative hurdles. No replication achieved the scale or impact of Tucumán's original program (Figure 3f).

> "[Northern province] is in an *impasse*. Officials were enthusiastic, (…) but it stalled—new authorities came in and the project was left on standby." (STI Ministry official, 2013, interview)

> "There are periods that are sensitive and you need to seize them—like elections (…)—where public opinion matters, *and a product like this helps electorally*. But (…) if things don't move fast when there is an opportunity, *the network unravels*, and rebuilding it is hard. *There are always other priorities, urgent crises, and suddenly, funds disappear to deal with a flood or some emergency*. That's the reality of provincial budgets and management." (STI Ministry official, 2013, interview)

Phase 7 (2015-2024). Over the past decade, the *Yogurito* program stabilized, aligning its protocol with school food policies and holding annual planning meetings with Tucumán's MSD for the upcoming school year. Beneficiaries ranged from 200,000 to 300,000 children across 56 schools, with funding gradually shifting from national to solely provincial sources due to federal budget cuts. School distribution paused during the pandemic and resumed in 2022. As the project stabilized—an exception in Argentina's volatile political landscape—, and after the pandemic, the Intersectoral Board shifted to virtual coordination, maintaining ties between all stakeholders. Many original actors remained involved for years; while some have since retired or left public service, a core group still persists.

In 2020, French dairy multinational Danone expressed interest in the CRL 1505 strain, leading to a technology transfer agreement with CONICET (2022). CERELA conditioned the deal on including product donations to schools, preserving *Yogurito*'s social mission. Given CERELA's limited production capacity, the strain was licensed to and scaled up by the Italian ingredient firm Sacco for Danone's supply. The probiotic was incorporated into the *Yogurísimo* line in January 2023 (Figure 3h). Although a commercial product, CERELA views this as fulfilling the program's goals—addressing social needs, expanding access, and generating returns for the scientific system—while retaining technology governance, unlike the *Leche Bio* experience. Since 2024, amid drastic national budget cuts to science and welfare, *Yogurito* endures with provincial support, while CERELA sustains its work through technology royalties. *Ñulac*, created to boost local dairy production, faced economic hurdles, with its revival remaining uncertain. One of the lead scientists empha-

sizes how, in the final phase, diverse directions coexisted—and how CERELA played a key role in negotiating and preserving this balance through technology governance:

> "We were clear that *the backbone of this technology* transfer was—and remains—the Yogurito. Transfers (…) weren't conditional on suspending it; in fact, *we persuaded Danone*—though it's for commercial use of the strain—to also agree to donate a certain volume of yogurt (…). That social spirit behind the program gives us real satisfaction. The company accepted it, but had it not done so, we would've prioritized the program's original values." (*Yogurito*'s PI, interview, 2024)

> "Policy, timing, design, and scope changes *enabled us to sustain the social program while also allowing private use of the strain*—so it could reach broader society, which was always part of the goal. (…) Not everything must fall under social programs. *We all agree that developing the socio-economic fabric is key*—so *the private sector can work alongside the state, not in opposition*. We are public science, Argentine S&T, and *this technology can serve both state food policies and the private market*." (*Yogurito*'s PI, interview, 2024)

Figure 3. Location of Tucumán and main artifacts identified during Yogurito's.
Source: own elaboration. **(a)** Tucumán in Argentina; **(b)** *Leche Bio* at its 1995 commercial release (source: CERELA); **(c)** *Yogurito* as was launched in Tucumán, 2008; **(d)** New packaging and probiotic chocolate milk; **(e)** Biosec (lyophilized probiotic); **(f)** *Yogurito* in Misiones (*El Diario*, Córdoba); **(g)** *Yogurito* pavilion, Tecnópolis national expo, 2014; **(h)** Yogurísimo Cerela–Danone (CONICET). Unless otherwise noted, photos by Gabriela Bortz.

3.2. PARANÁ RIVER AQUARIUM

The Scientific, Technological, and Educational Center "Paraná River Aquarium", inaugurated in February 2018 in Rosario, Santa Fé, is the only freshwater aquarium in Latin America dedicated to native and established species of the Paraná River—one of the region's most biodiverse ecosystems (Figure 4). Initiated by researchers, it evolved into a strategic subnational project that combines biodiversity conservation, R&D, science education and interactive museum, and a hub for sustainable aquaculture services (Gázquez, 2024).

Phase 1 (2000-2007). In 2000, a fish biotechnology group was formed at the Institute of Molecular and Cellular Biology of Rosario under the National University of Rosario (IBR-UNR/CONICET). Initially focused on basic science, the group soon turned its interest to apply knowledge to river conservation and sustainable resource use. By 2003, driven by the need to secure live specimens, they partnered with Santa Fe's Ministry of Agriculture and the historic Rosario Hydrobiological Station (est. 1940), enabling controlled fish culture and supporting efforts to improve silverside aquaculture—a provincial priority.

Phase 2 (2007-2011). In 2007, the incoming socialist government elevated S&T to Secretary of State status (SECTeI), promoting collective project design and cross-sector collaboration (Bercovich and Bortz, 2024). As part of a participatory provincial Strategic Plan, the idea of a new *Paraná River Aquarium* on the site of the old Hydrobiological Station took shape. Close ties between the research team and SECTeI—rooted in shared academic and political backgrounds—fostered a joint vision of science as a collaborative, transparent, socially engaged public good.

> "We had an advantage (…) one of my team members (…) made things easier for us. (…) (He) is a socialist activist (…), we met when he was president of the Student Union, so he had a strong background in political leadership. He was key in convincing the government. (…) and making the Center idea seem viable" (Researcher, 2019, interview)

> "We already knew each other—I come from the university (…) and knew several key players in the system. So there was already a relationship in place. (…) Though I come from academia, my roots are in Socialist Party university activism. For us (…) everything is teamwork and collective effort (…). What you see at the aquarium is (…) a committed team that knows what they have to do (…)." (Government official, 2019, interview)

In a participatory Citizen Assembly, the Aquarium project was embraced into the Strategic Plan's "social quality" axis, promoting civic engagement. The project's scope, originally steered by the scientist, expanded to integrate human activity into conservation, restructuring it around three pillars: (a) scientific research, (b) fish production, and (c) education and recreation. To advance this vision, the research team and SECTeI submitted a co-developed proposal to the National R&D Agency, with SECTeI as partner. The agency rejected the initial broad conservation project and recommended narrowing the focus to fish-related R&D. A revised negotiated proposal centered on aquaculture, biotechnology, and genetic research was approved, specifically targeting fish conservation. By 2010, the Aquarium facility was upgraded, and the Aquatic Biotechnology Platform was launched on-site with the awarded grant.

In 2009, the provincial governor assigned the Aquarium's oversight to SECTel. A 2010 follow-up workshop, co-led with the research team, expanded the conservation agenda through dialogue with key Paraná River stakeholders—fishers, sport fishing groups, environmentalists, researchers, students, government agencies, solidarity economy groups, and national parks representatives, and general public.

Phase 3 (2011-2017). The 2011 provincial government shift, within the same political coalition, marked the consolidation of both fish biotechnology R&D and the start of aquarium's construction. In 2012, the Aquatic Platform secured an IDRC-funded project under the International Barcode of Life (iBOL) for sustainability research, enhancing its global visibility. The project advanced genetic barcoding for ecosystem monitoring, which required deep local knowledge of the Paraná River. The team partnered with the Espinillo Association of artisanal fishers—a vulnerable community, long-established in the area—whose extensive local knowledge, practical taxonomy and fishing expertise enriched the research. This collaboration also prompted outreach efforts by scientists and the Aquarium to support the fishers' livelihoods, while successfully advocating for the inclusion of dedicated river access in the facility's design.

> "We wanted to connect with the fishermen *because they know the river best*." (Researcher, 2019, interview)

> "Most of us fishermen used to think scientists looked down on us—that we were just (...) statistics. But they truly value the *empirical knowledge we have, the weight of years fishing and knowing the river*, and they *give it a meaningful place in their work*." (Fisherman, 2019, interview)

> "Once, while sampling, we caught a type of *tarucha* we thought was the common one. [The lead fisherman] pointed out morphological differences, and though we didn't see them at first, *genetic tests confirmed he was right*—it was a different species." (Researcher, 2019, interview)

With the launch of construction bidding, design decisions on the building and its grounds took shape around transparency and exchange: glazed labs, open views of the river, clear tanks showcasing murky native fish (Figure 4d). As the science coordinator put it: "(...) the first ones to step into the fishbowls were us the researchers" (2019, interview). The plan included new public walkways reclaiming previously closed riverfront with native plant areas (Figure 4b-4c-4g), acclimatization and fish care zones (Figure 4h), labs (Figure 4d), aquaculture pools to provide services (Figure 4e), a cafeteria, the aquarium (Figure 4h, 4i), and a fishermen's dock (Figure 4f), including their claims into the structural design.

> "(...) the transparency of the buildings reflects a concept—bringing people closer to research and vice versa. Those exchanged glances matter in construction. It wasn't just throught of as a building, but as the ideology behind it." (Researcher, 2019, interview)

> "For the first time, the local government took systematic action regarding fishermen (...)" (Cityhall worker, 2019, interview)

In 2015, the riverwalk opened (Figure 4c, 4g), and a scientist from the Aquatic Biotechnology Lab—active in socialist politics—was appointed as on-site director.

In the following years, designing the large tanks for coexisting freshwater species—an unprecedented task in the region—became a challenge. It required combining international expertise, fishermen's ecological knowledge, and the research team's ingenious workarounds (Bortz, 2025), leading to novel tank design skills. Organizing the Aquarium's structure also proved a complex task, which reflected negotiated priorities between the multiple involved stakeholders. Although the original plan included a fishermen's port, its construction was never completed (Figure 4f), exposing the unequal inclusion of artisanal fishing in the project and broader power asymmetries among public actors[4] (Roldan and Arelovich, 2020).

Phase 4 (2017-2019). In 2017, the research team relocated to the new site, and the *Paraná River Aquarium* opened to the public in 2018. This coincided with the consolidation of Santa Fé's STI policies, notably Law No. 13,742/2018, which boosted provincial funding for STI, mandated a 10-year strategic plan, and created the ASaCTeI, Santa Fé's STI agency, to ensure continuity and strengthen key initiatives (Bercovich and Bortz, 2024).

Within the productive axis, the Aquarium also operated between two contested systems. While artisanal fishing was participated—though subordinately—in space and knowledge-sharing, new insights into the Paraná River have yet to impact decision-making in either artisanal or industrial fishing. In contrast, the Aquarium advanced sustainable aquaculture—aligned with provincial priorities—through tools and services, a priority also reflected in the space assigned in the building's structure (Figure 4e). Another priority was the educational and recreational axis, which fostered river stewardship by engaging the public: research was translated into interactive exhibits (Figure 4i, 4j) and guided tours led by 18–30-year-old local residents showing the river's ecosystem and resources. This residency program, aimed to bridge between research and the public, encouraging participants to internalize the experience and even to launch their own outreach projects, such as studying river microplastics. Educational materials were co-developed by specialized staff and the resident team.

[4] This restricts artisanal fishing, while private clubs expand with little oversight despite irregularities.

> "That interaction, that *conversation with producers sparks development ideas*. (…) There are preliminary [biological] questions we need to answer (…) to then advance with development (…) These are paths to explore." (Researcher, 2023, interview)

> "The *inclusion of producers* (…) *is essential to keep our feet grounded*. But (…) *researchers* also have the *ability to look beyond* immediate concerns—even when they are not framed as demands. We are obliged to *look a little further*…" (Researcher, 2013, interview)

> "Science for whom, and for what? We cannot ignore *we're part of a society with needs*. (…) So we do science, but also try to *reach out to society and make a difference*." (Researcher, 2013, interview)

Phase 5 (2019-2023). After three Socialist administrations, Santa Fé elected a Justicialist Party government in 2019. Although the Ministry of STI was downgraded to a Secretariat under the Ministry of Production, the Provincial S&T Law held, and by 2022 the STI Strategic Plan and Council were established. The Aquarium governance came under the new STI Secretariat, now managed by the Innovation Projects Directorate. Without an on-site director, operations were impacted.

The COVID-19 pandemic (2020) exposed structural weaknesses at the newly opened Aquarium: contract lapses, payments were delayed, and key systems faced disruptions. Though a smaller team was rehired by 2021 for maintenance and education, staffing remained below 2019 levels, limiting programming and the guided tours that served as societal bridges (Gázquez, 2024). QR codes for self-led visits replaced in-person guidance, straying from the participatory, interactive education model co-developed with the community in 2010. Under the new management, a divide emerged between provincial authorities and the lab, as conservation goals gave way to tech-driven infrastructure and reduced educational staffing.

> "*Before*, the tour was *longer* and covered the whole park, upper floor, and a full lab explanation. *Now* it's *shorter*. The park is open, with some comments on what is there, and there's a brief overview of research at the hall entrance before heading upstairs. (…) *There are also self-guided visits now*—which I personally don't like. (…) *I don't think they serve the purpose the Center was created for*." (Researcher, 2023, interview)

Despite showing public support, the government offered limited backing, shifting the Aquarium's focus from conservation to innovation—a shift resisted by the lab. The research team upheld and expanded its conservation role, for instance, applying genetic expertise and collaborating with the local university on wetlands and fire-related biomonitoring. Meanwhile, authorities repositioned the Aquarium within a broader STI agenda—promoting startups, productivity, and Rosario's global biotech image. This included hosting a biotech startup on-site, or positioning the Aquarium as a gathering hub for the local biotech community.

In 2023, a new coalition led by the Radical Party—with socialists included—took office, naming former socialist science minister as STI Secretary. Despite a national STI funding crisis, the province resolved contract and maintenance issues. Still, amid a national budget cuts, funding for the Aquatic Biotechnology Lab remains uncertain, threatening the Aquarium's research and conservation stability.

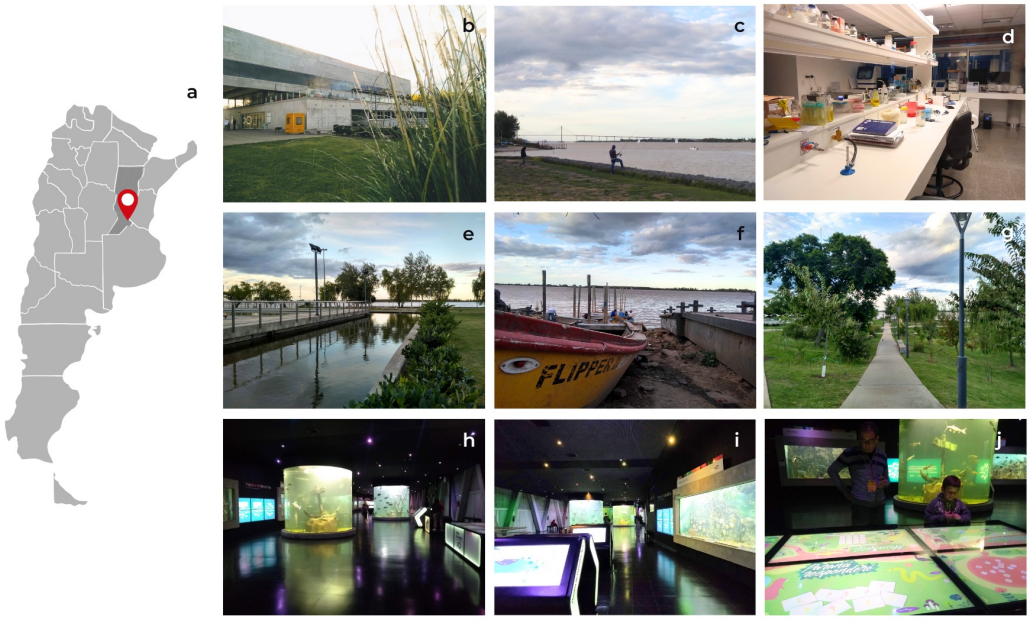

Figure 4. Location of Rosario and main features of the *Paraná River Aquarium*.
Source: own elaboration. **(a)** Location of Rosario in Argentina; **(b)** view of the Aquarium from the park; **(c)** public recovery of the riverside; **(d)** aquatic biotechnology laboratory; **(e)** aquaculture pools; **(f)** artisanal fishing port; **(g)** native species park; **(h)** main exhibition hall with fish tanks; **(i–j)** educational interactive devices. Photos by Gabriela Bortz.

4. NEGOTIATING POLICY AND INNOVATION ALTERNATIVES

Following Transformative Innovation Theory (Weber and Rohracher, 2012; Schot and Steinmueller, 2018), these cases could be read as niches that drive socio-technical change to tackle complex societal challenges. Notably, these initiatives arose organically from local needs, predating—but aligning with—later frameworks of transformative innovation and mission-oriented subnational policies. Key transformative elements include: (1) Directionality – initiatives are purpose-driven, aiming at social goals like access to basic goods, local development, territorial recovery, public space, biodiversity, and marginalized group support; (2) Inclusivity – diverse actors, especially marginalized groups, shape innovation through participatory methods, democratizing innovation; (3) Learning and Reflexivity – continuous adaptation and feedback guide responses to uncertainty, driving

further innovation; and (4) Systemic Impact – essential for sociotechnical change, evidenced by cross-sector and provincial coordination, embedding S&T in broader change processes. While all these aspects merit deeper analysis, this section centers on the challenge of analyzing negotiating directionality (and its governance) in the pursuit of social transformation[5].

Building on the framework in 2.2 and Figures 1–2, Figures 5–6 map shifting directionalities in the *Yogurito* and Aquarium journeys. Each chart functions as a radar, tracing how directionality evolved across different levels and orientations over their respective 40- and 20-year trajectories.

Figure 5 shows how initially focused on basic research (1), the lab pivoted in the 1980s to develop a functional food for malnutrition at a children's hospital's request. Though unsuccesfully intended for poverty alleviation (2), the first phase led to *Leche Bio*—a niche product controlled by two firms—driven by preferred infrastructures at the time such as IP, tech transfer infrastructures, and market logics (3) (Bortz *et al.*, 2018). In contrast, *Yogurito*'s second phase re-centered public health and poverty alleviation, distributing yogurt to schools and community kitchens (4). Backed by the Ministry of Social Development and local dairies, within a peak of social development policies, the project grew through co-creation (5), local adaptation and grounded policy mixes, and territorial networks, forming the Intersectoral Roundtable to coordinate stakeholders, co-produce knowledge, and link health goals with local recovery and science education. These dynamics made *Yogurito* a mission-oriented project, sustaining its transformative goals despite Argentina's unstable policy context (Arza and Brau, 2021). Phase 6—the attempted expansion to other provinces—showed the limits of scaling a technology fix for poverty alleviation without local co-creation (6), while Phase 7 saw successful tech transfer to Danone and Sacco, expanding markets while safeguarding *Yogurito*'s core values on territorial impact—thanks to CERELA's governance and the project's robust foundations (7).

[5] Other dimensions are explored in Bortz and Thomas (2017), Bortz, Gázquez and Santos (2022), Gázquez (2024).

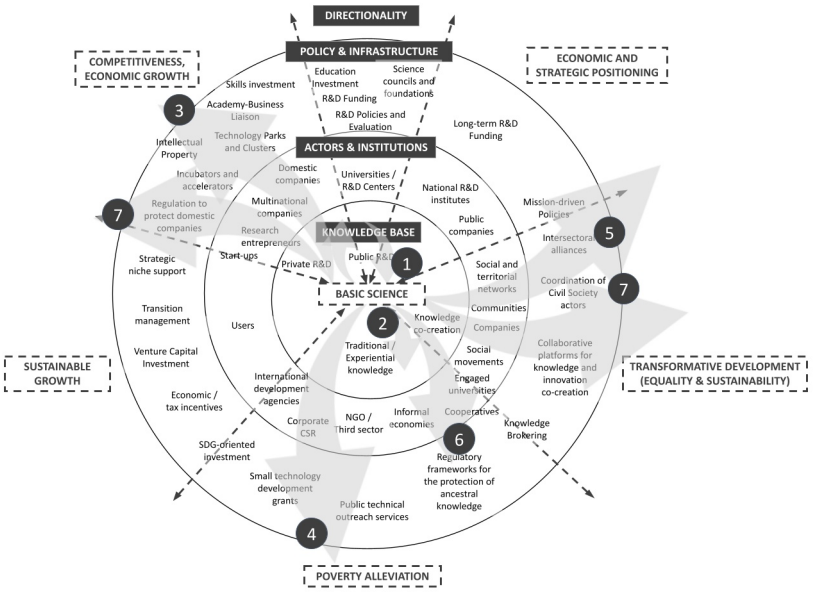

Figure 5. Negotiating directionality in *Yogurito*'s journey.
Own elaboration. Numbers reflect the shifting directionalities throughout *Yogurito*'s journey, as discussed in the text: **(1)** basic research, **(2)** poverty alleviation, **(3)** competitiveness, **(4)** poverty alleviation, **(5)** transformative development, mission-oriented policy, **(6)** poverty alleviation, **(7)** transformative development coexisting with competitive agendas.

Figure 6 traces the Aquarium's shift from a science-focused lab (1) to a mission-oriented, government-backed initiative aimed to sustainability. Early partnerships with local actors enabled species access and facility development, while informal networks across university, municipal, and provincial levels promoted river conservation and citizen engagement (2). Meanwhile, SDG-oriented international cooperation through iBOL broadened the knowledge base toward sustainability (2). Long before mission-oriented frameworks gained policy traction, the Aquarium functioned as a context-specific policy mix with sustained provincial funding—unusual in Argentina's volatile STI landscape (3). Its model combined global knowledge production with services for local producers, biodiversity preservation, environmental education, recovering public urban space, and public outreach (4). At one point, it included poverty reduction efforts via support to fishing families, though these waned due to limited network backing (4). In its later phase, the project aligned with national STI shifts favoring startups, venture capital and market-driven innovation (Cressman, 2019), drawing new actors and investment (5). While the government emphasized biotech visibility and competitiveness, the research team continued to uphold the original conservation mission (5).

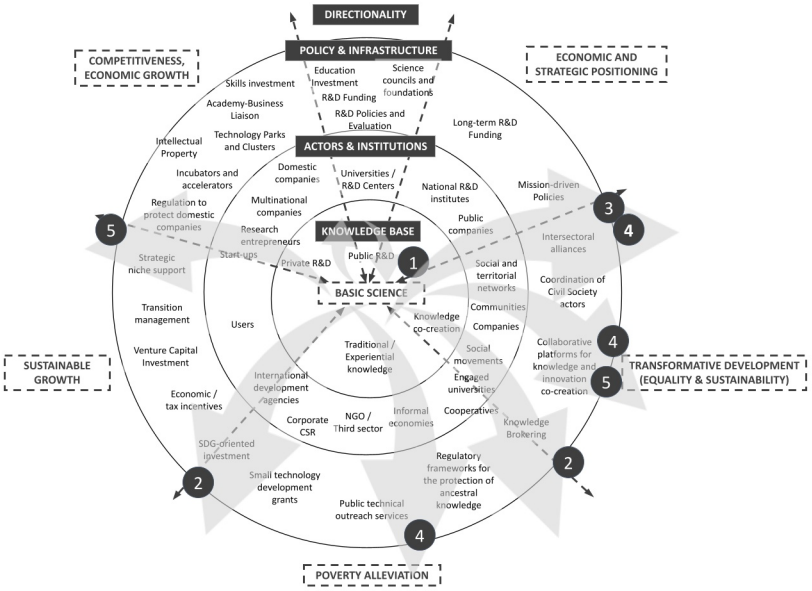

Figure 6. Negotiating directionality in the *Paraná River Aquarium* journey.
Own elaboration. Numbers indicate shifting directionalities in the Aquarium's journey: (1) basic science, (2) transformative development and sustainability, (3) strategic economic positioning, (4) strategic positioning with transformative and poverty-reduction goals, (5) transformative aims contested by competitiveness agenda.

Building on these cases, we highlight four points:

1. Rethinking directionality. In Transformative Innovation Theory, "goals" are concrete, measurable targets, while "directionality" refers to broader normative trajectories—such as sustainability or inclusion—that guide innovation toward systemic change. Though distinct, both are interlinked: goals may shift with context or new knowledge, while directionality acts as a compass, aligning innovation with long-term societal values (Smith *et al.*, 2005; Weber and Rohracher, 2012). This interplay allows initiatives to adapt while remaining anchored in a transformative purpose. However, our cases show the reverse: goals like aiding underserved children or conserving ecosystems remained stable, while directionality was renegotiated as future visions evolved. We therefore conceptualize directionality not as fixed, but as a dynamic, co-constructed process shaped by actors' visions, knowledge, and means—often reflecting diverse or conflicting orientations. Transformative directionality thus emerges through negotiation, expanded participation, and evolving notions of inclusion and sustainability.

Also, as "societal change" is often loosely defined, drawing on theory and empirical cases, Figures 1–2 and 5–6 help clarify what counts as transformation and to what extent. The lower triangles in the graphs represent transformation goals pursued through different pathways—revealing how directionality aligns with actors, chosen means and

framings. For instance, sustainability as decarbonization or inclusion via poverty alleviation contrasts with deeper aims of transformations of material, epistemic, political, and socioeconomic structures.

2. Agency and instrument selection. The cases underscore the central role of agency in shaping transformative change by negotiating future visions and the paths to reach them (van Lente, 2012). Even with shared goals, the directionality of change is co-shaped by actor networks, policy preferences, and selected instruments—highlighting the political economy of policy tools (Lascoumes and Le Galès, 2007), normative preferences embedded in policy design (Akrich, 1992), and the constructed functions of technology and policy (Bijker, 1995).

The cases—echoing studies such as Thomas *et al.*, (2017) and Bortz and Thomas (2017)—show that rigidly applied instruments designed or scientific advancement or competitiveness, often failed to enable transformative development. This misalignment between policy means and societal ends is especially clear in the *Leche Bio* outcome. In contrast, the most transformative outcomes emerged from flexible, context-specific policy mixes—combining citizen assemblies, participatory management, community engagement, science education, IP tools, tech transfer, services to third parties, and co-creation platforms.

These subnational, bottom-up mission-oriented policies predated recent STI frameworks, initially led by researchers and later adopted by governments through iterative negotiation, co-creation and grassroots legitimacy. Sustained by public funding, competitive R&D grants, and autonomous revenue, they ensured long-term viability and impact.

3. Territorial sensitivities. The cases illustrate how transformative goals, actors, and tools are deeply rooted in territorial dynamics—shaped by local ties, knowledge of social and productive realities, and political context. This grounding fostered broad local engagement, collective visions of change, and the development of relevant knowledge and technologies to pursue them. Though initially addressing specific local problems, both cases grew through engagement with wider networks drawn from the local fabric. They challenged dominant technoproductive models—e.g., dairy industry concentration vs. support for small producers, or extractive vs. artisanal fishing or sustainable aquaculture. Artisanal fishing was reexamined as both a livelihood and a neglected identity bounded to the river. Strong territorial anchoring, continuity of technical staff, and deep-rooted local legitimacy helped the initiatives persist despite shifting national politics. Both relied on collaborative efforts based on formal and informal participatory mechanisms—assemblies, roundtables, workshops, informal networks—that evolved into lasting consultative spaces. This broad alignment enabled durability, even across political divides.

4. Limits to transformation. While both cases stand out as promising STI policies for inclusion and sustainability—reviving neglected sectors, improving nutrition, restoring public space, and conserving ecosystems—they remained isolated niches. They did not reverse structural issues like poverty, systemic inequality, agribusiness concentration, or environmental degradation. Latin America's deep-rooted inequalities, fragmented and extractive economies, and underfunded STI systems compound the region's socio-economic and environmental challenges. These subnational missions demonstrate the value and potential of locally driven change as catalysts for transformation, but also expose their limits when not aligned with national policies and resources—restricting them to isolated interventions rather than systemic change. Though they move beyond "tech fixes," without broader cross-sectoral federal commitment, they risk remaining "sociotechnical fixes"—shifting sectors without transforming systemic regimes.

5. CONCLUSIONS

This paper examined how inclusive and environmentally focused research and innovation policies challenge dominant models by reshaping directionality and governance for social transformation. We contribute to Critical and Transformative Innovation Studies by addressing gaps around agency, continuity politics and territorial sensitivity bringing Latin American perspectives. Expanding a Knowledge Systems approach, we advocate for a broader, more symmetrical view of innovation that values diverse actors, policies, infra-structures, and knowledge—beyond competitiveness-driven assumptions.

Through case studies and literature review, we reframed directionality as both the negotiated process shaped by actors' conflicting visions, knowledge, and value-laden policy choices—and its evolving outcome, rather than a fixed endpoint. Tracing each case as an innovation journey, we suggest it is not the path of a vessel with a single captain but one where multiple actors contest the wheel, each seeking to steer through shifting waters. This lens highlights how innovation is steered, toward which goals, and why some directions prevail over others.

The cases show that while specific inclusion or sustainability goals may persist, directions and outcomes shift as power dynamics evolve and new actors reshape policy preferences—often reframing these contested concepts in turn (Gallie, 1956) in broader or narrower terms. Our grounded empirical research aimed to specify these evolving interpretations, showing how they are shaped by the paths taken.

A key insight is the role of the political economy of policy instruments, which embed future visions and co-shape directionality. Instruments designed for growth or competitiveness often fall short of transformative goals, underscoring the need for context-sensitive policy mixes. Territorial actors and networks were essential to expanding these initiatives from tech fixes to sustained, multi-actor interventions involving policy, organizational, and technological experimentation. Yet, while these substate mission-oriented policies offer opportunities for meaningful sociotechnical change, their transformative success depends on cross-sector federal political commitment. Without this, and sound advocacy to push this agenda forward beyond STI realms, they remain "sociotechnical fixes," impactful, capable of localized change but insufficient to shift systemic regimes.

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