



Embedded experimentalism:

A framework and three hypotheses for STI policy, governance and management under strategic uncertainty

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Abstract:

This paper explores the need, challenges and opportunities for STI research and practice to advance the cross-fertilization of innovation, governance and strategic public management studies. It argues that the effective implementation of emerging forms of STI policy – mission-oriented, transformative and Partnerships for Regional Innovation – relies on the ability of public managers to ‘embed experimentalism’ (EE) in their operating context. Based on a problematising literature review, the concept of EE is advanced as a unifying framework to analyse and devise forms of managerial deliberation, organisational structures and incentives for collective action that can fit and transform different institutional contexts under conditions of strategic uncertainty. The EE framework and its three hypotheses are then tested in three cases: the US’ DARPA’s operations; China’s Torch programme; and the EU’s RIS3 policy. Overall, this paper aims to open new avenues for STI research and practice to support attempts at tackling urgent societal challenges, such as industrial decarbonisation.

Keywords:

Experimentalism, public governance, strategic management, transformative innovation, mission-oriented innovation, public sector.

JEL codes:

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1. Introduction

In the last decades, the role of the state in the economy has been brought back to the forefront of the research and policy debate. Evidence of state-led industrial transformation sparked interest in its ability to engage with private actors to advance innovation (O’Riain 2004; Block 2008; Mazzucato 2011). The rise of a global agenda centred on societal challenges – best exemplified by the Sustainable Development Goals (SDGs) – led to efforts to explore how the state can shape the direction, rather than just the quantity, of innovation (United Nations 2015). These trends fed into new forms of ‘contemporary’ science, technology and innovation policy (CSTIP) that find a proactive role for the state to act as purposeful change agent in societal transformations – for example transformative (Schot and Steinmueller 2018), mission-oriented (Kattel and Mazzucato 2018) and Partnerships for Regional Innovation policies (Pontikakis et al. 2022). Yet there is widespread confusion among researchers and practitioners about the effective ability of such policies to fulfil the promise of meeting urgent societal challenges (Janssen et al. 2021). Most of these doubts relate to implementation: how CSTIP can be operationalised and governed in practice. The challenge can be captured in the three micro-foundations of CSTIP (Felin et al. 2015):

1. *The lack of a policy strategy*: current research offers no guidance to public sector organisations (PSOs) adopting CSTIP. While this pushes practitioners to experiment with their institutional tools (Larrue 2021; Janssen et al. 2023a), it also deprives them of clarity in navigating its challenges – for example designing policy targets, coordinating policy mixes or adopting formative evaluation approaches (OECD and Danish Design Centre 2022; Janssen et al. 2023b).
2. *The lack of a governance strategy*: beyond the repeated plea for multi-actor experimentation (Mazzucato 2016; Wanzenböck et al. 2020; Ghosh et al. 2021), available research offers no solution for how PSOs can organise a regime of collective action capable of balancing the need for experimentation with the need for accountability (Radošević et al. 2023).
3. *The lack of a management strategy*: likewise, beyond the plea for dynamic capabilities in PSOs as a key enabler of STI policy implementation (Kattel and Mazzucato 2018; Borrás et al. 2023), research has no answer for how their leadership can nurture them proactively (Gullmark 2021; Gullmark and Clausen 2023).

The main implication is that, due to the lack of such micro-foundations, CSTIP is often implemented via business-as-usual practice and reduced to a ‘label for [...] existing policies and ideas’ (Kattel and Mazzucato 2023, 12). Against this background, this paper aims to explore the opportunities for the debate to overcome the implementation challenge by drawing a framework and set of hypotheses to address the following research questions:

RQ1. What makes the policy strategy of CSTIP effective?

RQ2. What makes the governance strategy of CSTIP effective?

RQ3. What makes the management strategy of CSTIP effective?

To do so, this paper deepens and widens the current debate through a problematising literature review (Alvesson and Sandberg 2020), which bridges three areas of research: innovation; public governance; and strategic public management. On the one hand, this builds on recent efforts to investigate PSOs’ ability to adopt ‘tasks’ for ‘systemic transformation’ (Borrás et al. 2023, 14), acknowledges the constraints imposed by administrative traditions on STI policy implementation

(Braams et al. 2022) and, more generally, 'take[s] implementation seriously' (Kattel and Mazzucato 2023, 14). On the other hand, it scrutinises the assumptions behind such attempts; scopes a broader range of insights that are coherent with, yet beyond, conventional disciplinary boundaries; and develops hypotheses to solve the implementation challenge.

As a result, this paper proposes an original framework for CSTIP implementation: the embedded experimentalism (EE) framework. Akin to existing literature, the EE assumes that the environment of CSTIP is characterised by strategic uncertainty: the inability of actors governing a policy to know how to pursue the declared goal (Wanzenböck et al. 2020). However, it departs from the existing literature by leveraging the notion of experimentalism as a 'form of deliberation [...] an organisational structure [...] and set of incentives' (Sabel and Victor 2022, 35) as a metatheoretical language against which hypotheses on policy implementation can be formulated, compared and tested (cf. Rangoni 2022). The framework is underscored by three hypotheses on how change agents within PSOs (for example public managers; Klausen 2023) may support the three micro-foundations of CSTIP at the policy, governance and management level. First, EE identifies the set of incentives behind stakeholders' willingness to pool their innovation resources and regulate their access for entrepreneurial discovery: i.e. innovation commons (Potts 2019). Second, EE identifies an organisational structure in which PSOs hold partners accountable for committing to collaborative experimentation towards such a shared goal: i.e. dynamic accountability (Sabel and Zeitlin 2012). Third, EE identifies a form of deliberation by which the leadership of PSO can empower its frontline employees to renew organisational practices to achieve a new mission: i.e. strategic learning (Boin and Christensen 2008).

H1. CSTI policy aims to address societal challenges by reshaping the rules of collective action followed by PSOs' partners to forge innovation commons (Potts 2019).

H2. CSTI governance aims to forge innovation commons by establishing forms of dynamic accountability among PSOs and their partners (Sabel and Zeitlin 2012).

H3. CSTI management aims to establish forms of dynamic accountability among PSOs and their partners by leveraging strategic learning and thus activating PSOs' dynamic capabilities (Boin and Christensen 2008).

Together, these hypotheses compose a multi-level model of public sector innovation spanning policy, governance and managerial dynamics (Sørensen and Torfing 2022). Building on these hypotheses, this paper suggests that the implementation of CSTIP may rest in the ability of change agents in PSOs to institutionalise forms of embedded experimentalism within them (Lawrence and Suddaby 2006). The main implication of the argument is two-fold. On the one hand, it identifies the 'original sin' of CSTIP in PSOs' inability to handle strategic uncertainty (Bouckaert 2023). On the other, it identifies its resolution in the deliberate attempt to leverage experimentation as the trigger of an evolutionary process transforming the PSOs themselves (cf. Bodrozic and Adler 2018). The conclusion is counter-intuitive: the more transformative the goal of a policy, the more limited the use of long-term planning, and the greater the importance of learning by experience (cf. Hirschman and Lindblom 1962).

While the main contribution of this paper is theoretical, it also illustrates the analytical, heuristic and policy relevance of the EE framework via a pre-study (Swedberg 2012) of three STI policies: the US' DARPA's operations; China's Torch programme; and the EU's RIS3 policy. The pre-study exploits outstanding differences across critical cases' political, economic, institutional and cultural contexts (Yin 2009; Przewoski and Teune 1970) to show how EE can detect and evaluate commonalities and divergences in their key policy, governance and management underpinnings. Drawing on the use of this method by Borrás and Edler (2020), illustrations are based on literature review and data sources chosen for their relevance, credibility and quality.

This paper aims to open avenues for research and practice to overcome key bottlenecks hampering ongoing attempts at tackling urgent societal challenges in two ways: i) by providing a holistic theory of change for CSTIP (cf. Ghosh et al. 2021; Larrue 2022; Haddad and Bergek 2023); and ii) deepening our understanding of the crucial, yet largely neglected, role of strategic public management and governance in shaping its implementation.

2. Literature review

In the introduction I presented the implementation challenge as the key driver of the gap between the research and practice of CSTIP. In this section I deepen the argument by locating the gap within the state-of-the-art literature on innovation, governance and strategic public management. To do so, I leverage a 'problematizing' rather than 'integrative' approach to existing scholarship (Alvesson and Sandberg 2020). The problematizing literature review follows four key principles: i) questioning assumptions, perspectives and vocabularies within existing streams of research; ii) reading broadly, but selectively (beyond disciplinary boundaries and looking for new links); iii) not accumulating, but problematizing (revealing assumptions behind the disciplines); and iv) developing new perspectives on the issue at hand. From this perspective, the literature review becomes itself a research tool to advance the analysis of a given societal phenomenon – CSTIP. As a result, I advance a hypothesis for each of the three fields covered in the review and thus, in the next section, articulate the foundation for the EE framework. The hypotheses are the following:

1. As policy strategy, crafting innovation commons (Potts 2019).
2. As governance strategy, crafting dynamic accountability (Sabel and Zeitlin 2012).
3. As management strategy, crafting strategic learning (Boin and Christensen 2008).

2.1 CSTI policy: crafting innovation commons

I define STI policy as the set of 'government policies aimed at fostering the use of the best science and technology to produce competitive "first- to-market" or new production processes' and 'organisational approaches and management practices' that support such effort (Martin 2016, 158). There are several forms of STI policy (Edler and Fagerberg 2017). Among their many differences, a key one lies in the intent to tackle different 'failures' arising from the inability of market processes to fulfil social welfare (Arrow 1962), accelerate innovation (Freeman 1987) or tackle societal challenges (Ergas 1987). In this context, CSTIP is characterised by a strong focus on 'transformational failures' that prevent the long-term reorientation of innovation systems towards politically desirable objectives – for example industrial decarbonisation. Weber and Rohracher (2012) identify four such failures: i) directionality (lack of shared vision for the direction and purpose of technological change); ii) demand articulation (lack of opportunities for understanding user needs and stimulating demand); iii) policy coordination (lack of multi-level, vertical and horizontal policy coordination); and iv) reflexivity (lack of opportunities to experiment, monitor and learn about policy outcomes). A non-exhaustive list of CSTIP addressing these include transformative innovation policy (TIP), mission-oriented innovation policy (MOIP) and Partnerships for Regional Innovation policy (PRIP) (see Table 1).

Table 1. Contemporary strands of CSTI policy literature

CSTI policy	Roots	Rationale	Recommendations
Transformative innovation policy	Sustainability transitions: innovation as an evolutionary process shaped by tensions across technological niches, existing socio-technological regimes and societal landscapes (Geels 2002; Schot and Geels 2008; Loorbach 2010)	Devising 'experimental policy engagements' able to trigger 'transformative outcomes' by developing new niches, supporting their expansion and destabilising regimes (Ghosh et al. 2021)	Advancing 'institutional arrangements [...] across governments, markets, civil society [...] to achieve coordination, anticipation and learning' through co-creation (Schot and Steinmueller 2018, 1564)
Mission-oriented innovation policy	Neo-Schumpeterian economics and neo-developmental state: innovation as the outcome of broad societal dynamics that drive the succession of techno-economic paradigms (Dosi 1982; Freeman and Perez 1988; Perez 2002) proactively advanced by states (Block 2008; Block et al. 2011)	Adopting a 'market shaping' approach by influencing the 'interactions between different agents' involved in the innovation process towards clear societal challenges (Mazzucato 2016, 145)	Grounding the identification of key societal challenges into proactive engagement of societal stakeholders; conditionalities; and active portfolio management that focuses on common good (Mazzucato 2023)
Partnerships for Regional Innovation policy	New industrial policy and EU cohesion policy: innovation as a 'discovery process' arising from the 'strategic coordination' of firms, public and civic actors for entrepreneurial discovery (Rodrik 2004, 3; Hausmann and Rodrik 2002; Foray et al. 2012; Morgan 2017)	Forging regional 'partnerships across all stakeholders [who are to be involved in European Green Deal policies] to align efforts and co-create transformation pathways' to advance place-based innovation (Pontikakis et al. 2022, 2)	'Setting the condition for broader and dynamic planning'; by leading 'co-creation with stakeholders'; and by 'orchestrating [policy] actions under a coherent logic' (Pontikakis et al. 2022, 32-39-53)

Source: Author's elaboration

There is an open debate on the differences between TIP, MOIP and PRIP as forms of CSTIP. However, Table 1 reveals two insights: first, that their origins are rooted in scholarship and the insights which it advances and operationalises within the contemporary policy context; and second, that they have much in common. This includes a view of innovation as a political and societal process; a view of the state as critical in shaping the conditions under which that process unfolds; and a view of STI policy as a means to ignite multi-stakeholder experimentation and learning towards societal goals. Hence, the interpretation suggested is that their differences are more pertinent to the epistemic and intellectual heritage behind them than to their substance. This view is corroborated by growing efforts to scope what each tradition can learn from the others (see Foray 2018; Cappellano et al. 2023; Janssen et al. 2023a;

Velasco et al., forthcoming).

Despite evidence that CSTIP policy recommendations seem to converge, practitioners still struggle to implement it (Ulmanen et al. 2022; Rohracher et al. 2023; Larrue 2022). A first limitation lies in that CSTI policies are 'boundary objects', whose meaning varies across epistemic and policy communities (Janssen et al. 2023a). In MOIP, practitioners adopted institutional solutions that vary in objective, governance and policy mix (Chicot et al. 2018; Wanzenböck et al. 2020; Wittman et al. 2021; Larrue 2021; Janssen et al. 2023b). Such diversity reflects contextual institutional conditions in which any public policy is conceived. Yet without a clear definition of MOIP it also opens the road to 'mission-washing' (i.e. policies labelled MOIP, but largely unchanged) and thus jeopardises their assessment. A second limitation is the link between the intended means and ends of CSTIP. In TIP, the 'transformative outcomes' framework hints at 12 outcomes actors shall 'work towards' to address transformational failures and induce socio-technical transitions (Ghosh et al. 2021, 741). Yet it does not articulate how policy can tilt actors' incentives to induce the sought 'outcomes'. A clearer distinction between the impact of TIP on stakeholders' ability to 'work towards' transitions and the effect of their action on the 'transformative outcomes' may help improve the precision of TIP design and implementation.

To address the lack of a policy strategy in CSTI, I anchor its intervention logic in the theory of innovation commons proposed by Potts (2019) whereby commons-like rules of collective action enable actors' collaborative experimentation towards a shared goal. I hypothesise that rising forms of STI policy are based on a similar, yet somewhat implicit, view of innovation as a 'problem of collective action under uncertainty' (Potts 2019, 223). Building on Hayek, Williamson and Ostrom, Potts (2019) locates such problem in the ability of stakeholders to pool effectively decentralised innovation resources – for example tacit knowledge and production factors – to elucidate new opportunities for entrepreneurial discovery (Kirzner 1997). To do so, actors must develop mutual trust in each other by developing (formal or informal) rules of collective action regulating the access to said resources. By doing so, they give life to 'commons' that accelerate the discovery process in two ways: by helping actors manage uncertainty in market formation by knowledge and expectation alignment (Gomes et al. 2018; Boon et al. 2022; Gomes and Barros 2022); and by inducing social learning to unearth new opportunities (van Mierlo and Beers 2020).

From a policy perspective, the theory of innovation commons opens up to the possibility that PSOs may be able to steer the formation of innovation commons by persuading stakeholders to partake in collective experimentation towards a shared objective. In their analysis of experimentalism 'as a set of incentives', Sabel and Victor (2022) show how this can be achieved by imposing unfair benefits or sanctions based on stakeholders' decision to partake or withdraw from the experimentation process. As in the case of policy conditionalities (Mazzucato and Rodrik 2023), the aim is 'to break the grip of the status quo and encourage participation' in collective 'problem-solving when public interest requires it, but immediate self-interest does not' (67). Be it grounded in political or moral suasion, a threat of hard regulation, or a power asymmetry, the ultimate impact of such policy is to shape actors' incentives towards a form of collective action where collective problem-solving may take place, and the innovation process is oriented and accelerated, i.e. innovation commons.

Based on this account, I hypothesise that the goal of CSTIP is to accelerate market formation (and socio-technical transitions) by targeting the rules of collective action that underpin the formation of innovation commons. Such rules correspond to the seven design principles identified by Elinor Ostrom (2010) in her research on common pool resources: i) monitored use of information; ii) clear system boundaries; iii) proportional distribution of costs and benefits among stakeholders; iv) inclusive decision-making; v) autonomy of individual stakeholders; vi)

sanctioned rule violation; and vii) transparent means for conflict resolution. The ‘crafting’ of ‘innovation commons’ thus constitutes the first hypothesis underpinning the EE framework.

H1. CSTI policy aims to address societal challenges by reshaping the rules of collective action followed by PSOs’ partners to forge innovation commons (Potts 2019).

2.2 CSTI governance: crafting dynamic accountability

The previous subsection identified a policy strategy for CSTI. Building on it, this subsection goes one step further by exploring the governance mechanisms that underpin its design and implementation. I define governance as the set of formal or informal institutions by which public, private and societal stakeholders target collective goals (Peters 2022). Within CSTIP, governance concerns the ‘process in which policy instruments are designed and executed through the interactive efforts of state and societal actors’ (Zhang 2022, 304). Lately, STI governance has been explored in innovation systems research (Hillman et al. 2011), science and technology (Borrás and Edler 2020), and social network studies (Whetsell et al. 2020). Yet only a few studies have formulated hypotheses on the governance underpinnings of CSTIP. I review two strands in this literature: functional design and organisational design. The functional design literature focuses on the tasks deemed key to successful CSTIP implementation. The organisational design literature complements the functional one by focusing on the design of the PSOs in charge of innovation processes and also innovation bureaucracies (IBs).

Table 2. Contemporary strands of CSTI governance literature

CSTI policy	Roots	Rationale	Recommendations
Functional design	Sustainability transitions: Multi-level perspective (Geels 2002), technological innovation systems (Hekkert et al. 2007), strategic niche management (Schot and Geels, 2008); transitions management (Loorbach 2010)	The purpose of governance is to ‘orchestrate socio-technical transformation’ by balancing the presence of five features in a given innovation ecosystem: ‘diversity, connectivity, polycentricity, redundancy, directionality’ (Könnölä et al. 2021, 20)	Five ‘transition tasks’: i) ‘giving direction’ to the generation of innovation; ii) ‘create governance’ to involve actors; iii) ‘support the new’ by funding and aiding socio-technical niches; iv) ‘destabilize the unsustainable’ by phasing out the incumbent; v) and ‘develop internal capabilities and structures’ to do the above (Braams et al. 2021)

<p>Organisational design</p>	<p>Neo-developmental state: Weber I IBs (for example Johnson 1982; Evans 1995); Weber II IBs – including ‘systemic innovation intermediaries’ (Kivimaa et al. 2019), ‘Schumpeterian developmental agencies’ (Breznitz et al. 2018) or ‘Neo-Weberian agencies’ (Kattel, Drechsler and Karo 2022)</p>	<p>Weber II IBs (‘agile networks’) are better placed than Weber I IBs (‘centrally governed organisations’) to lead experimental policy processes as they sit ‘below the radar’ of politics. On the other hand, Weber I IBs enjoy greater legitimacy and the ability to bring policies at the core of a political agenda (Breznitz and Ornston 2018)</p>	<p>Effective IBs are defined by agile stability – namely, the combination of Weber-I ‘long-term policy and implementation capacities’ and Weber-II ‘dynamic exploration and learning capabilities’ (Kattel et al. 2022, 53). The authors speculate on the rise of ‘Neo-Weberian agencies’ (Weber III) capable of achieving ‘agile stability’ as key to PSOs’ ability to implement CSTIP</p>
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Source: Author’s elaboration

As found in the synthetic review by Braams et al. (2021), the functional design literature identifies five key ‘transition tasks’ underpinning CSTI governance: i) ‘giving direction’ to generation and diffusion of innovation; ii) ‘create governance’ to involve stakeholders in the transition process; iii) ‘support the new’ by funding and aiding emerging socio-technical niches; iv) ‘destabilize the unsustainable’ by phasing out incumbent regimes; and v) ‘develop internal capabilities and structures’ to facilitate the execution of such tasks. Conversely, the organisational design literature fails to identify in a clearcut fashion how government could structure those functions into a distinctive governance architecture. Kattel, Drechsler and Karo (2022) argue that effective IBs are defined by the paradoxical combination of ‘agile stability’, i.e. the combination of ‘long-term policy and implementation capacities’ available to ministerial bureaucracies and ‘dynamic exploration and learning capabilities’ available to small and independent agencies (53). However, they provide no indication of how such architecture may actually be designed, nor how it should operate in practice.

In the literature, there is a growing consensus that the problem may lie in the trade-off between the demand for accountability made to PSOs (at least those that are politically salient) and the experimental nature of CSTIP (cf. Braams et al. 2022, Radošević et al. 2023). Radošević et al. (2023) review existing solutions to the trade-off and conclude that ‘in conditions of conventional public administration, we do not (yet) have an organisational solution to facilitate the development of public policies’ (8). As such, they propose the establishment of ‘learning networks’ as communities of practice convened by a ‘network moderator’ and ‘group facilitators’ to engage all CSTIP actors in a regular assessment of outcomes from experimentation (9-10). I argue that their solution, which is theoretically convincing, is a limited example of a broader governance architecture called experimentalist governance (XG).

XG is defined as a ‘recursive process of provisional goal setting and revision based on learning’ (Sabel and Zeitlin 2012, 169-170). The conceptualisation of XG is rooted in the analysis of a large sample of empirical cases that differ in policy domain, geographical scale and institutional context (Rangoni 2022), but share a condition of strategic uncertainty where ‘neither the official decision-maker nor actors know how to achieve their goals’ (Rangoni 2019, 68-69). This condition reflects that of CSTIP, the purpose of which is, by definition, defined by political, organisational and epistemic uncertainty (Wanzenböck et al. 2020). As uncertainty begs for experimentation, XG solves the ensuing trade-off by creating ‘dynamic accountability’, i.e. accountability for the production, diffusion and uptake of learning emerging

from experimentation, rather than for meeting a pre-defined and pre-specified target (Sabel and Zeitlin 2012, 176). It does so in a four-fold architecture: i) 'provisional goal setting' based on multi-stakeholder engagement; ii) 'dynamic experimentation' based on discretionary action of local actors; iii) 'learning' based on the periodic comparative review of their initiatives; and iv) 'revision' based on the uptake of the findings emerging from experimentation.

Relative to existing theories, XG provides a superior hypothesis for CSTI governance in several ways. First, as in the functional design literature, it identifies 'functional features' coherent with the 'tasks' identified by Braams et al. (2021) (Sabel and Zeitlin 2008, 274). Second, it improves on organisational design literature by providing a solution grounded in an accountability architecture, rather than in a specific organisational form. Third, it improves the learning networks hypothesis by accounting for a wider range of cases, in particular, those where collaboration is not the main option for stakeholders and 'penalty defaults' must be enacted to reshape their incentives (see section 2.1; cf. Mazzucato and Rodrik 2023). Sabel and Victor (2022) describe experimentalism as 'an organisational structure' that helps transform collective action when 'conception cannot be separated from execution' by showing how 'actors collaborate, defining projects in the process of trying to carry them forward, and using such progress as they make to reassess the feasibility of the undertaking' against strategic uncertainty (50). As such, XG addresses the lack of a governance strategy in the CSTIP debate.

Based on this account, I hypothesise that the goal of CSTI governance is to engender forms of dynamic accountability for multi-stakeholder experimentation and learning. This can take place through the four functions identified by XG, which identify how PSOs can target and reshape the rules of collective action underpinning the formation of innovation commons towards a societal goal. The 'crafting' of 'dynamic accountability' therefore constitutes the second hypothesis of the EE framework.

H2. CSTI governance aims to forge innovation commons by establishing forms of dynamic accountability among PSOs and their partners (Sabel and Zeitlin 2012).

2.3 CSTI management: crafting strategic learning

The previous subsection identified a public governance strategy for CSTI. Building on this premise, the following subsection explores how PSOs can adopt it, focusing upon the role of strategic public management. I define strategic public management as the deliberate realignment of aspirations and capabilities within the PSOs to achieve goals within a specific context (Bryson and George 2020, 6). In this paper, this concerns how public managers and frontline employees adapt their work to implement CSTIP. Despite neglect from contemporary scholars, the role of STI management in the public sector is key, as highlighted by research on dynamic capabilities (Kattel 2022). The CSTI literature presents three challenges for management: complexity, organisational and legitimacy. The complexity challenge arises from the demands made by CSTIP compared to policy tools in four respects: coordination, accountability, information and conflict management (Zhang 2022). The organisational challenge relates to ensuring consistency and coherence to policy delivery, for example in linking the strategic agenda, thematic orientation and frontline (Kroll 2019). Last, the legitimacy challenge involves reconciling CSTIP with existing institutionalised principles of policy work, which often limit civil servants' latitude to adopt CSTIP (keeping long-term ambitions stable against short-term politics; an aversion to opening up government to stakeholders; and facing the risk of overstepping their mandate) (Braams et al. 2022).

These challenges stretch PSOs' capacity (Painter and Pierre 2005). Complexity requires an

analytical capacity to finetune policy design. Organisational asks for operational capacity to steer administrative resources and legitimacy requires political capacity to secure politico-administrative coordination in often-unstable environments (Bouckaert 2022). Kattel and Mazzucato (2018) argue that such capacity can be nurtured through dynamic capabilities (DCs): the abilities enabling organisations to achieve new resource and process configurations to adapt to a changing environment (Eisenhardt and Martin 2000; Teece 2022). While this concept emerged in private sector literature (Teece, Pisano and Shuen 1997), it is now explored as a key driver determining PSOs' ability to design and implement CSTIP (Borrás et al. 2023; Jackwerth-Rice et al. 2023). In this context, DCs have been studied both as content and as process (see Table 3).

Table 3. Contemporary strands of CSTI management literature

CSTI policy	Roots	Rationale	Recommendations
DCs as content	Strategic management: Teece, Pisano and Shuen (1997) Strategic public management: Ongaro and Ferlie (2022)	There is no consensus on the number or nature of public sector DCs. Meijer (2019) identifies five: mobilising; experimenting; institutionalising; balancing; and coordinating. Mayne et al. (2020) identify three: reflective; collaborative; and data-analytic. Kattel (2022) identifies three: sense-making; connecting; shaping. Spanó et al. (2023) articulate the three capabilities identified by Kattel (2022) into nine lower-order ones	Learning represents the 'principal means' that an organisation can adopt to 'achieve strategic renewal' (Crossan et al. 1999)
DCs as process	Resource-based view of the firm: Penrose (1959) Evolutionary economics: Nelson and Winter (1982)	Gullmark (2021) provides empirical evidence of how public sector DCs may be deployed at the managerial level (lowly routinised and grounded in individual skills) or at the organisational level (highly routinised and grounded in collective routines). Gullmark and Clausen (2023) identify in empirical evidence the six micro-foundations of public DCs: i) individual entrepreneurship; ii) group-level alertness learning; iii) organisation-level culture, management and structure	Public managers can support the growth of dynamic organisational capabilities by acting on PSOs' innovation culture, management and structure (Gullmark and Clausen 2023, 275)

Source: Author's elaboration

The ultimate question in the CSTI debate concerns the search for a management strategy for seizing on and/or nurturing the capabilities needed to empower CSTIP implementation. In this sense, the small but growing literature on public sector DCs provides valuable insights. On the side of content, considerable overlap across different definitions of DCs implies that learning is currently seen as the 'principal means' to 'achieve strategic renewal' (Crossan et al. 1999). On

the side of process, available evidence shows that public managers can support the 'flourishing' of organisational DCs by acting on PSOs' innovation culture, management and structure, so as to empower such learning (Gullmark and Clausen 2023, 275). This defies the assumption of a dichotomy between deliberate innovation processes pursued by public managers (Klausen 2023) and emergent innovation processes by frontline employees (Pedersen et al. 2023). In the longstanding debate on 'who is the public strategist' (cf. Ongaro and Ferlie 2022), the ability of public leadership (i.e. managerial DCs) to trigger diffuse learning processes across the PSO (i.e. organisational DCs) seems key to enabling the 'realignment' of existing capabilities with novel aspirations that eventually empower a PSO to 'adopt' a new mission (Vera and Crossan 2004).

In the private sector, strategic learning has been found to reinforce DCs at managerial level – for example by enabling 'agile' strategy formation and execution (Mintzberg and Waters 1985) – and organisational – for example by enabling absorption and retention of new routines (Cohen and Levinthal 1990, March 1991). While this has not been directly tested in the public sector, public administration research shows that it may apply there, too. Building on Selznick (1957), Boin and Christensen (2008) argue that public leadership can support the institutionalisation of new working practices by four 'design principles': i) facilitating trial and error in pursuit of effective practices; ii) monitoring emerging practices as they diffuse; iii) embedding accepted norms in formal rules; and iv) balancing organisational identity and resilience against environmental changes. Empirical evidence shows that 'public leaders' using such principles can support their PSOs' growth into high-performing, durable 'vessels of societal aspiration' (Selznick 1957; Goodsell 2001; Boin et al. 2021). In the light of the impact that strategic learning can have on public sector performance and the few empirical studies available (Ongaro and Ferlie 2022), this insight paves the way for a first hypothesis on how CSTI management can nurture DCs.

From a management perspective, the institutionalisation dynamics presented by Boin and Christensen (2008) show how the pursuit of strategic learning by a PSO's leadership can lead to the renewal of the PSO's routines, thus enabling achievement of its ultimate mission. Such a form of strategic learning can also be traced in the presentation of experimentalism by Sabel and Victor (2022) as 'a form of deliberation', where such a process is organised as a peer review: 'actors of equal standing – all with experience of the problem, of different kinds, and all with a stake in the outcome – evaluate an identical situation [...] dispel enough doubt to enable action [...] learn from their differences' (60). This process addresses the lack of a clear strategy fit for CSTI management, while building on insights from state-of-the-art research, i.e. that managerial and organisational DCs complement each other (Gullmark 2021); that their micro-foundations are found in individual, group and organisational dynamics which leadership can manipulate (Gullmark and Clausen 2023); and that, by doing so, PSOs can achieve new resource and process configurations (Kattel, Drechsler and Karo 2022).

Based on this account, I hypothesise that the goal of CSTI management is to use strategic learning to nurture and steer PSOs' capabilities towards a new mission, thus enabling effective CSTIP governance. This may take place through the four design principles identified by Boin and Christensen (2008), which together show how strategic renewal unfolds under adoption of a new governance and policy strategy (for example H1 and H2). Thus, the 'crafting' of 'strategic learning' is the third hypothesis of the EE framework.

H3. CSTI management aims to establish forms of dynamic accountability among PSOs and their partners by leveraging strategic learning, and thus activate PSOs' dynamic capabilities (Boin and Christensen 2008).

3. Analytical framework and case selection

Building on the three hypotheses of the literature review, this section proposes a framework for CSTI research and practice: the embedded experimentalism (EE) framework. Its rationale lies in the premise that the implementation challenge faced by CSTIP may benefit from the articulation and assessment of its micro-foundations, i.e. from 'locating its proximate causes [...] at a level of analysis lower than the phenomenon itself' (Ferlin et al. 2015, 586). The breadth and depth of the debate in CSTIP shows how policy is grounded in governance arrangements and governance arrangements are reflected in managerial approaches, too. Akin to Sørensen and Torfing (2022), and Gullmark and Clausen (2023), EE draws on this insight to develop a multilevel model of public sector innovation that shows 'how relations between macro variables' of CSTI policy can be 'mediated by [meso and] micro actions and interactions' related to governance and management (Ferlin et al. 2015, 576). The EE framework has four components: i) strategic uncertainty as context; ii) management; iii) governance; and iv) policy.

To begin with, the EE framework follows CSTI literature on the assumption that the environment of today's PSOs is characterised by strategic uncertainty, i.e. the difficulty of the actors entrusted with a challenging policy mandate to know how to pursue it (Wanzenböck et al. 2020). For Wanzenböck et al. (2020), the drivers of strategic uncertainty are three: epistemic ignorance (lack of exhaustive/trusted knowledge on a problem/solution); organisational complexity (lack of a streamlined option for policy design/implementation); and political contestation (lack of a shared consensus around the definition of a problem/solution). Thus, strategic uncertainty is not intrinsic to the policy mandate, but to the epistemic, organisational and political conditions around it. Under strategic uncertainty, the policy mandate is 'ill-structured' and thus not amenable to problem-solving (Turnbull and Hoppe 2019). In this context, the value of experimentalism is that of a theoretical argument, repository of evidence and practical guidance for a policy, governance and management strategy to navigate such circumstances (Rangoni 2022).

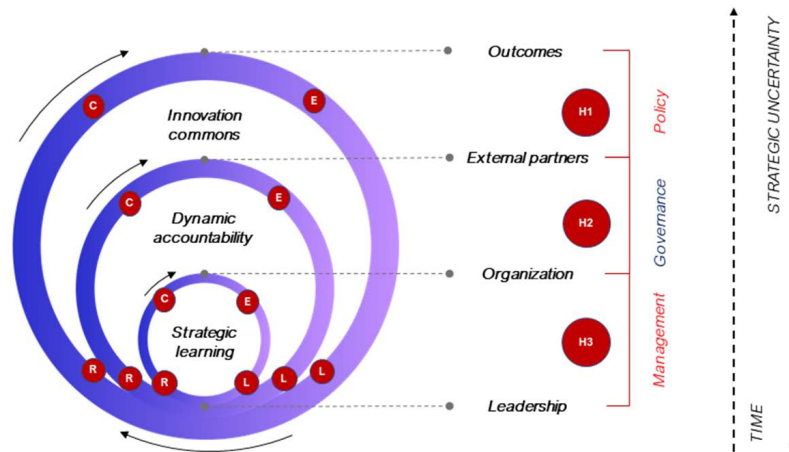
As previously seen in the discussion of XG, experimentalism shows how the need for experimentation and accountability in CSTIP can be reconciled by embedding the experimentation-based learning at the core of the accountability relationship between those mandating the policy and those executing it (Sabel 2004; Sabel and Victor 2022). The argument encompasses policy, governance and management, thus achieving two goals at once: deepening the rationale of CSTIP; and addressing its implementation challenge by unpacking its key micro-foundations. As a result, EE maps out how change agents working in PSOs (for example public managers) may empower CSTIP by 'embedding experimentalism' in their policy, governance and management (see Figure 1). To qualify such experimentalist character, each level of the framework is interpreted as a four-steps 'loop': consensus; experimentation; learning; and revision (Sabel and Zeitlin 2012; Sabel and Victor 2022). Each hypothesis can be revised as follows:

- Management can leverage strategic learning by (C1) championing a mission; (E1) facilitating trial-and-error experimentation to prototype new working practices; (L1) monitoring emerging results; and (R1) codifying new norms within PSOs' formal rules (Boin and Christensen 2008).
- Governance can establish dynamic accountability by (C2) forging new coalitions of stakeholders around a shared goal; (E2) supporting stakeholders' experiments to develop new solutions; (R2) facilitating stakeholders' sharing of the results of the process; and (L2)

embedding the new results of the mission within its governance (Sabel and Zeitlin 2012).

- Policy can forge innovation commons by helping stakeholders (C3) define system boundaries for mutual interaction; (E3) support decentralised experimentation; (L3) monitor the use of information; and (R3) resolve emerging conflicts in transparent ways (Potts 2019).

Figure 1. Embedded experimentalism framework



Source: Author's elaboration

To be clear, this linear exposition of the experimentalist argument is artificial; in reality, processes underlying the hypotheses occur concurrently within the PSO (H3), in interactions with partners (H2), or externally (H1) concur in parallel. These processes can reinforce or undermine each other, prompting new hypotheses on policy implementation. Weak CSTIP micro-foundations may hinder their execution. For example, without a management strategy grounded in strategic learning, PSOs may struggle to hold partners accountable for experimentation outcomes; or without dynamic accountability, governance may fail to incentivise resource pooling. Equally, external policy challenges faced in CSTIP implementation could yield important learning opportunities for managers to enhance CSTIP over time, or, if overlooked, lead to disillusionment (Larrue 2022; Janssen et al. 2023b). Overall, EE suggests that CSTIP success may hinge on PSOs' leadership and their ability to 'activate' their organisations towards the embedding of experimentalism as a 'form of deliberation, organisational structure and set of incentives'. Although research is nascent, this hypothesis underscores EE's heuristic value for CSTIP research and practice, serving as a benchmark for real-world experiences.

To my knowledge, the EE framework is the first fully fledged 'theory of change' in the current debate to cover the entire policy process and be based on solid theoretical and empirical research. Ghosh et al. (2021) provide a conceptualisation of the socio-technical dynamics underpinning TIP, but do not account for governance and management. Larrue (2022) covers the whole policy process by identifying outputs, outcomes and impact of MOIP, but does not explore the conditions in which each level feeds into the other, i.e. EE's hypotheses. Haddad and Bergek (2022) elaborate a methodology to evaluate TIP, but do not propose a theory of change: rather, they suggest that such theory should be identified by the policymaker and the researcher

at the onset.¹ Relative to this proposal, EE articulates a theory of change specific enough to help the empirical assessment of CSTIP, and general enough to capture diverse policy mixes, governance structures and competing theories in the current debate.

In this respect, an important caveat of the EE framework concerns its utilisation. In the social sciences, frameworks are developed to 'provide a metatheoretical language to enable scholars to discuss any particular theory' and theories 'specify which parts of the framework are useful to explain outcomes and how they relate' (Ostrom 2010, 646). In line with this understanding, the EE framework does not aim to contest or substitute current theories of CSTI policy, governance and management. Rather, it aims to provide them with a common language against which they can be compared and assessed at a greater level of analytical and empirical depth than what has been possible so far. At the same time, the EE framework is grounded in a set of three hypotheses on CSTI policy, governance and management. Together, they form a distinctive, preliminary theory of CSTIP implementation that aims to deepen and widen the debate with a new interpretation of the conditions under which the ambitious promises of CSTIP can be realised in practice.

To illustrate the functioning of the EE framework and hypotheses, I conduct a pre-study (Swedberg 2012) of three STI policies. While the research design is based on a selection of critical cases (Yin 2009) and a 'most different systems' logic (Przeworski and Teune 1970), in line with the pre-study approach, its purpose is not to claim causal inference, but to demonstrate the applicability and relevance of EE to a variety of political-economic, institutional and cultural contexts. The three cases are: the US's DARPA R&D approach; China's Torch programme; and the EU's R&I Commission Smart Specialisation Strategy (RIS3) approach. Based on the use by Borrás and Edler (2020) of the pre-study method, the case studies are based on a review of the available primary research on each case study, the selection of which has been curated for relevance, credibility and quality. The pre-study is enabled by the wide availability of high-quality evidence on each case study – each of them broadly cited for illustrative purposes within the CSTIP discourse (see, for example, DARPA epitomised by Mazzucato (2011) as an example of MOIP or RIS3 by Foray (2018) as a special case of MOIP). Based on the preliminary logic of the pre-study method to support the theorisation of a new research framework, I refer to the cases as illustrations.

¹ The limit of this approach is that it refrains from formulating any general hypothesis for how TIP may succeed. In line with the EE framework, the authors argue that theory can be used 'as a counterfactual' to enable 'the exploration [...] of the patterns between interventions and outcomes' and therefore evaluate CSTIP implementation (14). Yet, it is theoretically ambiguous and practically dubious that the elaboration of said theory may be 'outsourced' on a case-by-case basis to the evaluator and policymaker. As they put it, 'Can evaluators be expected to do that within usually limited timeframe and budget?' (14).

4.Pre-study: three illustrations of STI policy

4.1 The US: DARPA's embedded network governance

The first illustration is US' Defence Advanced Research Projects Agency (DARPA). This case has been extensively researched in the CSTI debate to affirm the persistence in the neoliberal era of a 'hidden developmental state' in the US (Block 2008) and the role of the 'entrepreneurial state' in 'shaping rather than fixing markets' (Mazzucato 2011). However, the debate has often missed out on the rationale that made DARPA's operations particularly successful in this context. An exception is the study by Fuchs (2010), which interprets them as a form of 'embedded network governance' where programme managers 'rearchitect social networks among researchers so to identify and influence new technology directions' for the fulfilment of a public goal (1145). For Fuchs, this model reflects 'a set of lasting, informal institutions' that outlasted changes in DARPA's leadership and established routines (1134).

Drawing on archival evidence, Fuchs (2010) shows how DARPA's managerial approach has developed since the 1960s with several directors encouraging a reliance on scientifically respected, independent programme managers, even as DARPA's organisational priorities changed to best support the US' innovation ecosystem during and after the Cold War. On the one hand, directors developed DARPA's peculiar management approach to steer the capabilities of its managers around broad-based goals (C1) while empowering them with the autonomy to experiment (E1): in the 1960s, as today, 'It really comes down to [having] a program manager that has a passion for an idea, that understands the technical elements of an idea, and has some vision for where it might go' (1145). On the other hand, directors frequently adapted (L1) and rearranged (R1) organisational routines to ensure that DARPA programme managers' activities reflected the changing priorities of the time – be it in terms of sectoral focus (military versus industrial) or technology readiness level (basic versus applied research). As Keller et al. (2023) highlight, 'Policy-makers and agencies diffused established models and experimented with new tactics in efforts to meet perceived challenges' in what turned out to be a 'gradual and layered' rise (9).

On top of management, Fuchs' argues that DARPA managers enforced governance relationships with its external partners to enable them to steer the identification, testing, revision and broad validation of emerging directions for technology development, i.e. they acted as experimentalist principals. To do so, they fostered experimentation across many project portfolios and propelled learning across them with respect to similar technological domains (cf. Bonvillian 2018). This is done in five processes that reflect the mechanisms of experimentalism: 'identifying directions for technology development' (C2); 'seeding joint research themes' (E2); 'building community by supporting knowledge flows' as key to enable peer learning (L2); 'providing validation for new directions' to revise emergent technological trajectories (R2); and 'discontinuing unpromising technologies' to ensure that the overall governance process creates effective dynamic accountability between, on the one hand, the programme managers leading project portfolios and, on the other, external partners carrying out projects.

Historically, DARPA showed an impressive track record in catalysing ground-breaking technological trajectories and transitioning early-stage ideas up to development and commercialisation, including laser, Internet, personal computer and smartphone-related

technology (Fuchs 2010). As shown in neo-developmental state literature (Block 2008; Block and Keller 2011), this is reflected into a policy rationale that helps actors navigate market uncertainty by 'opening new windows' (C3); setting boundaries to experimentation through 'targeted resourcing' (E3); stimulating the formation of interdependencies among stakeholders by 'brokering' opportunities for learning (L3); and removing legal, economic, institutional barriers to the integration of their efforts in the 'facilitation' of the innovation process (R3). As found by Whetsell et al. (2020) in the case of SEMATECH for semiconductor manufacturing, the outcome is the state-led catalysis of new networks targeting shared objectives: in other words, innovation commons.

4.2 China: Torch Programme's experimentation under hierarchy

The second illustration concerns China, a country in which scholars have detected major components of experimentalism across different policy areas, including the dynamics behind the restructuring of state-controlled enterprises; the liberalisation of foreign investment and trade; the toleration and promotion of private businesses; the introduction and regulation of stock regimes; and the development of new innovation strategies (Heilmann 2008a; Heilmann 2008b; Ang 2016; Zhang et al. 2022). Accounting for the peculiar Chinese institutional context, this phenomenon has been defined as 'experimentation under hierarchy' (EUH): 'a process of policy generation that legitimizes local initiative while maintaining ultimate hierarchical control' (Heilmann 2008b, 1). While a rational policy process is traditionally expected to flow in a linear fashion from formulation to implementation, EUH suggests that the Chinese government has often executed the opposite: 'innovating through implementation first and drafting universal laws and regulations later' (Heilmann 2008a, 4).

It is important to contextualise this within the distinctive mechanisms of the Chinese bureaucracy. As Ang (2016) puts it, EUH is made possible by the ongoing interplay between the 'direction' set at the central level of government and the ensuing 'improvisation' that emerges at the lower levels of government in response to 'locally specific and ever-changing problems' (17). First, the design of national reform packages is often premised on 'experimental regulations' which define goals for local policymakers without imposing clear rules on how to achieve them (C1). Second, the implementation is structured around 'experimental points' or 'zones' that see local policymakers testing their preferred strategies and solutions in practice (E1). Third, the results of the experimentation stimulate learning processes that lead to the expansion of successful models 'from points to surface': that is, via replication (L1). Fourth, extensive processes of inter-ministerial review may underpin the codification of new policies in national regulation (R1) (Heilmann 2008a). Among many factors enabling such interplay, including, most prominently, the stability secured by the authoritarian integration of party and state structures (Heilmann 2008b, 16), a key role has been played by a multi-layered cadre evaluation and compensation system that distributes to, and withholds from, local bureaucracy economic incentives, forms of political patronage and opportunities for career advancement (see Drechsler 2015).

In the context of this paper, a relevant illustration of how EUH contributes to innovation policy can be found in the Torch Programme, first initiated in 1988 and lasting up to the 2010s (Heilmann et al. 2013). The Torch Programme was launched to promote R&D commercialisation in High-Technology Zones, the administration of which was intentionally left to local administrations and barely endowed by central government funding (C2). In response to this, local administrations developed markedly different strategies, including in terms of

organisational patterns, policy mixes and stakeholders to be targeted (e.g. start-ups, firms or universities) (E2). Frequent central-local communication was enabled by several mechanisms for horizontal and vertical learning, including liaison officers, national associations and joint conferences of High-Technology Zones directors (L2). Taking stock of the emerging outcomes (including substantive departures from the programme's original objectives), central government redefined its priorities several times to streamline policy dissemination 'from points to surface' (R2).

As highlighted by Heilmann et al. (2013), 'the mission drift observed in many [Zones] resulted from the discovery of tangible economic potential [...] that had not been recognized by national policy-makers beforehand' (915). In particular, the Torch Programme's High-Technology Zones produced a disproportionately strong contribution to the rise in Chinese exports of technology-intensive products (from 2% in 1995 to 16.7% in 2009 over total exports) relative to its costs for central government. While its results in promoting 'indigenous innovation' have been comparatively limited, the Torch Programme succeeded in identifying new directions for local partners to invest in (C3); provided them with the freedom to define specific boundaries for experimentation (E3); stimulated learning across different attempts (L3); and enabled them to adapt the institutional landscape accordingly (R3).

4.3 The EU: RIS3's entrepreneurial discovery process

The third illustration is the EU's Research and Innovation Smart Specialisation Strategy programme (RIS3), which has informed the Commission's cohesion policy approach since 2014. The RIS3 approach centres on the provision of technical guidance and economic support to regional governments across the EU to develop and implement 'place-based economic transformation agendas' (Foray et al. 2012, 8). Each regional agenda is expected to identify targeted forms of 'policy support and investments on regional priorities, challenges and needs for knowledge-based development [...] and] get stakeholders fully involved [in the process] to encourage innovation and experimentation' (Foray et al. 2012, 8). By doing so, they are expected to accelerate the Entrepreneurial Discovery Processes (EDP) in which 'entrepreneurial actors [...] play leading roles in discovering promising areas of future specialisation' thanks to the facilitation provided by the public sector in developing shared agendas, coordinating key private stakeholders and providing opportunities for joint learning (Foray et al. 2009).

Originally emerging from the work of Expert Groups convened by the European Commission's DG for Research and Innovation in the early 2010s, the RIS3 approach was mainstreamed in EU regulation in 2014 as a precondition for regions to access the European Regional Development Fund – the main source of EU cohesion policy in the latest Multiannual Financial Frameworks (2014-2020; 2020-2027). While the RIS3 approach covers all regions, its main targets are the less developed ones, which, in line with cohesion policy, receive the largest share of funding. However, those regions are often also those with comparatively weaker capacity to make strategic use of funding (Oughton et al. 2002; Marques and Morgan 2018). Acknowledging this condition, the Commission has set up several solutions to help EU regions prompt and govern the institutional changes required to implement effective RIS3 agendas. First, the Commission set up for EU regions the ambitious but ill-defined goal of 'smart specialisation' (C1) along with ample autonomy to contextualise and operationalise it (E1). To support regions in this effort, it provided them with extensive guidance on how to do so, for example with step-by-step process outlines (Foray et al. 2012). Second, the Commission also put in place a 'smart specialisation platform' (now 'S3 community of practice') that aims to enable peer learning among regions (L1), as well as map, analyse and revise the results of the RIS3 approach as a whole (R1).

As mentioned before, the premise of the RIS3 approach is a public governance strategy that aims to boost 'entrepreneurial coordination within a framework structured by the government' – hence in a way that is 'neither purely bottom-up [...] nor totally top-down' (Foray 2018, 828). From this perspective, most of the six-step process that underpins the bulk of the S3 approach reflects experimentalist mechanisms, including the 'production of a shared vision on the future of the region' (C2); the 'establishment of suitable policy mixes' for multi-stakeholder experimentation (E2); the 'integration of monitoring and evaluation mechanisms' during the strategy implementation process (L2); and the 'selection of a limited number of priorities' against which to revise emerging results halfway and at the end of each strategy period (R2) (Foray et al. 2012).

Scholars have interpreted the impact of the RIS3 approach on place-based structural transformation in diverging ways. At its best, RIS3's conditionality has been able to provide an 'external induced shock that shaped "exogenously" the policy learning process' (C1) even in those regions where there has been 'more experimentation of tentative models' of EDP 'than consolidation of a permanent discovery routine' (E3) (Bellini et al. 2021, 424). At its worst, it has failed to translate into policy measures that reflect the intended priorities, with 'tangible signs that regions [may] have put in place mechanisms that can circumvent the very rationale' of RIS3 (Gianelle et al. 2020). In this respect, the cases that seem most successful are those that highlight the regional government's ability to nurture effective 'policy network learning' among its external partners (L3) and build on their contribution to adapt the strategy accordingly (R3) (Moodysson et al. 2017).

5. Summary and discussion: varieties of (embedded?) experimentalism

The pre-study of these three STI policy schemes demonstrates how experimentalism has been adopted in different institutional environments. At the same time, it also shows that such attempts have met with various degrees of success in terms of embedding them within such environments (see Table 4).

- The DARPA case is the quintessential success story of CSTIP, showing all the three dynamics highlighted by the EE framework: i) strategic learning takes place among DARPA directors and programme managers; ii) dynamic accountability is ensured by active portfolio management and stage-gating of funding for external partners; and iii) innovation commons emerge as a result of the set of incentives thus generated – as in the SEMATECH case.
- The Torch Programme provides a successful, yet relatively mixed, picture: i) strategic learning happens through continuous feedback loops between the central and local level of the Chinese bureaucracy; ii) dynamic accountability is ensured by strong career and economic incentives, albeit there is a weaker connection to learning than in the DARPA case; and iii) innovation commons fail to emerge as a new, more relevant strategic purpose for the programme emerges.
- Lastly, the RIS3 case highlights best the challenges of embedding experimentalism at scale: i) strategic learning among EU regions and between regions and the Commission is only weakly ensured by the voluntary nature of the participation in the community of practice; ii) dynamic accountability is in principle ensured by the funding conditionality, but – as noted – limited by the disconnection to effective learning mechanisms; and iii) as such, whether innovation commons emerge or not may depend on each region's commitment to experimentalism.

Table 4. Comparative assessment of embedded experimentalism

Experimentalism	(US) DARPA	(CH) Torch	(EU) RIS3
Strategic learning	Strong	Strong	Weak
Dynamic accountability	Strong	Medium	Weak
Innovation commons	Strong	Weak	Weak

Source: Author's elaboration based on the previous section's empirical analysis

The pre-study also demonstrates the theoretical and analytical value of the EE framework in at least three ways: first, by identifying the distinctive nature of each case's micro-foundations; second, by enabling their comparative review; and third, by illuminating their distinctive strengths and weaknesses towards producing embeddedness. This section briefly reviews each of these (see Table 5).

First, the EE framework identifies the micro-foundations of STI policy, i.e. how policy is grounded in governance arrangements and governance arrangements are reflected in management approaches. The US illustration highlights the role of DARPA directors in deliberately nurturing and steering the dynamic capabilities of the organisation, including in the composition of its personnel (i.e. a cadre of technology experts), decision-making processes (i.e. changing forms of technology road mapping and stage-gating) and policy tools (i.e. new forms of public procurement). The China illustration shows how the Torch programme would likely not have achieved its successes without drawing upon well-consolidated institutions at both governance (i.e. 'from points to surface') and management level (i.e. the cadre evaluation systems). Finally, the EU illustration underlines how the effectiveness of the RIS3 approach is ultimately dependent on its own ability to trigger governance change at the regional level, be it via the situational reliance of each region on multiple forms of policy support (i.e. RIS3 guidance) or peer learning (i.e. community of practice).

Second, the EE framework enables a comparative review of STI policy that highlights how the same policy, governance and management functions can be performed in different ways in different political, economic and geographical contexts. As a result, it also allows for the identification of 'varieties of experimentalism' that share a similar rationale, despite very different institutional characteristics. The US illustration highlights a form of 'administrative' experimentalism led by a technocracy relatively siloed from the political debate and targeting technological objectives. The China illustration identifies a form of 'political' experimentalism prompted and seized on by the state's central executive branch to attain transformative goals. Finally, the EU illustration shows a form of 'politico-administrative' experimentalism, the implementation of which is negotiated among multiple actors (experts, civil servants, policymakers) at local and continental level, and varying degrees of political visibility.

Third, the EE framework illuminates the strengths and weaknesses of each instance of experimentalism relative to its objectives. In this respect, a core mediating factor seems to be not the distinctive variety of experimentalism, as much as the degree of embeddedness presented by each variety. In the US, the ability of DARPA's approach to continuously achieve outstanding results is connected to the ability of its management to balance out continuous adaptation to new priorities with preservation of policy and governance institutions (Bonvillian 2018). In China, the Torch Programme has both met difficulties in advancing indigenous innovation and been caught under the pressure of growing 'political and legal constraints' that narrowed its relevance (Heilmann 2008a; Ang 2016). In the EU, the quality of the RIS3s varied from region to region, thus leading to key questions about its ability to prompt the embedding of a new governance approach to economic development at the regional level.

Table 5. Comparative analysis of embedded experimentalism

Experimentalism	(US) DARPA	(CH) Torch	(EU) RIS3
Micro-foundations	Organisational	Institutional	Situational
Contextualisation	Administrative	Political	Politico-administrative
Embeddedness	High	Varying	Weak

Source: Author's elaboration based on the previous section's empirical analysis

It is important to express caution in that this discussion is grounded in a pre-study based on existing work. A fully fledged comparative case study analysis is needed to qualify both the EE framework and its three hypotheses. At the same time, the scope of the pre-study yields at least three provocations.

- The theoretical provocation lies in the implications of democracy for CSTIP implementation. As seen earlier (Breznitz and Ornston 2018), the greater need for accountability imposed by democracy seems to tighten the trade-off identified by Radosevic et al. (2023) relative to technocratic (DARPA) or autocratic (China) institutions.
- The empirical provocation concerns the relative irrelevance of scale for successful CSTIP implementation. DARPA and China provide examples of EE addressing strategic uncertainty at both micro- and macro-scale. The main weakness of the RIS3 approach seems to lie in the lack of routines and mechanisms to help regions nurture their DCs, rather than width.²
- Last, the policy provocation concerns the dynamics through which innovation can emerge in a PSO. While the earlier points may seem to cast a shadow on the prospects for EE in liberal-democratic PSOs, there are cases showing how such bureaucracies have been transformed to cope with uncertainty across policy domain and administration tradition (Rangoni 2022; Sabel and Victor 2022). While these dynamics are always in the end a combination of deliberate and emergent dynamics (Mintzberg and Waters 1985; Sabel 1995), the EE framework aims to help practitioners navigate the variables and interdependencies behind such dynamics.

Rather than imposing a blueprint, the EE acknowledges the role of individual and collective agency in experimenting and ‘tilting’ the norms, resources and routines available in a given context as the main way by which new institutional solutions can be advanced (Sewell 1992; Carstensen et al. 2022).

² This insight is critical in the context of today’s EU innovation policy, which includes programmes with a strong translocal dimension in several ongoing programmes of EU Horizon 2020 (see Kok et al. 2022), as well as in the five so-called Horizon Europe ‘missions’, for example ‘100 Climate Neutral and Smart Cities Mission’ (see Shabb et al. 2022).

6. Conclusions

While recent calls for new forms of STI policy aim to help govern current societal transformations, researchers and practitioners have struggled with developing diagnostics that articulate these ambitions into actionable strategies for public action. Scholars are working on different forms of CSTIP to enable the progress of this critical policy agenda (Ghosh et al. 2021; Larrue 2022; Haddad and Bergek 2022; Elzinga et al. 2023; Borrás et al. 2023). However, a framework to map out how CSTIP may lead to the co-evolution of administrative and societal action, and become institutionalised practice, is missing. In a pathbreaking study, Evans (1995) argued that ‘bureaucratic structures [can] create an affinity [or mismatch] between the incentives facing state managers and the policies required for capitalist growth’ – thus calling for a bureaucracy ‘embedded’ in the processes of market formation and yet ‘autonomous’ in its ability to define and implement independent policy goals (30). Today, it is unclear whether this solution is enough. The co-evolution of bureaucratic and economic processes is still seen as key to structural transformation (Kattel and Mazzucato 2018). Yet, whereas Evans (1995) referred to the ‘Weberian’ bureaucracy as an enabler of ‘embedded autonomy’, research proves it to be least likely to implement CSTIP for its rigidity and restrained administrative discretion (Braams et al. 2021, 2022). The debate on the rise of a ‘Neo-Weberian’ paradigm is open (Kattel, Drechsler and Karo 2022), but there is little clarity on how to trace its emergence in theory and evaluate current action in practice.

In this paper, I have argued that a strategy for addressing these gaps and supporting the implementation of CSTIP already exists but is ‘hidden in plain sight’ due to severe fragmentation among multiple epistemic communities involved in the debate. Paraphrasing Evans (1995), this strategy can be defined as ‘embedded experimentalism’ (EE): a framework of bureaucratic action ‘embedded’ in the processes of market formation, and ‘experimentalist’ in its ability to define and implement independent policy goals and to revise them through learning. EE has three micro-foundations: ‘innovation commons’ as a set of incentives (Potts 2019); ‘dynamic accountability’ as an organisational structure (Sabel and Zeitlin 2012); and ‘strategic learning’ as a form of deliberation (Boin and Christensen 2008). The implication of the argument is two-fold. On the one hand, it identifies the ‘original sin’ of CSTIP in PSOs’ inability to handle strategic uncertainty (Braams 2023). On the other, it identifies its resolution in the deliberate attempt to leverage experimentation as the trigger of an evolutionary process that can transform PSOs themselves by means of strategic learning (cf. Bodrozic and Adler 2018). The conclusion is counter-intuitive: the more transformative the goal of a policy, the more limited the use of long-term planning and the greater the role of learning by experience (cf. Hirschman and Lindblom 1962). Clearly, this paper has several limitations.

- First, the role of power should be further discussed and accounted for more extensively. To be clear, a premise of experimentalism is that when collaboration is not the first option by external actors, PSOs may adopt ‘penalty defaults’ to impose unfair costs on withdrawal from collective action (cf. conditionalities in Mazzucato and Rodrik 2023). Yet research shows this is often obstructed by vested interest (Geels 2014; Avelino 2017). Thus, the political economy of experimentalism should be explored to test whether and how EE can itself transform individual interests to forge coalitions transcending the dichotomy between incumbents and challengers (Ansell and Bartenberger 2016; Mukand and Rodrik 2018).
- Second, the theoretical apparatus behind EE requires empirical validation in the CSTIP context both relative to its hypotheses and to the whole framework. Evidence of successful EE is broad and large (Sabel and Victor 2022). Yet its argument has never been

contextualised within the CSTI literature with the granularity attempted here, hence the need for empirical research.

- Third, and relatedly, the framework needs a stronger operationalisation of the EE hypotheses. This can be done by building on available solutions in the literature, including commons-like design principles (Ostrom 2010), experimentalist functions (Rangoni 2019) and institutional design principles (Boin et al. 2021), and integrating outcomes with contemporary CSTIP research, for example transformative outcomes (Ghosh et al. 2021).

Despite these limits, this paper provides a key contribution to the current debate in at least three ways: i) grounding the 'boundary object' of CSTIP into a hypothetical theory of change; ii) identifying the micro-foundations that enable (or prevent) its implementation within PSOs; and iii) showing how such theory of change can be used to assess STI policy past and present. In this sense, EE identifies multiple exciting lines for future research at the crossroads of innovation, governance and public administration studies. From a theoretical perspective, these include: i) deepening the analysis of the role of learning (organisational and societal) in advancing sustainability transitions (van Mierlo and Beers 2020); ii) exploring new forms of accountability as a solution to the constraints imposed by administrative traditions (Braams et al. 2023); and iii) exploring the link between uncertainty in market formation processes and the role of the state in 'orchestrating' them (Gomes and Barros 2022). From an empirical perspective, these include the chance to rely on the EE framework for the systematic analysis, comparison and evaluation of the many initiatives in the CSTIP space at the three levels of policy, governance and management. At the time of writing, more than 80 'net-zero missions' that leverage CSTIP ideas are being deployed in 20 OECD countries to achieve radical carbon emissions reductions in a short to medium timeframe (Larrue 2022). By opening up a new research agenda for 'taking implementation much more seriously' (Kattel and Mazzucato 2023, 14), I hope that this paper can provide researchers and practitioners with a cohesive foundation for studying them holistically and contributing to their ability to fulfil their intended promise to public value.

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