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Designing fit-for-context climate change adaptation tracking: Towards a framework for analyzing the institutional structures of knowledge production and use

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ABSTRACT

The Paris Agreement encourages countries to monitor and regularly report on their progress in responding to the impacts of climate change. So far, discussions on adaptation tracking have focused on the technocratic reasons for limited progress on adaptation tracking, for example, financial, methodological, and technical capacity gaps. Substantial variation exists in the institutional context within which adaptation takes place and is being tracked. Yet, recent discussions overlook the importance of the extent to which new systems of adaptation tracking fit within the prevailing rules and practices of knowledge production and use. Although such a fit-for-context approach has been considered important in other fields, no adequate frameworks exist to operationalize it within adaptation tracking. We develop a six-dimensional framework for analyzing institutional structures as the first step towards alignment in the design and use of adaptation tracking: 1) stakeholder participation, 2) transparency, 3) bureaucratic accountability, 4) engagement with experts, 5) politico-administrative relations, and 6) coordination within the administration. For each dimension, we synthesize academic literature, provide variables for operationalization, and provide examples drawn from various regions. The resulting framework allows the description of the institutional structures of knowledge production and use and supports the context-specific design of new programs, tools, and practices for tracking adaptation progress.

1. Introduction

Governance by disclosure has become a popular mechanism for catalyzing action and keeping countries accountable to their peers and their constituents. Although there are no 'hard' sanctions for not fulfilling commitments made, disclosure mechanisms aim at raising ambitions and enhancing accountability through informal praising and shaming of government efforts as information on their performance becomes accessible to other state and non-state actors (Gupta and van Asselt, 2019; Karlsson-Vinkhuyzen et al., 2018; Weikmans et al., 2020). While recognizing the varying capacities among countries, the Paris Agreement requires countries to submit Nationally Determined Contributions (NDCs) to communicate their ambitions for climate action and regularly report on progress and achievements through the Enhanced Transparency Framework (ETF). Although making adaptation commitments and reporting on

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adaptation is voluntary, many countries have included adaptation commitments in their NDCs (UNFCCC, 2021) and discussions are underway on how to monitor and evaluate progress towards enhancing adaptive capacity, strengthening resilience, and reducing vulnerability. This process of assessing adaptation progress and reporting on achievements is known as *adaptation tracking* and involves the systematic application of tools to monitor and evaluate progress across broad spatial and temporal scales (Berrang-Ford et al., 2019; Ford et al., 2013)[1]. The Paris Agreement encourages countries to submit and regularly update Adaptation Communications (UNFCCC, 2015, Article 7.10). Thereafter, a constituted body will use multiple information sources, including national communications such as Biennial Transparency Reports and reports from non-state actors, to determine collective progress on adaptation through the global stocktake (Adaptation Committee, 2021). As a process of monitoring and making information on countries' efforts towards adaptation available, adaptation tracking is a crucial component of the ETF.

But tracking progress is not necessarily simple. Literature indicates a range of conceptual, methodological, empirical, and political challenges. These include, inter alia, lack of consensus on the definition of key concepts around adaptation tracking, uncertainty and complexity inherent in evaluating an ongoing process with shifting baselines, diversity of contexts and scales within which adaptation takes place, lack of universally applicable methodologies for tracking adaptation, and data limitations (Berrang-Ford, 2017; Bours et al., 2014; Craft and Fisher, 2018; Dilling et al., 2019; Ford et al., 2015). To address some of these challenges and to advance reporting on adaptation, practitioners and scholars are discussing how to design adaptation tracking. However, most adaptation tracking discussions focus on technicalities, primarily through the development of adaptation tracking frameworks that are applicable across countries and emphasize the need for capacity-building (e.g., Klostermann et al., 2018; Olhoff et al., 2018; Tompkins et al., 2018). These discussions are based on the presumption that the limited progress in adaptation tracking is attributable to technical capacity gaps such as knowledge, staff, time, financial resources, and monitoring tools. For instance, Klostermann et al. (2018) propose a common framework for designing adaptation monitoring and evaluation. The framework recommends the use of local research and stakeholder participation to define adaptation and the elements to be monitored, the designation of a trusted and independent organization to monitor and report on adaptation, and the adoption of a flexible monitoring approach. While these are useful recommendations, it is highly uncertain to what extent existing institutional structures in different countries would adequately be able to support them.

We argue that efforts to design and implement adaptation tracking tend to overlook the broader question of institutional alignment and fit: the compatibility between the design of new adaptation tracking programs, tools, and practices, and the institutional structures already in place, such as formal rules, processes, relations, meanings, and practices for collecting, analyzing and using policy-relevant knowledge (Hargadon and Douglas, 2001; Howlett, 2018). Countries have unique ways of producing and using knowledge which are codified in their institutional structures through formal and informal rules (Howlett, 2018; Howlett and Tosun, 2019). These institutional structures play an important role in determining the diversified response to policy issues, including climate change policies (Biesbroek et al., 2018a, 2018b; Vink and Schouten, 2018). Vink and Schouten (2018), for example, found that policy blueprinting, whereby certain adaptation planning criteria are forced on countries, creates institutional misalignment and potentially hampers progress and usefulness of adaptation (Vink and Schouten, 2018). Similarly, in a study of biotechnology knowledge production and use in the US, Britain, and Germany, Jasanoff (2005) found that the three countries have distinct styles, which she associated with variation in the formal and informal rules in place (Jasanoff 2005).

Prevailing institutional structures are thus important to consider in the design of new adaptation tracking programs, tools, and practices, since, for instance, having in place climate change laws and plans that outline knowledge production mandates, level of advancement in the design and implementation of knowledge production systems, and the purpose for which these systems are designed are found to matter (Hammill and Dekens, 2014; Leiter, 2021; Price-Kelly et al., 2015). Strengthening institutional alignment may enhance bureaucrats' willingness and ability to implement adaptation tracking while reducing potential conflicts by building on established knowledge production mandates thus, contributing to the continuity and effectiveness of adaptation tracking (Howlett, 2018; Leiter, 2021). Bureaucrats' willingness and capacity are vital given the nature of actor relations required for the government to provide a nationwide account of progress in adaptation, including understanding the effects of adaptation policies among its diverse constituents (Ford et al., 2013).

Although some studies like Hammill and Dekens (2014) and Price-Kelly et al. (2015) consider institutional context as an important dimension in the design of national adaptation tracking systems, they tend to focus on the policy context of adaptation tracking, the rationale behind tracking, and the purpose and scale of application. These studies, therefore, omit critical aspects such as the broader institutional structures within which the adaptation tracking systems are embedded and, in turn, the suitability of those systems. Therefore, despite evidence in broader policy studies literature about the importance of institutional alignment and fit (Hargadon and Douglas, 2001; Howlett, 2018; Howlett and Tosun, 2019), and for national adaptation tracking in particular (Hammill and Dekens, 2014; Leiter, 2017), there are no frameworks for systematically and comprehensively analyzing institutional alignment. To fill this gap, we develop a six-dimensional framework for characterizing the institutional structures of producing and using policy knowledge that is relevant for adaptation tracking, as the first step towards strengthening alignment in designing adaptation tracking.

In Section 2, we introduce the general principles of the framework and the underlying assumptions. In section 3, we discuss the

[1] Although the process of monitoring and reporting on adaptation under the Paris Agreement is also commonly referred to as adaptation monitoring and evaluation (M&E), authors prefer to use the term *adaptation tracking* to distinguish the process from the traditional M&E which is often associated with interventions monitoring and evaluation within programs and projects. Although adaptation tracking is a subcomponent of M&E (Berrang-Ford et al., 2019; Ford et al., 2013), the two differ. Adaptation tracking involves broader temporal and spatial scales that go beyond the typical time and spatial boundedness of programs and projects.

relevance of each of the six dimensions for adaptation tracking and review diverse streams of academic literature to identify the key variables for operationalizing the dimensions. In section 4, we reflect on the implications of this framework for adaptation tracking and discuss opportunities for further research.

2. Theoretical foundations of the framework for examining institutional structures of knowledge production and use

There are two main aspects of institutional structures that are critical for knowledge production and use: the interaction between the government and society, and how the government is organized internally. The interactions between government and society are important as they influence how knowledge is produced and used, including integrating the adaptation experiences and needs of non-state actors. Adaptation tracking also requires collaboration within the government to account for the activities of the various sectors and to ensure that there is adequate government support towards the production and use of knowledge related to adaptation tracking, making intra-governmental dynamics and relations equally important.

To understand the relations between the government and society, we draw from Science and Technology studies which are concerned with the mutual relationship between social contexts and knowledge (Gupta et al., 2012; Jasanoff, 2004). The concept of civic epistemology, in particular, captures the institutionalized relations between the government and non-state actors in the production, dissemination, and use of knowledge (Jasanoff, 2005). Perspectives and narratives are found to be established, reinforced, or changed through such relations as they determine which knowledge claims are considered legitimate and credible (Jasanoff, 2005). This concept positions adaptation tracking within state-society relations, focusing on the various stages of the knowledge production cycles, including decision making on what knowledge is produced, development of tools, knowledge production, validation, dissemination, and use. From this literature, we identify four relevant dimensions (Table 1). The first dimension is stakeholder participation in knowledge production and use (Jasanoff, 2005). We define stakeholders as those societal actors who affect or are affected by a particular adaptation decision, and they vary depending on the sector and system of interest (Kaur and Lodhia, 2018; Reed, 2008). For this dimension, we have drawn on relevant points of consensus in the diverse literature that addresses stakeholder participation (e.g., Ayantunde et al., 2015; Glucker et al., 2013; Luyet et al., 2012; Reed et al., 2008). The second dimension is transparency, by which we understand the accessibility of government-held knowledge by non-state actors. Examples of literature that is relevant for this dimension include Meijer et al., (2018) and Meijer et al., (2012). The third dimension is bureaucratic accountability, which subsumes several elements discussed by Jasanoff (2005), including measures of objectivity and credibility. For this dimension, we draw on the literature that focuses on the arrangements for keeping the behavior of bureaucrats in check (e.g., Bovens, 2007, 2010; Mees and Driessen, 2019; Brandsma and Schillemans, 2013). The fourth dimension considers how knowledge and expertise get into bureaucracies. For this dimension, we draw on the literature on Policy Advisory Systems (PAS), which is concerned with the constellation of actors who guide policymakers (e.g., Craft and Howlett, 2013; Howlett and Migone, 2017; Howlett and Fraser, 2014; Veselý, 2013).

To understand how governments are organized internally, we primarily draw on public administration and public policy theories which are concerned with the underlying administrative routines and institutions that influence policymaking and implementation. From this literature, we identify two dimensions that are relevant for knowledge production and use within the government: the relations between political and bureaucratic realms and coordination within the administration (Jamil et al., 2013; Painter and Peters, 2010a). Concerning the relations between political and administrative realms, which is the fifth dimension, we draw on literature that characterizes the politico-administrative linkages (e.g., Ayee, 2013; Demir, 2009; Svara, 1999). In addition to the literature on coordination among government agencies as the sixth dimension (e.g., 6, 2004; Peters, 2018; Peters, 1998), we also use literature that discusses data sharing within governments (e.g., Bellamy et al., 2008) and institutional logics in knowledge management (e.g., Laihonen and Huhtamäki, 2020; Laihonen and Kokko, 2019).

The proposed framework, therefore, has six dimensions: 1) stakeholder participation, 2) transparency, 3) bureaucratic accountability, 4) engagement with experts, 5) politico-administrative relations, and 6) coordination within the administration. As shown in

Table 1
Summary Table of Dimensions and Variables for Characterizing Institutional Structures of Knowledge Production and Use.

Dimension	Definition	Variables
Stakeholder participation in knowledge production and use	Engagement between the government and relevant stakeholders in knowledge production and use	Nature of participation Participation criteria
Transparency	Accessibility of government-held knowledge by non-state actors	Established transparency rules Characteristics of accessible knowledge
Bureaucratic accountability in knowledge production and use	Mechanisms for holding bureaucrats accountable in their activities of producing and using knowledge	Established knowledge production standards and procedures Accountability forums
Engagement with experts in knowledge production and use	Modalities of engagement with individuals or organizations that government relies on for specialized advice on knowledge production and use	Location of experts relative to the bureaucratic structure
Politico-administrative linkages in relation to knowledge production and use	Interactions between the political and administrative realms of the government and their implication on knowledge production and use	Bureaucratic autonomy
Coordination within the administration in knowledge production and use	Interactions between interdependent administrative units and how they consider each other's decisions and actions in knowledge production and use	Administrative structure Degree of formalization of coordination

Table 1, we also adapted the framing and the definitions of the dimensions to limit the focus to knowledge production and use.

There are several underlying assumptions in this framework. First, countries have distinct and internally heterogeneous combinations of these six dimensions because of differences in governance and administrative systems as well as due to external influences (e.g., international agreements and the rise of new public management) (Dubash, 2021; Howlett, 2002; Painter and Peters, 2010b). We recognize that countries may vary along a spectrum within the dimensions. Contrary to deficit models that see divergence from an ideal characteristic as inadequacy, our 'scores' are descriptive and have no basis that supports a normative evaluation of the prevailing institutional structures. Second, although countries might undergo reforms that influence these dimensions, change typically follows the existing rules and practices, which strongly suggests path dependency in the institutionalization of policy innovations (Dubash, 2021; Pierson, 2000). Third, the framework aims to capture the formal and informal rules which we presume determine the behavior of government officials in knowledge production and use. However, we recognize that actors' behavior is also key in setting the course for deviating or following what is prescribed by the formal and informal rules (Howlett and Tosun, 2019). Fourth, the framework identifies the rules of knowledge production and use, thus broadening the focus beyond ad hoc practices such as those associated with project monitoring and evaluation. Fifth and finally, the framework is scale neutral and can be applied to one or multiple levels of government. While discussions on adaptation tracking primarily focus on the national level, this framework intends to capture how other scales within which adaptation takes place are incorporated in knowledge production and use as this will affect their inclusion in adaptation tracking.

3. The six-dimensional framework for characterizing the institutional structures of knowledge production and use

In this section, we elaborate on each of the six dimensions. We start by defining the dimension, how it relates to adaptation tracking, followed by one to two variables that can be used to characterize it. We also outline possible variations and draw on cases from different geographical regions to show how countries may vary along the dimension.

3.1. Stakeholder participation in knowledge production and use

This dimension is concerned with the engagement between the government and relevant stakeholders in designing, producing, and using knowledge (Jasanoff, 2005; van Kerkhoff and Pilbeam, 2017).

Adaptation strategies should ensure that stakeholders effectively respond to climate risks, underscoring their critical role in planning and assessing the outcomes of adaptation policies, interventions, and practices (Dilling et al., 2019; Falzon, 2021). Stakeholder participation can facilitate the integration of multiple knowledge types in vulnerability and adaptation assessments, thus offering a better understanding of the various priorities and experiences (Falzon, 2021). For instance, integrating contributions formed through contextual perspectives and experience has been found to lead to holistic indicators (Reed et al., 2008) and could be a strategic approach to identifying appropriate indicators for adaption tracking. Stakeholder participation could also enhance the consideration of dimensions that are critical for adaptation, including contextualized understanding of adaptive capacity and the socially differentiated adaptation strategies and aspirations (Dilling et al., 2019). Participatory processes contribute to knowledge exchange on experiences and adaptation strategies and could facilitate closer collaboration between the various stakeholder groups in addressing climate vulnerability (Ayantunde et al., 2015; Fazey et al., 2010). However, participatory styles vary depending on external influence and the capacity of governments to steer participation processes (Holler et al., 2020; Sherman and Ford, 2014). Two variables help in understanding the engagement between the government and relevant stakeholders.

The first variable, the nature of participation, considers the influence stakeholders have in knowledge production and use (Fazey et al., 2010; Glucker et al., 2013; Hassenforder et al., 2015; Luyet et al., 2012; Rowe and Frewer, 2005). For instance, when the objective is to have stakeholders substantially contribute to knowledge production, they are likely to be involved at the design stages, where they can influence the tools and indicators used as well as in knowledge production (Kaur and Lodhia, 2018). On the other extreme, stakeholders might only be seen as data sources or peripheral to knowledge production processes.

The second variable considers the criteria used to determine who participates. For stakeholder participation to be effective, a widely shared argument is that the participants should be representative of the broad population affected by a certain issue (Hassenforder et al., 2015) or have a specific goal of empowering the marginalized to engage in decision making (Glucker et al., 2013). As such, stakeholder selection criteria should be centered on making participation effective and fair, including organizing participation in a manner that encourages active contribution and consideration of heterogeneity among stakeholders (Ayantunde et al., 2015; Glucker et al., 2013; Hassenforder et al., 2015; Zuhair and Kurian, 2016). Although stakeholder participation in climate change adaptation is often concerned with the engagement with local communities, for adaptation tracking, determination of the relevant stakeholders should be based on the policy domain of interest and could include various stakeholder groups operating at various levels such as

Table 2
Varieties of Stakeholder Participation Styles.

Communicative	Consultative	Deliberative
Stakeholders are informed but have low influence on knowledge production and use. Lacks elaborate participation criteria.	Stakeholders have moderate influence at selected stages. Participation criteria are defined, but not necessarily representative.	Stakeholders have high influence on knowledge production including in designing and producing knowledge. Participation criteria are geared towards representative participation.

producers within agricultural systems, business operators at various stages of the value chain, or sub-national and national input suppliers.

Given the variables, the nature of participation and the identity of participants, we identify three examples of varieties of stakeholder participation styles (Table 2). Under the top-down communicative style (Luyet et al., 2012; Reed et al., 2018), stakeholders' degree of influence is limited since participation is only geared towards informing the stakeholders without really seeking their input in knowledge production. In such systems, there are no defined criteria that describe with whom the government engages (Reed et al., 2018; Rowe and Frewer, 2005). In the consultative style (Rowe and Frewer, 2005), the government informs and seeks input from stakeholders but only at selected stages of the process. For instance, stakeholders serve as sources of data, and in some cases, they engage in the validation of the knowledge produced. Often, defined criteria determine who participates in these consultative processes, although the input may not necessarily be representative (Brombal et al., 2017; Rowe and Frewer, 2005). In the deliberative style (Reed et al., 2018), stakeholders have shared roles with the government in designing and implementing knowledge production. Participation aims at allowing those who are engaged to have substantive influence, including in setting the objectives of knowledge production, co-designing tools, data collection, and translating knowledge into reports and decisions. The participation criterion involves deliberately seeking the representation of various stakeholder groups, and strategies are used to maximize their contributions. In a study of stakeholder engagement in sustainability reporting in Australia, Kaur and Lodhia (2018) found that the local councils had varying participatory styles, including the stages at which stakeholders were involved. In some councils, stakeholders who included local businesses, residents, and transient resource users participated in the selection of sustainability indicators and in developing sustainability reports, while in other councils the council leadership had authority over specific stages of the accounting and reporting process (Kaur and Lodhia, 2018).

3.2. Transparency

The second dimension considers the accessibility of government-held knowledge by non-state actors. Transparency can be proactive where the government voluntarily makes knowledge accessible or demand-driven, whereby government makes knowledge accessible following requests from stakeholders (Fox, 2007).

Transparency enhances the awareness of interested stakeholders on the state of adaptation within and beyond their local contexts, thus contributing to the gradual realization of the benefits of disclosure requirements while supporting the use of knowledge from adaptation tracking for sub-national and national adaptation planning (Gupta and Mason, 2014; Leiter, 2021). Transparency could also enhance the credibility of knowledge held by the government and the legitimacy of policy decisions and actions (Jasanoff, 2005). Making knowledge accessible has been argued to incentivize government integrity and effectiveness as information on government activities and outputs becomes accessible (Meijer, Curtin, and Hillebrandt, 2012; Ruijer and Meijer, 2016). The degree of transparency varies within and between countries depending on government capacity to process and publish knowledge and the extent of institutionalization of transparency requirements (Shao and Saxena, 2019; Tang and Jiang, 2020).

Two variables, rules governing transparency and the characteristics of accessible knowledge, are central to characterizing transparency. The first variable, the transparency rules, includes the formal rules that shape how knowledge is made accessible, such as the various forms of freedom of information legislation as well as informal rules that are formed through practice. These rules define the mandates for bureaucrats to support access to knowledge by assigning roles to individuals and administrative units while also outlining procedures for accessing that knowledge (Ruijer and Meijer, 2016; Shao and Saxena, 2019). Formal rules also reduce the perceived risks of transparency since bureaucrats have legal backing when sharing knowledge, and they have guidance on which knowledge should be made accessible and how (Huang et al., 2020; Shao and Saxena, 2019). Transparency rules may also help in setting the scope of transparency, thus avoiding overburdening bureaucrats with transparency demands, for instance, by requiring interested parties to meet specific requirements before they can access knowledge that is yet to be made public.

The second variable is the characteristics of accessible knowledge. This variable reflects an understanding of transparency that goes beyond mere openness to consider the appropriateness of the accessible knowledge to diverse users (Meijer et al., 2012). For instance, although websites and other online portals are some of the popular channels for transparency (Huang et al., 2020), tailoring strategies to make knowledge suitable to the diverse information needs and capacities of users is vital (Meijer et al., 2018; Shao & Saxena, 2019; Tang & Jiang, 2020). The timing and frequency at which knowledge is released are critical determinants of its usefulness, including the government's responsiveness to access requests (Schapper et al., 2021). For instance, Shao and Saxena (2019) find that the success of the Tanzania open government data initiative is hindered by multiple challenges, including poor data quality that is availed in technical formats that impede its further use.

Possible variations in government transparency are exemplified in Table 3. In closed systems, transparency is low since knowledge is essentially inaccessible (Fox, 2007; Ruijer et al., 2020). This closedness could be due to the absence of transparency rules assigning

Table 3
Varieties of Government Transparency.

Closed systems	Semi-open systems	Open systems
Rules on transparency are lacking or misused. There is none to little access to knowledge, thus low transparency.	Transparency rules exist but the nature of knowledge that is made accessible only supports moderate transparency.	Rules defining roles and procedures for accessing knowledge exist and are adhered to. Strategic measures are taken to make knowledge accessible and useful resulting in high transparency.

responsibilities and guiding bureaucrats' actions, inadequate compliance with transparency rules, or capacity limitations (Shao and Saxena, 2019). Bureaucrats may also exploit loopholes in existing rules to hinder transparency, for instance, by establishing overly bureaucratic processes or overusing disclosure exemptions (Schapper et al., 2021). In semi-open systems, bureaucrats release knowledge that does not necessarily reveal their actions (Greiling and Spraul, 2010). Here, transparency rules exist and, therefore, bureaucrats may only release knowledge as part of symbolic compliance resulting in moderate transparency. For instance, in a study of transparency in Taiwan, Huang et al. (2020) observed that, despite the enactment of Open Government Data (OGD) policies, bureaucrats show resistance by using workarounds, such as knowledge overload whereby they publish enormous amounts of knowledge, regardless of its usability. Under open systems, transparency is high, with bureaucrats adhering to established transparency rules and principles. There are clear mandates for bureaucratic units, and bureaucrats deliberately make knowledge accessible and usable. Strategies that have been argued to support this level of transparency include translating knowledge to overcome language barriers, releasing multiple formats to match the capacity and needs of different users, and simplifying accessibility requirements (Shao and Saxena, 2019; Tang and Jiang, 2020).

3.3. Bureaucratic accountability

This dimension is concerned with the bureaucrats' conformity to knowledge production standards and the forums for holding bureaucrats accountable for their actions (Bovens, 2010, 2007).

Accountability mechanisms oblige bureaucrats to adhere to set standards on the assumption that this enhances government effectiveness in knowledge production while boosting the credibility of knowledge produced (Bovens, 2007; Jasanoff, 2005; van Kerkhoff and Pilbeam, 2017). This dimension provides insight into the existing and acceptable knowledge production standards and the mechanisms for holding bureaucrats accountable. It also considers the overall effects of accountability on knowledge production and use, given that bureaucratic accountability could also constrain knowledge production, for instance, in rule-based systems where rule-following overrides effectiveness (Ruijer and Meijer, 2016). Therefore, whereas accountability is often thought to consist of an interest in conformity to set standards, from our perspective, it should be sensitive to the risks of impeding the innovations needed to address emerging knowledge needs. Two variables support the characterization of bureaucratic accountability.

The first variable considers the standards available, including the formal and informal rules and procedures, for knowledge production and use (Bovens, 2010; Lindberg, 2013; van Kerkhoff and Pilbeam, 2017). These standards define the roles of bureaucrats and establish criteria for evaluating their activities (Lindberg, 2013; Mees and Driessen, 2019). For instance, most countries have enacted laws that outline which data bureaucrats should collect, from whom, and how. The general mandate often lies with a central statistics agency with support from sectoral units. Some countries complement this by formulating climate change policies that allocate knowledge production mandates to new or existing administrative units (Klostermann et al., 2018).

The second variable is the existing processes or forums for holding bureaucrats accountable, particularly concerning bureaucrats' answerability for their actions and the consequences for any observed deviations from expected behavior (Bovens, 2007; Lindberg, 2013; Schillemans, 2016). The configuration of accountability structures varies, depending on a country's governance system (Brinkerhoff and Wetterberg, 2016). Accountability can be hierarchical, whereby subordinate bureaucrats are answerable to those higher in the ranks or more networked, whereby relevant state and non-state actors engage in mutual oversight and control (Mees and Driessen, 2019). For instance, Rwanda, Indonesia, the Philippines, and Guinea vary in various aspects, including the willingness and institutional capacity to support social accountability, which leads to variation in the role of the public and the responsiveness of bureaucrats to the public (Brinkerhoff and Wetterberg, 2016).

At least three variations in bureaucratic accountability are possible, as summarized in Table 4. In a system with low accountability, there are no defined standards, hence the ambiguity in bureaucratic mandates (Bovens, 2007; Han, 2020; Mees and Driessen, 2019). Little information is available on how bureaucrats should produce and use knowledge, it is unclear who holds them accountable, and even where accountability structures exist, they are ineffective or conflicting (Brandsma & Schillemans 2013; Kim & Lee 2010). In moderate accountability, there are established standards that also enhance the authority and credibility of the bureaucrats. Clear linkages show who holds bureaucrats accountable as well as the consequences for not following established procedures (Brandsma and Schillemans, 2013). In such a system, accountability is geared towards effectiveness, thus allowing innovation and discretion of bureaucrats. In a system with high accountability, knowledge production standards and structures for holding bureaucrats accountable exist. However, strict rule enforcement leads to accountability overload and the dominance of short-term accountability goals may not translate to effective knowledge production and use (Bovens, 2010).

Table 4
Varieties of bureaucratic accountability.

Low Accountability	Moderate Accountability	High Accountability
No established standards for knowledge production and use. Accountability structures are non-existent or ineffective leading to an accountability deficit.	Standards for knowledge production and use are established and enforced. Clearly defined and effective accountability structures that are geared towards effectiveness.	Established knowledge production standards and accountability structures exist. Rule-based logic results in short-term accountability goals and accountability overload.

3.4. Engagement with experts

The fourth dimension is concerned with the engagement modalities with individuals or organizations that provide specialized advice on knowledge production (Jasanoff, 2005). Although the broader PAS literature is concerned with the configuration of overall advisory systems, this dimension focuses on experts because tracking of adaptation may require specialized skills. Such experts influence the choices of bureaucrats, thus affecting what gets counted and how. This perspective also recognizes the growing role of external experts emanating from previous governance reforms that led to the downsizing of the administrative workforce (Saguin, 2018; Veselý, 2013). We address the involvement of other relevant non-state actors under dimension one.

To characterize engagement with experts, this dimension focuses on the variable of experts' location relative to the bureaucratic structure, i.e., whether they are governmental, in the case of civil servants, or non-governmental actors (Craft & Halligan, 2015). Depending on the established knowledge production rules, experts have varying degrees of influence based on their proximity to bureaucrats (Craft & Halligan, 2015; Hustedt, 2019). In some contexts, bureaucrats may prefer advice from external experts partly because of inadequate capacity within the bureaucracy (Veselý, 2013), especially when experts come from organizations with established authority for knowledge production in certain issue domains. In other cases, personal relations may determine the influence experts have on bureaucrats (Hustedt, 2019). For a long-term process such as adaptation tracking, expert engagement modalities may affect learning and capacity development within the bureaucracy over time (Klostermann et al., 2018; Veselý, 2013). However, engagement with external experts could also enhance the design knowledge production through the use of appropriate expertise, for instance, in developing tools that might limit the use of subjective or political reasoning in evaluations (Kaur and Lodhia, 2018).

We exemplify three varieties of expert engagement, as summarized in Table 5. In externalized systems (Craft & Howlett, 2013; Hustedt, 2019; Veselý, 2013), bureaucrats strongly rely on non-governmental experts to design and implement knowledge production. Reliance on external experts may lead to standardization of knowledge production as specific non-governmental organizations or individuals strongly influence knowledge production over time or within regions (Wright et al., 2012). For instance, externalization is critical, especially in developing countries, where knowledge production is donor-driven, which leads to the misalignment between new knowledge production systems and the national knowledge production practices and rules (Devarajan, 2013). A hybrid mode of engagement may lead to a complementary relationship between the bureaucrats and the external experts which enhances knowledge production and use by leveraging external and internal skills, experience, and expertise (Howlett & Fraser, 2014; Hustedt & Veit, 2017). An example of hybridization is in Finland, where the government established a coordination group constituted by different ministries, research institutes, funding agencies, and regional organizations to coordinate the assessment of adaptation across sectors (Klostermann et al., 2018). In internalized systems, bureaucrats use in-house expertise to design and implement knowledge production (Veselý, 2013). Internalization can involve engagement with individuals with specific skills who, by extension, become part of the bureaucratic structure permanently or for a defined period. For instance, in Israel, the government created chief scientist positions in relevant bureaucratic units to facilitate the entry of expert knowledge on climate change adaptation into the bureaucracy (Schmidt et al., 2018). This mode of engagement was found to be useful in brokering the linkage between technical expertise and policymaking and establishing long-term engagement between ministries (Schmidt et al., 2018)

3.5. Politico-administrative relations

The fifth dimension considers the interactions between the political and administrative realms of the government. These realms, respectively, comprise the elected officials and those employed to implement policies and serve the government of the day (Alford et al., 2017; Pepinsky et al., 2017; van Dorp and 't Hart, 2019).

This dimension captures the political context within which bureaucrats operate and its implications on the administrative capacity to produce knowledge (Ayee, 2013; Boräng et al., 2018). To support their political ambitions, elected officials influence knowledge production by determining if and how knowledge is produced, including regulating the available financial and human resources (Boräng et al., 2018; Devarajan, 2013). Politico-administrative relations may also influence the political value of adaptation tracking, thus determining its political feasibility and usefulness for policymaking (Ford et al., 2013; Grasso, 2016; van Rüth and Schönthaler, 2018). For instance, the ease with which politicians are able to interpret and make use of knowledge for policymaking is relevant in the design of adaptation tracking systems (van Rüth and Schönthaler, 2018). Elected officials might also affect adaptation tracking by preferring indicators that can show quick results at the expense of more long-term targets.

Bureaucratic autonomy is central to understanding politico-administrative relations. Autonomy refers to the freedom of bureaucrats to determine their preferences in knowledge production and use (Maggetti and Verhoest, 2014). The degree of autonomy depends on several factors, including the influence of elected officials on hiring and dismissal of bureaucrats, which, in turn, shapes the technical capacity of bureaucrats and the opportunities for elected officials to influence knowledge production and use (Boräng et al.,

Table 5
Varieties of expert engagement.

Externalized Expertise	Hybrid Expertise	Internalized Expertise
High reliance on experts that are outside the bureaucratic system.	Moderate reliance on external experts with the use of mechanisms to enhance collaboration between bureaucrats and external experts.	Dependence on in-house expertise through hiring or co-option of experts thus low reliance on external experts.

2018; Dasandi and Esteve, 2017; Onyango, 2020; Zafarullah, 2013). Bureaucrats are accountable to their political counterparts, but the extent of recognition of their authority could influence the effectiveness of bureaucrats in fulfilling their tasks (Ayee, 2013; van Dorp and 't Hart, 2019).

In politically dominated systems, the autonomy of bureaucrats is limited due to political interference in the recruitment and dismissal of bureaucrats and in controlling resources for knowledge production (Pepinsky et al., 2017). Knowledge production is politicized, as bureaucrats aim at proving their political alignment (Boräng et al., 2018). For example, in India and the US, political agenda has been found to have a strong influence on climate action by determining the extent of institutional reforms for climate governance, bureaucratic capacity and, in turn, the fulfillment of bureaucratic mandates towards climate action (Mildenberger, 2021; Pillai and Dubash, 2021). In complementary systems (Svara, 1999), there is a balance between political interests and bureaucratic freedom, which may lead to high political and technical capacity (Howlett et al., 2015). The complementary nature of the relations allows elected officials to provide oversight and political legitimacy while providing the autonomy required for bureaucrats to produce and use knowledge (Cameron, 2010). Such systems are observed, for instance, in countries such as the Netherlands, where bureaucrats balance between political responsiveness and professionalism (Alford et al., 2017; van Dorp and 't Hart, 2019). In bureaucratic-dominated systems, there is high bureaucratic autonomy but the lack of oversight results in bureaucratic clientelism. For example, in Bangladesh, public administration is bureaucratized, which despite its correlation with an increase in climate finance, could lead to the dominance of generalist bureaucrats who lack the specialized expertise required for effective implementation and monitoring of adaptation policies (Rahman and Tosun, 2018). Table 6 outlines these examples of varieties of politico-administrative relations.

3.6. Coordination within the administration

The sixth dimension involves the nature of interactions between interdependent administrative units and how they consider each other's decisions and actions (Bolleyer & Börzel, 2010; Koop & Lodge, 2014; Peters, 1998).

Adaptation cuts across multiple sectors and ministries, hence, adaptation tracking will require inter-administrative and intersectoral coordination to facilitate knowledge flow (Bauer et al., 2012; Laihonen and Huhtamäki, 2020; Laihonen and Mäntylä, 2018). Coordination has been argued to help overcome institutional and organizational barriers to knowledge production while boosting the government's capacity to address climate change adaptation (Shao and Saxena, 2019; Tosun and Howlett, 2021). It is also crucial to consider the competing perceptions that influence how bureaucrats make sense of and implement knowledge production (Hathaway and Askvik, 2020; Laihonen and Kokko, 2019) as their (non-)alignment may determine the compatibility of knowledge produced by different administrative units. Coordination is, therefore, essential for facilitating conceptual and methodological coherence and consistency between administrative units (Arnaboldi & Palermo 2011). For instance, in Germany, close collaboration between national authorities has been shown to be valuable in ensuring cross-sectoral methodological consistency in adaptation monitoring (van Rüth and Schönthaler, 2018). Administrative coordination also facilitates the vertical integration of the subnational levels and established climate departments within broader knowledge production systems (Klostermann et al., 2018; Renner, 2020). Countries such as Kenya and the UK, for example, have established coordinating units that collate and synthesize adaptation knowledge (Klostermann et al., 2018; Renner, 2020). These units have been argued to be vital for aggregating and maintaining a broad view of adaptation (Klostermann et al., 2018).

Two variables are important for characterizing coordination. The first variable looks into the administrative structure and considers the institutionalized boundaries that demarcate administrative units and the ensuing relations between them (Bellamy et al., 2008; Hathaway and Askvik, 2020). These demarcations influence the values and interests within administrative units and, in turn, the relations between them (Hathaway & Askvik 2020; Peters 2018). This variable helps in mapping the relevant administrative units, their approaches to knowledge production, information needs, and their roles in knowledge production. In addition, this variable identifies the linkages between administrative units or networks which influence the consistency in methods and outputs of policy knowledge production. Under this variable, administrative units can have strong or weak ties depending on the alignment of knowledge production activities and approaches.

The second variable, which captures the degree of formalization, is based on the extent to which procedures for interactions between relevant administrative units are embedded in agreements and laws and their degree of enforcement (Bolleyer and Börzel, 2010; Hathaway and Askvik, 2020; Jensen, 2014; Koop and Lodge, 2014). Formalization may enhance coordination by legitimizing the exercise of authority through the formal assignment of responsibilities to the various administrative units while determining the available coordination mechanisms (Bolleyer and Börzel, 2010).

At least three varieties of bureaucratic coordination are possible, as summarized in Table 7. In individualistic systems, bureaucrats depend on loose networks and interests of individuals and fragmented administrative units since coordination is weakly formalized (6, 2004; Bellamy et al., 2008; Laihonen and Huhtamäki, 2020). Coordination is maintained only to the extent to which it aligns with individual interests and could result in incompatibility as different rationales drive processes of knowledge production (Bellamy et al.,

Table 6
Varieties of politico-administration relations.

Political dominance	Complementarity	Bureaucratic dominance
Elected officials control majority of bureaucratic decisions hence limited bureaucratic autonomy.	There is mutual respect between elected officials and bureaucrats, resulting in moderate bureaucratic autonomy.	Bureaucrats dominate the administrative structure leading to high bureaucratic autonomy.

Table 7
Varieties of bureaucratic coordination.

Individualistic coordination	Bureaucratic coordination	Mutualistic coordination
Weak formalization and weak ties. Coordination is driven by interests of individuals or specific administrative units, leading to low administrative coordination.	Clear distinction of roles between multiple administrative units. High formalization of coordination with rigid rule-following, leading to moderate administrative coordination.	Flexible application of coordination rules. Mutual agreements facilitate strong ties in knowledge production, sharing, and use, resulting in high administrative coordination.

2008; Laihonen & Huhtamäki, 2020; Yang & Wu, 2014). Inadequate formalization of coordination and the weak ties between the various bureaucratic units limits bureaucratic coordination. In bureaucratic systems, coordination is formalized, with procedures for knowledge production and dissemination providing a clear distinction of roles between the various administrative units (6, 2004; Bellamy et al., 2008; Hathaway and Askvik, 2020). However, emphasis on rules and procedures leads to rigidity resulting in moderate coordination (Hathaway and Askvik, 2020). For instance, in India, Pillai and Dubash, (2021) find that climate commitments are typically distributed across line ministries which are expected to outline how they are going to support the implementation of national ambitions. However, planning and reporting follow a 'rule of appropriateness' logic that is based on short-term results that follow predefined targets and actions, limiting the sustainability and effectiveness of coordination (Pillai and Dubash, 2021). In mutualistic systems, bureaucrats prefer mutual and voluntary commitments to produce and share knowledge resulting in flexibility in the otherwise formalized coordination (6, 2004). As a result, there is a high degree of coordination with strategic and strong ties between administrative units (6, 2004).

4. Discussion and conclusion

In the previous sections, we have presented a theory-informed framework for analyzing the institutional structures of knowledge production and use relevant for the institutionalization of adaptation tracking. This framework contributes to scientific and policy discussions by proposing the use of Science and Technology studies, public administration, and public policy theories to guide contextually appropriate design of adaptation tracking. These theories provide insights into prevailing state-society relations and intra-governmental dynamics which are fundamental for knowledge production and use. The framework proposed in this paper helps to unpack the starting conditions of relevant institutions based on six dimensions that are relevant when designing adaptation tracking that aligns with the prevailing institutional structures. By highlighting the dimensions that will shape the adoption and effectiveness of adaptation tracking, this diagnostic approach enriches technical conceptualizations of adaptation tracking that typically only look at indicators and frameworks.

If the influence of the established organizational structures and rules matters, then institutional alignment is integral to the successful uptake of adaptation tracking. Institutional alignment will entail a determination of whether the existing institutional structures support the ambitions of adaptation tracking as conceived, including maintaining a broad view over space and time while ensuring quality knowledge production. Alignment may range from complementarity, where the prevailing institutional structures are supportive of adaptation tracking, to competitive, in cases where the new reporting requirements come at the expense of existing requirements within the institutional structures or vice versa (Helmke and Levitsky, 2012). It is also crucial to understand the suitability of the existing systems of knowledge production and use, as this may affect the usability and comparability of knowledge from adaptation tracking across countries (Jerven, 2013) and sectors. The study of institutional characteristics may also provide insights into the feasibility of strategies for enhancing governance by disclosure. For instance, for domestic organizations to hold the governments accountable, as suggested by Karlsson-Vinkhuyzen et al. (2018), they will require supportive political and administrative relations, administrative coordination, transparency, and functional accountability structures; and these vary across and within countries. For successful institutionalization of adaptation tracking, its design should incorporate existing elements that invoke familiarity and legitimacy while maintaining the flexibility required to catalyze reforms towards more effective knowledge production and use (Hargadon and Douglas, 2001).

There are diverse perspectives on the dimensions included in this framework. Our goal was to provide a workable framework for characterizing the institutional structures of knowledge production and use by outlining a set of dimensions and variables that are applicable to diverse governance contexts and capture both the national and sub-national levels. The operationalization of the dimensions should be guided by the sector of interest. This framework, we are convinced, is a useful step towards institutional alignment. However, our work serves as a starting point. Further research is required to test and improve the framework so that it can usefully guide a contextually appropriate design of adaptation tracking. This framework is by no means self-sufficient, and we anticipate that new dimensions may emerge as more empirical assessments are conducted. Although presented as distinct, the six dimensions are interrelated. For example, coordination between administrative units could reinforce transparency as coordination facilitates knowledge integration and ease of access, for instance, through the establishment of a central knowledge base. It is also likely that more transparent systems will score high on accountability as more disclosure increases bureaucratic answerability (Fox, 2007). Trade-offs might also exist between the dimensions. On the one hand, transparency and participation can be complementary or synergistic as stakeholder participation contributes to innovative approaches to government transparency (Kim & Lee, 2019; Meijer et al., 2012). On the other hand, more participation may lead to less transparency as governments avoid scrutiny (Meijer et al., 2012). This means that a high representation of a particular dimension is not always ideal. Therefore, to develop a comprehensive strategy for designing adaptation tracking, the characteristics of each dimension should be interpreted in light of the other dimensions. Empirically, the

interactions between the variables may be more complex, resulting in context-specific characteristics that extend beyond those exemplified in this paper. The examples provided above aim to illustrate the possible contextual diversity.

We suggest three areas of work that may be useful in advancing discussions on institutional alignment in adaptation tracking. First, our proposed framework should be empirically tested. Empirical studies could involve examining whether the dimensions and variables have equal importance across diverse governance arrangements and if there are dimensions not captured by the framework. This will help prioritize which dimensions to pay most attention to, depending on their characteristics and influence on adaptation tracking. Secondly, it may be helpful to examine the utility of the framework in evaluating the extent to which emerging adaptation tracking methodologies align with knowledge production and use systems. In addition to testing the framework, this would predict the degree of institutionalization of such methodologies. Thirdly, it would be useful to test the framework's usefulness in guiding the design of more effective adaptation tracking interventions. We presume that guided by the framework, practitioners will develop a better understanding of the institutional structures of knowledge production and use within a targeted policy domain, more accurately evaluate the feasibility of specific designs of adaptation tracking, and plan for future reforms. Applications of this framework should consider the uniqueness of the formal and informal rules to policy domains and not the general country characteristics (Howlett and Tosun, 2019).

To conclude, countries vary in state-society relations, dynamics within their governments, and in the institutional structures that shape knowledge production and use. These country-specific characteristics, as well as differences within countries, will influence the institutionalization of adaptation tracking, making institutional alignment fundamental for the effectiveness of adaptation tracking. As adaptation tracking remains to be of global and national value, adding to technocratic framings of adaptation tracking more deliberate consideration of how adaptation tracking frameworks align with the institutional structures of each country is not only strategically important but also crucial to the success and effectiveness of adaptation tracking in the long-term.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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