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Re-examining policy stability in climate adaptation through a lock-in perspective

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Abstract

Responding to current and future climate change demands urgent, transformative adaptation, yet in many policy systems inaction continues to prevail. This paper examines apparent resistance to policy change and the persistence of business-as-usual through a ‘lock-in perspective’, which means that attention is paid to how reinforcing mechanisms drive stabilisation and resistance in policy systems. Offering a fresh synthesis of known lock-in mechanisms in the literature, this paper explores the role of those mechanisms in two empirical cases of coastal adaptation: England (U.K.) and Schleswig-Holstein (Germany). While several known lock-mechanisms are observable, some are newly identified in this adaptation context. We offer a critical reflection on the added value of the lock-in perspective for understanding policy stability. In turn, the identification of self- and mutually-reinforcing mechanisms provides a much-needed foundation for targeted policy interventions and efforts to ‘unlock’ climate adaptation pathways.

Keywords: dynamic policy stability, lock-in mechanisms, path dependence, policy feedback, climate change adaptation, coastal management

Introduction

Understanding policy dynamics has long been a staple of policy studies and political science. Policy stability is being studied more and more too. Initially seen as the mere absence of dynamics, it is becoming increasingly clear that policy stability is actually the outcome of dynamic processes (Weible & Sabatier, 2018). Such stabilising dynamics can include, among others, self- or mutually-reinforcing mechanisms that make policy (sub)systems rigid and resistant to change, or ‘locked in’ (Pierson, 2000). Lock-ins have been studied in a range of different contexts (such as infrastructure projects, government policies and consumer products) and through different disciplinary lenses, including political science, economics, geography and science and technology studies (Siebenhüner et al., 2021). In line with the increasingly prominent view of dynamic stability, it has been suggested that lock-ins are characterised by positive feedbacks and their net reinforcing effect on policies (Foxon, 2002; Barnes et al., 2004; Pierson, 2004).

Lock-ins have come under increasing scrutiny in the research on *climate mitigation*, where studies of ‘carbon lock-in’ have demonstrated how these self-reinforcing dynamics restrict decarbonisation agendas (Klitkou et al., 2015; Seto et al., 2016; Kotilainen et al., 2019). Interest in the lock-in perspective has only recently emerged in the field of *climate change adaptation* (CCA), which focuses on the process of adjustment to experienced or expected climate change impacts (UNEP, 2021). Here too, the necessity of transformational change is contrasted with the lack of action on the ground, and the notion of an ‘adaptation gap’ has been employed (Huitema et al., 2016; UNEP, 2021). Moreover, the notion of stabilising dynamics is becoming increasingly important as more and more calls are

heard to move beyond the simplistic heuristic of ‘barriers’ to change, towards the deeper, systemic dynamics through which policy stability is constructed and sustained and adaptation hindered (Biesbroek et al., 2014; Siebenhüner et al., 2021).

Responding to these calls, this paper considers the transferable potential and utility of the lock-in perspective to the CCA literature and asks whether and how lock-in mechanisms help sustain business-as-usual and restrict adaptation efforts. The research focuses on coasts, where the need for adaptation is paramount given projected sea level rise and increasing coastal hazards (storm surges, flooding and erosion; OECD, 2019). Coastal management is a mature policy field that often reflects decades, if not centuries, of developments. Yet, aforementioned climate change impacts will mean that in many jurisdictions traditional coastal management based on ‘hard’ defences may not be economically, environmentally or socially sustainable in the long run (Jones et al., 2012). Adaptation demands innovative and diverse approaches, involving a combination of protection, accommodation, recovery and retreat strategies (OECD, 2019). However, coastal management is notably complex and involves disparate terrestrial and marine policy domains, with different institutional arrangements, agendas and sometimes competing interests. Moreover, each of these policy domains is subject to internal dynamics and varied in terms of rigidity and the extent to which adaptation is recognised as a policy issue and acted upon. Coastal management therefore provides a useful testbed for the lock-in perspective.

To engage with lock-in issues in coastal climate adaptation, the paper starts by drawing from various bodies of literature, including policy studies and political science, economics and climate mitigation to synthesise known lock-in mechanisms. Second, we present the results of a primarily inductive case study analysis of coastal CCA in England (United Kingdom) and Schleswig-Holstein (Germany) from which we identified whether known lock-in mechanisms are present, and whether new types of mechanisms exist in this context. While several known lock-in mechanisms were discernible, our analysis reveals four new types of lock-in mechanisms and demonstrates the interdependencies between institutions, actors and infrastructures and the contexts in which they are situated. This research demonstrates the utility of the lock-in perspective and added value in terms of revealing otherwise hidden sources of stability that are hindering adaptation. In turn, we reflect on the policy implications for targeting and tailoring interventions to dissolve undesirable lock-in dynamics and open up opportunities to accelerate adaptation action.

Taking a lock-in perspective

The concept of lock-in and mechanistic approaches to characterising lock-in dynamics have evolved through various disciplines, including economics, economic geography, policy studies and political science, science and technology studies and, more recently, climate mitigation. This section synthesises the key concepts in lock-in thinking and collates a list of previously documented lock-in mechanisms (Table 2).

In policy studies and political science, dynamic policy stability has been subject to considerable scrutiny (for instance Levin et al., 2012). Two theoretical concepts are central in these discussions: *path dependence* and *policy feedback*. Path dependence is rooted in historical institutionalism and emphasises the stabilising role of the structure and power relations of institutional systems (Pierson, 2000; 2004). It understands path dependence as ‘a social process grounded in a dynamic of increasing returns’, involving positive, self-reinforcing feedbacks, which make deviation from the chosen path increasingly costly (Pierson, 2000, p. 251). For example, previous institutional choices can create normative and interest-driven commitments that determine future events. These ‘institutional legacies’ create positive feedbacks that reduce the feasibility of change for subsequent policies and serve to reinforce the status quo (Pierson, 2000; Howlett, 2009). Accompanying historical institutionalist

perspectives, other schools of institutionalism in political science emphasise different drivers of policy stability. Rational choice institutionalism stresses the role of institutional cost-benefit structures and large switching costs, which make the alternative paths less palatable (e.g. Lindner, 2003). In contrast, sociological institutionalism focuses on cultural norms and values that shape actors' expectations about how institutions ought to be structured to be socially legitimate, thus reinforcing familiar institutional structures (Hall & Taylor, 1996).

Sources of policy stability are also considered through adjacent scholarship on *policy feedback*, which examines the means through which policies affect politics and subsequent policy decisions (Jordan & Matt, 2014). Weir (1993) interprets policy as a process of sequences in which new ideas restrict future initiatives. These sequences may cumulate into self-reinforcing feedbacks that 'serve to stabilise or expand early policy events' (Skogstad, 2017, p. 24). Policy feedback scholars identify specific design features that make policies more susceptible to self-reinforcing dynamics, such as those associated with high start-up costs or long-term sunk costs (Ibid.). More recently, scholars have highlighted how the intertwined development of policies and infrastructures or technologies can also create policy feedback and limit the decision space for future decisions (Schmid et al., 2020; Derwort et al., 2021).

The emphasis on self-reinforcing feedbacks has sparked interest in the concept of lock-in dynamics and specific lock-in mechanisms that 'reinforce a particular path or trajectory' (Pierson, 2004, p. 49). Mechanisms, consisting of agents, their properties, actions and relations producing an effect/phenomenon, form the causal building blocks that connect a continuous and contiguous chain of links between different elements in a policy system, which together create emergent system behaviour (Hedström & Ylikoski, 2010). Contextual conditions influence the type of mechanisms that are activated or deactivated, as well as the magnitude of the causal force and its effect on the outcome (Falleti & Lynch, 2009). While mechanisms more broadly may drive both change and stability in policy systems, *lock-in mechanisms*, by their self-reinforcing nature, exert a stabilising force. Therefore, the study of lock-in is concerned with identifying which specific lock-in mechanisms drive stability and what constructs, sustains or ultimately dissolves these under certain conditions.

It is important to consider agency in self-reinforcing dynamics, as these are not automatic. Both path dependence and policy feedback concepts include elements of agency and draw attention to the central role of actors in forging reinforcing, stabilising dynamics. To this end, Galik and Chelbi (2021) distinguish between passive, non-purposeful policy stability on the one hand and active, purposeful policy stability on the other. Whereas reflexive actions (e.g. framing, discourse) steer passive stability with standards regarding what is right or acceptable, active stability is driven by actors' intentional, proactive actions (Ibid.). The distinction between passive and active stability highlights the importance of examining policy stability (and lock-in dynamics therein) through the lens of intentionality.

The existing literature has documented a number of mechanisms through which institutions, infrastructures, technologies and behaviours drive self-reinforcing dynamics. For example, early economic research highlighted infrastructural and technological lock-in mechanisms related to *economies of scale*, *economies of scope* and *learning effects* (David, 1985; Arthur, 1994). Interest has since expanded to the role of institutional and behavioural mechanisms. Prominent examples include *institutional learning effects*, *network effects*, *adaptive expectations* and *habituation* (Pierson, 2000; Foxon, 2002; Barnes et al., 2004; Ebbinghaus, 2005). A combination of these mechanisms is often represented in studies of so-called 'carbon lock-ins' within climate mitigation research, as researchers have sought to understand the persistence of carbon-dependent socio-technical systems and barriers to decarbonisation (e.g. Klitkou et al., 2015; Kotilainen et al., 2019). Studies of carbon lock-ins have drawn attention to different types of institutional, infrastructural, technological and behavioural mechanisms that underpin lock-ins (Seto et al., 2016; Kurz et al., 2015).

However, such lock-in mechanisms have yet to be documented in the context of climate adaptation. Addressing this gap, this research examined the presence of these known mechanisms (see Table 2) in

selected case studies of coastal adaptation. Whilst self-reinforcing mechanisms have been introduced here individually, it has to be noted that in reality mechanisms may combine or overlap (Hedström & Ylikoski, 2010). Therefore, the same institutional development may be ascribed to more than one mechanism, i.e. causing observational equivalence and representing equifinality. That being said, each mechanism is still analytically distinct, and must therefore be highlighted in the analysis of lock-ins.

Methods

To test the analytical potential of the lock-in perspective for studying policy stability in CCA, this research adopts a case study approach, focusing on the coastal adaptation problem domain as our unit of analysis. Drawing inspiration from Arts et al. (2006), we define the *problem domain* as the arrangement of actors, rules, resources and discourses that coalesce around a collective problem. This approach recognises that CCA spans multiple policy areas and is often not a policy field in itself (Massey & Huitema, 2016). Therefore, we looked to a number of relevant policy areas, including coastal flooding and erosion risk management, terrestrial spatial planning, environmental conservation and water management. Two European case studies were selected as illustrative examples: England (U.K.) and Schleswig-Holstein (northernmost state in Germany). These cases share a similar risk profile under future climate projections, but differ in governance traditions, approaches to coastal management, and institutional scales (Bisaro et al., 2020). Although comparison was not the primary objective, these differences enabled us to interrogate the utility of the lock-in concept in divergent settings.

The research adopted a qualitative case study approach, involving document analysis and semi-structured stakeholder interviews. Documents ranged from legislation, policy statements, strategies and key plans, to inquiry reports and existing academic research. Stakeholder interviews were undertaken between November 2020 and January 2021 (Schleswig-Holstein) and June 2021 (England; Table 1). Discussions typically ranged from one to two hours and were recorded, transcribed and analysed using software packages NVivo and MAXQDA. Documents and interview transcripts were subject to thematic analysis (Fereday & Muir-Cochrane, 2006). To ensure consistency in coding, a shared coding protocol was developed through an iterative process, bringing together both data-driven and theory-driven codes informed through sensitisation with the literature. Although analysis was primarily inductive, this approach enabled us to examine whether known lock-in mechanisms documented in other settings are also applicable to CCA in coastal contexts.

Data were subject to a ‘fingerprints approach’ to process tracing, which aims to uncover plausible causal mechanisms to explain an event or situation as it unfolds over time (Collier, 2011). Starting from 2021 as a baseline, we traced backwards from perceived adaptation gaps to identify their origins, how they are sustained and why they persist, and used process tracing techniques to identify whether these could be attributed to underlying lock-in mechanisms. Process tracing was pursued as far as inferentially necessary. Although lock-in mechanisms were examined alongside other factors as part of a wider analysis, this paper focuses on identified lock-in mechanisms and the added value of the lock-in perspective for understanding climate adaptation gaps.

[Insert Table 1 here]

Results

The results of the empirical analysis from both case studies are summarised in Table 2. Here we document the presence and absence of known lock-in mechanisms (documented in other contexts within the literature), alongside newly identified lock-in mechanisms. These are discussed in-depth below.

[Insert Table 2 here]

Case Study: England

In England, an estimated 520,000 properties are currently located in areas with a 0.5% or greater annual risk of coastal flooding, with 8,900 properties exposed to coastal erosion (CCC, 2018). This is projected to increase significantly under future climate scenarios and sea level rise (CCC, 2021). Coastal change and flood risk thus remain top priorities in the National Adaptation Programme (Defra, 2018).

Flood and Coastal Erosion Risk Management (FCERM) policy is set by the Department for Environment, Food and Rural Affairs (Defra) (HM Government, 2020), who are also responsible for climate adaptation policy more widely.¹ The Environment Agency, as an executive, non-departmental public body, maintains strategic overview for FCERM and responsibility for developing and monitoring the implementation of the National FCERM Strategy for England (EA, 2020). Operational responsibilities are divided across designated Risk Management Authorities, including the Environment Agency, Lead Local Flood Authorities (namely unitary authorities, county councils or district councils where no unitary authority exists), Internal Drainage Boards, highways authorities and water companies (regulated by Ofwat). Coastal local authorities are also designated as Coast Protection Authorities, with permissive powers to protect the land against erosion and encroachment from the sea. Preferred coastal management policies are outlined in shoreline management plans for different epochs (0-20, 20-50 and 50-100 years); including policies for No Active Intervention, Managed Realignment, Hold The Line or Advance The Line (i.e. of existing defences). These are overseen by Coastal Groups, with representatives from the local authority, Environment Agency, Natural England and other bodies with vested interests. Although the shoreline management plans are intended to support long-term decision-making in other policy areas such as spatial planning, these are non-statutory documents and ultimately represent unfunded proposals only (CCC, 2018).

FCERM governance has evolved incrementally through three key paradigms – from land drainage (ca. 1930-1970s) and flood defence (1980s-1990s) to risk management (ca. 2000s-today) (Johnson et al., 2005). Contemporary policy recognises the necessity of a holistic approach, drawing from a portfolio of equally important strategies. However, translating this discourse into practice has remained challenging, with the Committee on Climate Change concluding that the current approach ‘*is unsustainable in the face of climate change*’ (CCC, 2018, p. 9). Despite FCERM policy promoting a diversified approach, legacy effects from the defence paradigm sustain a tendency towards defence-dominance and restrict the implementation of alternative approaches in FCERM. Several self-reinforcing mechanisms were discerned from document and interview analysis.

The current funding instrument employed by the Environment Agency to allocate national FCERM Grant-in-Aid funding is a central trigger for several lock-in mechanisms. Although Partnership Funding was introduced to enable additional sources of funding (public, private and civil society) to contribute to FCERM schemes, while aiming to stimulate innovation (Defra, 2012), the funding formula continues to prioritise the protection of people, property and businesses, and reductions in flood probability. This makes it easier for defence schemes to achieve more favourable cost-benefit ratios compared to alternatives (such as natural flood management or managed realignment). Once

¹ This information relates to England only and not the devolved administrations of the UK.

constructed, such schemes foster a sense of security and reinforce *adaptive expectations*, whereby land use decisions are driven by expectations that the Environment Agency will continue to maintain defence assets. In turn, as investment and development behind the defences grows, this mobilises *economies of scale*, as cost-benefit ratios increase and provide greater returns for continued investment in defence activities. Thus, *adaptive expectations* and *economies of scale* operate in mutually reinforcing ways. This effect has widely been documented in the flood risk management literature and often described as ‘the levee effect’ (OECD, 2019).

The design of funding policy instruments reflects established institutional cultures and identities, where defence-preferences arguably remain in the wake of the engineering paradigm (Harries & Penning-Rowse, 2011). Although these preferences are slowly dissolving as the Environment Agency diversifies its identity, there is still a degree of *habituation* and attachment to established ways of working. For example, one interviewee explained how the conventional ‘*predict and provide*’ approach to delivering defence projects is in stark contrast to the process required for complex coastal change management. Similarly, the language enshrined in the shoreline management plans continues to reinforce the notion of ‘the line’ of defence when ‘*it’s not a line it’s a zone ... it doesn’t lead you in a way that will start solving the problems*’ (FCERM consultant interviewee). *Habituation* goes hand in hand with *learning effects* as knowledge, skills and routines have increased with the adoption of established practices, procedures and implementation of defence-based interventions. Interestingly, document and interview analysis reveals how the Environment Agency is actively trying to counteract these reinforcing dynamics as it seeks to maintain a central position of power in FCERM governance by broadening the scope of its activities over the past 15 years. In turn, Partnership Funding is also evolving, with reforms announced in April 2020 intended to unlock funding for alternative approaches, though it is too soon to assess the extent to which this will be the case.

Nonetheless, efforts to implement alternative strategies in FCERM typically encounter resistance from civil society, who expect state intervention and defensive action, despite the absence of statutory rights to flood protection. This expectation has been forged through the increasing centralisation of FCERM governance since the 1950s and increasing complexity of roles and responsibilities, which are often poorly understood by the public. Expectations for state intervention are further exacerbated by politically-judged commitments of capital funding towards flood defences that often follow significant flood events (Alexander et al., 2021). This relationship between the State and civil society has been described in political philosophy as a social contract, referring to ‘how governments and responsibility evolve over time as emerging risks pose challenges to the established consensus concerning the role of the state’ (Adger et al., 2013, p. 330). Our analysis indicates how *social contracting* can operate in an active sense as a self-reinforcing mechanism, whereby civil society groups leverage their expectations for flood protection and lobby for action, which, when also combined with political pressure, can lead to defensive steps being taken even when this might not be sustainable long-term. Furthermore, research has shown how this mechanism can be mobilised through public consultation procedures to legitimise institutionalised defence preferences (Harries & Penning-Rowse, 2011). As a mechanism, *social contracting* displays similarities with *adaptive expectations*, as society’s actions are influenced by the (expected) actions of public actors. However, we argue that *social contracting* pertains more specifically to the (re)production of normative values and expectations attached to the state-society relationship, and how these are actively wielded to lobby (or alternatively contest) an agenda. This often coincides with *collective action* through locally-led community flood action groups, wherein shared beliefs about problems and solutions are constructed and collective agency is mobilised (Mees et al., 2018; EA, 2020). Interestingly, *social contracting* is also utilised by the state in an effort to re-shape this perceived social contract, with increasing emphasis placed on the need for citizens to adopt ownership for managing their personal risk. Thus, this mechanism plays an active role in both self-reinforcing and counteracting feedbacks, and appears to flourish under the English governance system, as a result of complex and often misunderstood roles and responsibilities.

The dominance of the defence-based paradigm has further been reinforced through various mutually beneficial agreements between the insurance industry and UK Government, which have maintained the availability of flood insurance for high-risk households since the 1960s (Penning-Rowse et al.,

2014). This is broadly characteristic of the *power differentiation* mechanism (Klitkou et al., 2015). However, more specifically it reflects a symbiotic dynamic, whereby the parties involved require something from the other and have established specific formal arrangements to secure mutual gains; although power may not necessarily be equally dispersed between parties, each are able to leverage the other. We refer to this self-reinforcing mechanism as *co-dependency*. As flood frequency and damages increased, the insurance industry increasingly demanded improved FCERM to minimise their financial exposure and only consented to agreements on the condition that public investment in defences be maintained, reinforcing the status quo (Harries & Penning-Rowsell, 2011). In turn, the availability of private market insurance has relieved Government of obligations to pay compensation. This arguably reflects what Trencher et al. (2020) describe as a lock-in by design (as opposed to a lock-in forged by consequence), in that this arrangement has been intentionally constructed and maintained between the two parties. This co-dependency has intensified for an interim period with the introduction of the Flood Reinsurance Scheme in 2016, a government-backed, not-for-profit scheme, which is intended to facilitate the transition to risk-reflective market pricing by 2039 (Flood Re, 2019); upon which we would expect this mechanism to be extinguished.

Coastal adaptation is further hindered by the absence of policy instruments and delivery mechanisms for implementing alternatives such as managed realignment. Whilst coastal risks fall within Defra's remit, adaptive responses extend beyond Defra's jurisdiction and require broader considerations of spatial planning, welfare, infrastructure, and decommissioning of assets, to name a few. Not only are formal responsibilities for adaptation unclear, but the functionalist structure of national and local government departments and quasi-privatisation of key sectors has created governance silos, as well as misalignment in planning and funding cycles which make it difficult to integrate agendas (Alexander et al., 2021). In the absence of clear responsibilities (and accountability) for adaptation, certain actors appear reluctant to embrace problem ownership and seem to employ avoidance tactics, typically justifying inaction in relation to resource constraints, statutory duties and remits. This is evidence of the *responsibility avoidance* mechanism. A notable example is Network Rail who frequently cite constraints created by the 5-yearly asset management periods through which funding is allocated to maintain (rather than enhance) the network. Examining this in detail, Uyl and Russel (2018) show how institutional fragmentation, and absence of deliberative structures for coordinating climate adaptation across government departments, enable blame and responsibility avoidance. Interviewees similarly confirmed the presence of this mechanism, particularly at the local scale; *'just because it's not written in the statute doesn't mean you don't do it ...they can push the system a bit ... [but] it's compliance leadership.'* Responsibility avoidance is not a self-reinforcing lock-in mechanism per se and is therefore not represented as such in Table 2. Instead, it is part of a causal chain of barriers which collectively impede adaptation.

[Insert figure 1 here]

Case Study: Schleswig-Holstein

Situated between the North and Baltic Seas, Schleswig-Holstein is defended against coastal hazards on the North Sea coast by 407km of embankments, which protect ca. 140,000 inhabitants and €28,5 billion worth of capital assets from flooding during storm surges (MELUND, 2022). Coastal protection is constitutionally defined as a joint task between federal, state and municipal governments (Bisaro et al., 2020). We focused strictly on the North Sea, where risk management responsibilities are primarily situated at the state level and outlined in the State Water Act. Whereas the state Ministry of Environment (MELUND)² is responsible for strategic planning, operational responsibilities for monitoring and maintaining coastal defences are assigned to the State Agency for Coastal Protection,

² The full name is the Ministry of Energy Transition, Agriculture, Environment, Nature and Digitisation for the State Schleswig-Holstein.

the National Park and Marine Protection. A coordinated approach to coastal defence has been pursued since 1963 and is outlined in the state Master Plan for Coastal Protection, which specifies the standards for coastal protection and is updated on a decadal basis (MELUND, 2022).

In 2015, MELUND published the Strategy for the Wadden Sea 2100 (WS2100) and in 2017 the State Plan for Adapting to Climate Change, which outline recommendations for future management options in response to projected sea level rise (MELUR, 2015; MELUND, 2017). Measures primarily focus on adaptive management of dike infrastructure and sediment management practices. However, additional adaptation measures and other strategies such as accommodation or retreat are notably absent (Hofstede & Stock, 2018) and not considered necessary (Hirschhäuser & Hofstede, 2020). Although the State Water Act and State Development Plans recommend non-statutory standards for development-free zones behind dikes and along sandy coasts prone to coastal erosion (Innenministerium, 2010), these decisions are ultimately made by the municipalities.

The State's approach to coastal protection has remained largely stable since the 1960s, where significant flooding in 1962 catalysed a state-coordinated approach to coastal protection (Reise, 2017). However, gradual paradigm shifts have occurred since. Land reclamation ceased in the 1980s and diverse policy goals have increasingly become more integrated with more cooperation between coastal defence, disaster management and nature conservation actors. Efforts to diversify the portfolio of measures deployed in coastal risk management are constrained by a host of barriers described by both governmental and non-governmental interviewees; therein, we identified the presence of several self-reinforcing lock-in mechanisms which serve to maintain the dominance of defences.

Dike heightening and maintenance, and sediment management, are ongoing activities that provide jobs along the coast, which has resulted in the emergence of engineering and construction firms with a strong interest in the continuation of the current coastal protection approach, as was described by an academic interviewee. This exemplifies a new lock-in mechanism that we refer to as *business network effects*. This occurs as a number of businesses and regional economic gains are fortified by specific public policies to maintain coastal defences. In turn, regional jobs are one of many incentives for political actors to continue to sustain their commitment to defence infrastructures. This notably differs from the *co-dependency* mechanism seen in England, in that *business network effects* is not a formalised arrangement. From economic theory and a known lock-in mechanism, network effects (Pierson, 2000) classically refer to gains increasing with the number of users of a product or service; here we refer to gains increasing with the number of jobs and businesses.

Additionally, the nature of federal capital funding and institutional rules favour continued investment in defence infrastructure. Due to high capital costs, alterations are limited to 3.6 km of dikes annually and require approximately 15 years of planning. This is primarily funded through federal finances, which can be used for pre-approved purposes only, including dike reinforcements and sediment distribution (SH Landtag, 2020); thus, funding for these established measures is notably easier to access than for alternative approaches. This policy feedback, documented in funding reports and described by interviewees, acts as a barrier to the implementation of more diverse measures. However, it also contributes to increasing investments as documented in England. These developments are forged by mechanisms of *adaptive expectations* and *economies of scale*, as assets amass behind the dikes and strengthen the case for continued defence investment.

Long-term reliance on dikes for safety and habitable land is further embedded in regional tradition. Over centuries, the pursuit of land reclamation and 'fighting' the sea (Reise, 2017) has become a cultural narrative of success that is credited to the effectiveness of the dikes. The data also revealed a regional saying that '*whoever doesn't support dikes, must go*'. Thus, the dikes, and safety they afford, have become an established part of cultural identity. This is further reinforced through the Master Plan

and risk awareness-raising documents, which emphasise the mortality of historic flood events and continued necessity of defences (MELUR, 2013). These policy documents both reflect and underpin the cultural framing around defences via a new type of lock-in mechanism that we describe as *framing (re)production*: the reaffirmation of values shared by separate actors.

Perceptions of the ‘*holiness of dikes*’, as described by an NGO interviewee, permeate the regional culture, from the state administration and engineering contractors to dike and drainage associations. These latter associations help maintain infrastructure but also embody a social community in coastal towns and therefore have both practical and social value. These ingrained values mean alternative measures struggle to gain the necessary public acceptance. In one instance near Husum, proposals for dike realignment and the re-design of the polder to allow for saltmarsh creation failed to win local approval despite the economic and ecological benefits (Hofstede, 2019). Such outcomes deter future proposals of alternative approaches because decision-makers assume they will fail to achieve the necessary public acceptance. Here, *adaptive expectations* and assumptions around what is considered acceptable determine outcomes and operate in a self-reinforcing manner, whereby actors prefer the familiar choice based upon past decisions. This mechanism coincides with their sense of identity attached to the dikes, part of the aforementioned *framing (re)production* mechanism.

This, in turn, legitimises the dominance of engineered defences managed and advocated for by a homogenous epistemic community of practitioners and decision-makers, many of which are trained in hydrologic and coastal engineering. Furthermore, state servants have close ties with (engineering) research networks and co-design research agendas, as mentioned in multiple interviews and supported by the document analysis. Consequently, ‘hard’ approaches to coastal protection remain prominent and preferences towards traditional defence infrastructure prevail. This is a further manifestation of *framing (re)production*, in that these values and homogenous knowledge systems co-evolve and reproduce, thus reinforcing commitment to defence-based adaptation and its dominance in education and training programs. Classic *learning effects* reinforce this dynamic as knowledge, skills and routines optimise with continuation of established practices, procedures and implementation of defence-based interventions.

[Insert figure 2 here]

Discussion

This research demonstrates the applicability of the lock-in concept to climate change adaptation, and its usefulness in operationalising the growing interest in stabilising dynamics and the growing desire to understand the growing ‘adaptation gap’ in global and national responses to climate change (UNEP, 2021). In this paper we have vetted the relevant literature for known lock-in mechanisms and subsequently studied the presence of these mechanisms in two case studies on coastal risks, namely England and Schleswig-Holstein. Not only did we observe lock-in mechanisms previously documented in other contexts (such as energy and decarbonisation transitions), we also identified new lock-in mechanisms of *social contracting*, *co-dependency*, *frame (re)production* and *business network effects* (Table 2).

Crucially, the research highlights how these mechanisms intersect and dynamically interact to reinforce the dominance of defence-based approaches in flood risk management. As a consequence, these lock-in mechanisms indirectly impact and restrict the implementation of alternative approaches to ‘hard’ defences (particularly nature-based approaches and managed realignment). Such alternatives are confronted by lock-in mechanisms that, whether intentionally or unintentionally, advantage defence-based approaches. This may coincide with other barriers and enabling conditions that make it harder to implement alternatives, such as governance silos and responsibility avoidance (as is the case in England;

Figure 1). The added value of the lock-in perspective is that it brings to light these otherwise hidden system dynamics that are restricting the ability to deliver fully diversified approaches to flood risk management and are thereby contributing to the adaptation gap.

In addition, the lock-in perspective supports processual, dynamic interpretations of policy stability that have increasingly been advocated by policy scholars (Jordan & Moore, 2020; Ishtiaque et al., 2021). Furthermore, it draws attention to the diversity of drivers that cultivate and reinforce stability, including institutional, technological, infrastructural, socio-cultural and behavioural forces, and the importance of understanding the interaction between these. The lock-in perspective thus promotes a more holistic analysis of lock-in dynamics and understanding of the co-evolution and interaction across different system elements and beyond policy systems (Schmid et al., 2020; Derwort et al., 2021). In this regard, lock-ins can be seen as a bridging concept for integrating different disciplinary interests and schools of institutionalism (historical, rational choice, and sociological) within political science, and bringing this to a new audience within adaptation scholarship.

Interestingly, we observe how the dominance of defence-based approaches is supported by both shared and different types of lock-in mechanisms in the two case studies. While behavioural dynamics (e.g. *adaptive expectations*, *habituation* and *learning effects*) and *economies of scale* are common features, unique mechanisms exist in England (*social contracting*, *collective action*, and *co-dependency*) and Schleswig-Holstein (*framing (re)production* and *business network effects*), which appear to flourish under these different governance and socio-cultural settings. In England for example, *social contracting* is enabled by the complex distribution of roles and responsibilities, and absence of statutory rights to flood protection, whereas this mechanism is not present in Schleswig-Holstein, where coastal protection is largely collectivised and legally codified as a public responsibility. These observations demonstrate that while the outcome may be similar in terms of defence-dominance and difficulties diversifying adaptation strategies (as observed elsewhere in Europe; Hegger et al. 2016), different sets of mechanisms, driven by the underlying institutional and societal fabric, are responsible for this homomorphism.

The observations from our two cases align with the framework of this special issue, which outlines cost-efficiency, technology/infrastructure and public support approaches to climate governance: all three aspects are components of lock-in mechanisms observed. For example, cost-efficiency rationales are reflected in the mechanism *economies of scale*, while technology/infrastructure is central to this. Moreover, the *collective action* and *social contracting* mechanisms demonstrate how public support influences the types of approaches that are supported (and contested).

Another important observation from the empirical analysis is that lock-in mechanisms operate in both passive and active forms, with unintentional and intentional effects. Whereas mechanisms such as *habituation* and *adaptive expectations* are initiated and maintained unintentionally, other mechanisms are consciously motivated and activated to either advance or contest policy agendas (such as *co-dependency* in England). This holds interesting insights for contemporary debates about passive and active stability (Galik & Chelbi, 2021). For example, whilst we observed that stability is sometimes brought about by lock-in mechanisms linked to framing about standards, norms and values, framing is not always passive (as Galik and Chelbi (Ibid.) indicate); indeed, the *framing (re)production* mechanism in Schleswig-Holstein demonstrates how actors sometimes subconsciously and sometimes intentionally reaffirm '*the holiness of dikes*'. Research needs to appreciate the complex role that mechanisms can play in this regard.

As our analysis focuses on the problem domain of coastal adaptation, our results should be seen in light of the particularities of this issue. Coastal protection against storms, floods and coastal erosion is not new but steeped in centuries of experience and tradition, which appears to be reflected in the lock-in mechanisms documented. In contrast, other climate adaptation challenges may be more recent and newly emerging without such legacies, and therefore subject to different types of lock-in dynamics.

Nonetheless, our study proves the fruitfulness of approaching the adaptation gap with a lock-in perspective. However, the recency with which this perspective has entered adaptation scholarship means that significant knowledge gaps remain. Further research and comparative studies are warranted to better understand how lock-in dynamics emerge within different adaptation contexts, different policy areas (outside of coastal adaptation) and different governance settings, and the underlying conditions through which lock-in mechanisms are initiated and flourish or are constrained and terminated.

Implications for policy and accelerating adaptation action

By revealing the otherwise hidden self-reinforcing mechanisms that maintain business-as-usual and hinder alternatives, lock-in analysis identifies opportunities for targeting and tailoring interventions to dissolve undesirable lock-in dynamics and open up opportunities for enabling innovative, diversified responses to adaptation. In this regard, further interdisciplinary research is needed to identify potential ‘unlocking’ strategies and how these might compare between different types of lock-in mechanisms. Herein, attention should be given to how certain mechanisms might be activated to counteract self-reinforcing lock-in dynamics, the mode of leverage, and crucially the point of intervention (e.g. targeting specific entities within the mechanism itself or through changing the enabling contextual conditions).

Inspiration can be drawn from climate mitigation scholarship and complex systems theory, where authors have highlighted how intervention points could be used to assist post-carbon transitions (Farmer et al., 2019). For example, two types of intervention points (a kick and a shift) are identified by Farmer et al. (Ibid.): whereas ‘a kick’ moves the current system onto a new trajectory while maintaining system dynamics, ‘a shift’ fundamentally changes these underlying dynamics and rules of the system. An understanding of lock-in dynamics can therefore help to direct purposeful interventions by revealing where and what types of intervention points may be required, and crucially, what forms of resistance these may encounter. Similarly, the concept of leverage points has been examined in the context of sustainability transformations. For example, Abson et al. (2017) identify different realms of leverage based on reconnecting people to nature, restructuring institutions and rethinking knowledge production. In turn, an understanding of lock-in mechanisms and the ways in which these incorporate institutional structures, human-nature connections and knowledge types, can help inform appropriate types of levers to stimulate incremental and transformative change in CCA.

In order to generate actionable knowledge, there is a need to establish methods for assessing the intensity of lock-ins and determining where to prioritise interventions. For instance, it may be useful to consider the lead and lag times between the point of intervention and realisation of benefits for climate adaptation. More widely, fundamental questions need to be asked about how desirable lock-ins and specific mechanisms could be intentionally established to avoid maladaptive pathways and minimise the risk of policy backsliding (Wilson, 2014; Ürge-Vorsatz et al., 2018), as well as the possibility of applying lock-in thinking to forestall and prevent detrimental lock-ins from occurring in the future.

Conclusion

This research demonstrates the utility of the lock-in perspective for understanding policy stability and resistance in climate change adaptation. Through two coastal case studies, we illustrate the added value of lock-in thinking for revealing otherwise hidden, self-reinforcing forces that interact across institutions, actors and infrastructures and collectively hinder adaptation efforts. We show how lock-in mechanisms create both intentional and unintentional effects, fostering active and passive forms of stability, respectively. This provides a useful approach for not only diagnosing the root causes of limited, incremental actions in adaptation and understanding the persistence of the ‘adaptation gap’, but holds important insights for targeting and tailoring interventions to dissolve undesirable lock-in dynamics. We therefore call for greater interdisciplinary collaboration to bring lock-in thinking to the forefront of

adaptation scholarship and efforts to accelerate adaptation action in response to the climate emergency we face.

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References

- Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C.D., Jager, N.W., & Lang, D.J. (2017). Leverage points for sustainability transformation. *Ambio*, *46*, 30–39.
- Adger, N., Quinn, T., Lorenzoni, I., Murphy, C., & Sweeney, J. (2013). Changing social contracts in climate change adaptation. *Nature Climate Change*, *3*, 330–333.
- Alexander, M., Priest, S., McCarthy, S., Penning-Rowsell, E., & Cobbing, P. (2021). *Evaluating the effectiveness of flood & coastal erosion risk governance in England and Wales*. FRS17186. Environment Agency.
- Arthur, W.B. (1994). *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press.
- Arts, B., Leroy, P., & van Tatenhove, J. (2006). Political modernisation and policy arrangements: A framework for understanding environmental policy change. *Public Organis. Rev.* *6*, 93–106.
- Barnes, W., Gartland, M., & Stack, M. (2004). Old habits die hard: path dependency and behavioural lock-in. *Journal of Economic Issues*, *38*(2), 371–378.
- Biesbroek, R., Termeer, C.J.A.M., Klostermann, J.E.M., & Kabat, P. (2014). Rethinking barriers to adaptation: Mechanism-based explanation of impasses in the governance of an innovative adaptation measure. *Global Environmental Change*, *26*, 108–118.
- Bisaro, A., de Bel, M., Hinkel, J., Kok, S., Stojanovic, T., & Ware, D. (2020). Multilevel Governance of Coastal Flood Risk Reduction: A Public Finance Perspective. *Environmental Science and Policy* *112*, 203–212.
- Collier, D. (2011). Understanding Process Tracing. *Political Science and Politics*, *44*(4), pp. 823–830.
- Committee on Climate Change (CCC). (2021). Independent assessment of UK climate risk. Advice for Government for the UK’s third Climate Change Risk Assessment (CCRA3). 16 June 2021. Available from

- Committee on Climate Change (CCC). (2018). *Managing the coast in a changing climate*. Committee on Climate Change, London.
- David, P.A. (1985). Clio and the economics of qwerty. *American Economic Review*.
- Defra. (2018). *The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting*. July. Defra, London.
- Defra. (2012). *Principles for implementing flood and coastal resilience funding partnerships*. Defra, London.
- Derwort, P., Jager, N.W., & Newig, J. (2021). How to Explain Major Policy Change towards Sustainability? Applying the Multiple Streams Framework and the Multi-Level Perspective on Socio-Technical Transitions to the German ‘Energiewende.’ *Policy Studies Journal*, online first.
- Ebbinghaus, B. (2005). *Can path dependence explain institutional change? Two approaches applied to welfare state reform*. MPIfG Discussion Paper 05/2, Max Planck Institute, Cologne, Germany.
- Environment Agency (EA). (2020). *National Flood and Coastal Erosion Risk Management Strategy for England*. Published 14 July 2020.
- Falleti, T.G., & Lynch, J.F. (2009). Context and Causal Mechanisms in Political Analysis. *Comparative Political Studies*, 42(9), 1143–1166.
- Farmer, J.D., Hepburn, C., Ives, M.C., Hale, T., Wetzer, T., Mealy, P., Rafaty, R., Srivastav, S., & Way, R. (2019). Sensitive intervention points in the post-carbon transition, *Science*, 364(6436), 132–134.
- Fereday, J. & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development, *International Journal of Qualitative Methods*, 5(1), 80-92.
- Flood Re. (2019). *Regulation 27: The Quinquennial Review*. July 2019.
- Foxon, T.J. (2002). Technological and institutional ‘lock-in’ as a barrier to sustainable innovation. *Imperial College Centre for Policy and Technology Working Paper*.
- Galik, C.S., & Chelbi, L. (2021). Revisiting Institutional Stability: A Systematic Review and Distillations of Dominant Modes. *Environmental Policy and Governance*, online first.
- Hall, P.A., & Taylor, R.C.R. (1996). Political science and the three new institutionalisms. *Political Studies*, 44, 936–957.
- Harries, T., & Penning-Rowsell, E. (2011). Victim pressure, institutional inertia and climate change adaptation: the case of flood risk. *Global Environmental Change*, 21, 188–197.
- Hedström, P., & Ylikoski, P. (2010). Causal Mechanisms in the Social Sciences. *Annual Review of Sociology*, 36(1), 49–67.
- Hegger, D. L., Driessen, P. P., Wiering, M., Van Rijswick, H. F., Kundzewicz, Z. W., Matczak, P., ... & Ek, K. (2016). Toward more flood resilience: Is a diversification of flood risk management strategies the way forward? *Ecology and Society*, 21(4).
- Hirschhäuser, T., & Hofstede, J. (2020). Meeresspiegelanstieg und die Konsequenzen für den Küstenschutz in Schleswig-Holstein. *Hydrographische Nachrichten*, 115(3), 10–17.
- HM Government (2020). *Flood and coastal erosion risk management Policy Statement*. Published 14 July 2020.

- Hofstede, J. (2019). On the Feasibility of Managed Retreat in the Wadden Sea of Schleswig-Holstein. *Journal of Coastal Conservation*, 23(6), 1069–1079.
- Hofstede, J.L.A., & Stock, M. (2018). Climate Change Adaptation in the Schleswig-Holstein Sector of the Wadden Sea: An Integrated State Governmental Strategy. *Journal of Coastal Conservation* 22(1), 199–207.
- Howlett, M. (2009). Process Sequencing Policy Dynamics: Beyond Homeostasis and Path Dependency. *Journal of Public Policy*, 29(3), 241–262.
- Huitema, D., Adger, W.N., Berkhout, F., Massey, E., Mazmanian, D., Munaretto, S., Plummer, R., & Termeer, C.J.A.M. (2016). The governance of adaptation: choices, reasons, and effects. Introduction to the Special Feature. *Ecology and Society*, 21(3), 37.
- Innenministerium des Landes Schleswig-Holstein. (2010). Landesentwicklungsplan Schleswig-Holstein, Kiel.
- Ishtiaque, A., Stock, R., Vij, S., Eakin, H., & Chhetri, N. (2021). Beyond the barriers: An overview of mechanisms driving barriers to adaptation in Bangladesh. *Environmental Policy and Governance*, 31(4), 316–329.
- Johnson, C.L., Tunstall, S.M. & Penning-Rowsell, E.C. (2005). Floods as Catalysts for Policy Change: Historical Lessons from England and Wales. *Water Resources Development*, 21(4), 561–575.
- Jones, H.P., Hole, D.G., & Zavaleta, E.S. (2012). Harnessing nature to help people adapt to climate change. *Nature Climate Change*, 2(July): 504–509.
- Jordan, A., & Matt, E. (2014). Designing policies that intentionally stick: policy feedback in a changing climate. *Policy Sciences*, 47, 227–247.
- Jordan, A., & Moore, B. (2020). *Durable by design? Policy Feedback in a Changing Climate*. Cambridge: Cambridge University Press.
- Klitkou, A., Bolwig, S., Hansen, T., & Wessberg, N. (2015). The role of lock-in mechanisms in transition processes: the case of energy for road transport. *Environmental Innovation and Societal Transitions*, 16, 22–37.
- Kotilainen, K., Aalto, P., Valta, J., Rautiainen, A., Kojo, M., & Sovacool, B.K. (2019). From path dependence to policy mixes for Nordic electric mobility: Lessons for accelerating future transport transitions. *Policy Sciences*, 52(4), 573–600.
- Kurz, T., Gardner, B., Verplanken, B., & Abraham, C. (2015). Habitual behaviors or patterns of practice? Explaining and changing repetitive climate-relevant actions. *Wiley Interdiscip. Rev. Clim. Change*, 6(1), 113–128.
- Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. *Policy Sciences*, 45, 123–152.
- Lindner, J. (2003). Institutional stability and change: Two sides of the same coin. *Journal of European Public Policy*, 10(6), 912–935.
- Massey, E., & Huitema, D. (2016). The emergence of climate change adaptation as a new field of public policy in Europe. *Regional Environmental Change*, 16(2), 553–564.
- Mees, H., Alexander, M., Matczak, P., Gralepois, M., & Mees H.L.P. (2018). Typologies of citizen co-production in flood risk governance. *Environmental Science and Policy*, 89, 330–339.

- MELUR. (2013). *Generalplan Küstenschutz des Landes Schleswig- Holstein – Fortschreibung 2012*. Ministerium für Energiewende, Landesplanung, Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein.
- MELUR. (2015). *Strategie Für Das Wattenmeer 2100*. Ministerium für Energiewende, Landesplanung, Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein.
- MELUND. (2017). *Anpassung an den Klimawandel: Fahrplan Für Schleswig-Holstein*. Ministerium für Energiewende, Landwirtschaft, Umwelt und Digitalisierung des Landes Schleswig-Holstein.
- MELUND. (2022). *Generalplan Küstenschutz des Landes Schleswig- Holstein – Fortschreibung 2022*. Ministerium für Energiewende, Landwirtschaft, Umwelt und Digitalisierung des Landes Schleswig-Holstein.
- OECD (2019). *Responding to Rising Seas: OECD Country Approaches to Tackling Coastal Risks*. OECD Publishing.
- Penning-Rowsell, E.C., Priest, S., & Johnson, C. (2014). The evolution of UK flood insurance: incremental change over six decades. *International Journal of Water Resources Development*, 30(4), 694–713.
- Pierson, P. (2000). Increasing Returns, Path Dependence, and the Study of Politics. *The American Political Science Review*, 94(2), 251–267.
- Pierson, P. (2004). *Politics in Time: history, institutions and social analysis*. New Jersey: Princeton University Press.
- Reise, K. (2017). Facing the Third Dimension in Coastal Flatlands Global Sea Level Rise and the Need for Coastal Transformations. *Gaia*, 25(4), 89–93.
- Schleswig-Holsteinischer (SH) Landtag. (2020). *Bericht Der Landesregierung: Gemeinschaftsausgabe 'Verbesserung der Agrarstruktur und des Küstenschutzes'*. Kiel.
- Schmid, N., Sewerin, S., and Schmidt, T.S. (2020). Explaining Advocacy Coalition Change with Policy Feedback. *Policy Studies Journal*, 48(4), 1109–1134.
- Seto, K. C., Davis, S. J., Mitchell, R., Stokes, E. C., Unruh, G., & Ürge-Vorsatz, D. (2016). Carbon Lock-In: Types, Causes, and Policy Implications. *Annual Review of Environment and Resources*, 41, 425–452.
- Siebenhüner, B., Grothmann, T., Huitema, D., Oels, A., Rayner, T., & Turnpenny, J. (2021). Lock-Ins in Climate Adaptation Governance. In: R. Djalante & B. Siebenhüner (eds.) *Adaptiveness: Changing Earth System Governance*. Cambridge: Cambridge University Press, 127–146.
- Skogstad, G. (2017). Policy Feedback and Self-Reinforcing and Self-Undermining Processes in EU Biofuels Policy, *Journal of European Public Policy*, 24(1), 21–41.
- Trencher, G., Rinscheid, A., Duygan, M., Truong, N., & Asuka, J. (2020). Revisiting carbon lock-in in energy systems: explaining the perpetuation of coal power in Japan. *Energy Research & Social Science*, 69, 101770.

Ürge-Vorsatz, D., Rosenzweig, C., Dawson, R.J., Rodriguez, R.S., Bai, X., Barau, A.S., Seto, K.C. & Dhakal, S. (2018). Locking in Positive Climate Responses in Cities. *Nature Climate Change*, 8(3): 174–177.

Wilson, R.M.D., & Russel, D.J. (2018). Climate adaptation in fragmented governance settings: the consequences of reform in public administration. *Environmental Politics*, 27(2), 341–361.

United Nations Environment Programme (UNEP) (2021) Adaptation Gap Report 2021: The gathering storm – Adapting to climate change in a post-pandemic world. Nairobi.

Weible, C.M. & Sabatier, P.A. (eds.) (2018). *Theories of the Policy Process*. 4th edition. New York: Routledge.

Weir, M. (1993). *Politics and Jobs: The Boundaries of Employment Policy in the United States*. Princeton: Princeton University Press.

Wilson, G.A. (2014). Community Resilience: path dependency, lock-in effects and transitional ruptures. *Journal of Environmental Planning and Management*, 57(1), 1–26.

Table 1: Summary of organisations interviewed

England, U.K. (N=10)	Schleswig-Holstein (Germany) (N=10)
<ul style="list-style-type: none">• Committee on Climate Change (CCC)• Academic experts (3)• National Flood Forum• Flood Re• Engineering consultancy• Department for environment, food and rural affairs (Defra)• Former employee for Defra and CCC• Environment Agency	<ul style="list-style-type: none">• State Ministry of the Environment (2)• State Ministry of the Interior (2)• State Administration for Coastal Defence and the National Park• Dike and Drainage Association• NGOs (3)• Academic expert

	Lock-in mechanism	Description	England, UK	SH, Germany
Known mechanisms	Economies of scale	This mechanism is typically described in the context of production capacity and units of production; as production becomes more efficient and the scale of the operation increases, costs are spread across units of production, which decreases the cost per unit and generates cost advantages (Arthur, 1994). Though typically related to technologies and infrastructures, it is also applicable to specific approaches in CCA (such as the scaling-up of Natural Flood Management techniques).	✓	✓
	Adaptive expectations	Individuals, organisations and actor groups adjust their expectations and actions based on their perceptions of what others will do; i.e. 'it derives from the self-fulfilling nature of expectations' (Pierson, 2000, p. 254).	✓	✓
	Learning effects	Increasing benefits result from 'learning by doing' and 'learning by using' associated with the development, production and/or application of a specific technology, product or approach (Arthur, 1994). The acquisition of knowledge and skills enables incremental improvements, which in turn promote continued use (David, 1985).	✓	✓
	Collective action	Problems and solutions for complex environmental issues are framed and (re)produced through social networks, culminating in shared views and commitment towards collective action (Klitkou et al., 2015).	✓	
	Habituation	Actors develop attachment towards certain approaches or technologies even when potentially superior alternatives exist. This is driven through routines and repetition and strengthened by actors' preference to weigh earlier gains compared to future efforts (Barnes et al., 2004; Kotilainen et al., 2019).	✓	
	Power differentiation	Actors impose rules on others and/or implement rule changes or a specific course of action to strengthen their position of power and advance their agenda. This mechanism is referred to in the literature under various guises, as 'differentiation of power and institutions' (Klitkou et al., 2015; Kotilainen et al., 2019) or 'power asymmetries' (Foxon, 2002; 2010).	✓	
	Economies of scope	This refers to the cost and/or competitive advantages induced by the production and use of a broader range of products (rather than specialising in the production of one type) (David, 1985; Klitkou et al., 2015).		
	Institutional learning effects	The increased adoption of institutions over time leads to complementary institutions. This can lead to a range of potential benefits, such as improved coordination and efficiencies, but may also have undesired consequences -e.g. increased complexity and interdependencies may prove resistant to change (Foxon, 2002; Kotilainen et al., 2019).		
New mechanisms	Network effects	Where there are (increasing) advantages of adopting a specific technology, product or approach, it becomes more widely used (Ebbinghaus, 2005). This mechanism has also been described as 'network economies' (Arthur, 1994; Janipour et al., 2020) and 'co-ordination effects' (Foxon, 2002).		
	Social contracting	The (re)production of normative values and expectations concerning the perceived state-society relationship influences the acceptance (or rejection) of proposed technologies or approaches and the decision-making process. Values and expectations related to the perceived social contract are actively wielded to lobby (or alternatively contest) an agenda.	✓	
	Co-dependency	This mechanism describes a type of relationship between two or more actors, whereby the parties involved require something from the other and have established specific formal arrangements to secure mutual gains. This mechanism can be viewed as a specific type of the differentiation of power mechanism; although power may not necessarily be equally dispersed between parties, each are able to leverage the other based on their co-dependency on one another. This reflects what Trencher et al. (2020) describe as a lock-in by design (as opposed to a lock-in forged by consequence), in that this arrangement has been intentionally constructed and maintained between the parties involved.	✓	
	Business network effects	Business network effects occur when economic gains are bolstered as a result of specific public policies; as these gains accrue and the number of businesses and jobs tied to these policies increase, this incentivises political actors to continue to maintain and/or strengthen commitments towards the policy in question. This mechanism is thus propelled by the motivations of political actors (rather than through direct lobbying from business actors). This mechanism displays similarities with network effects (Pierson 2000), but relates specifically to network effects associated with businesses that flourish as a consequence of policy decisions.		✓
	Framing (re)production	The framing of problems and their solutions are co-constructed or reproduced by different actors and institutions. These shared beliefs, norms, or values are communicated by different actor groups thus reinforcing their legitimacy and prevalence.		✓

Table 2: Summary of lock-in mechanisms affecting coastal adaptation in England (U.K.) and Schleswig-Holstein (Germany), some of which are mechanisms from the literature, while others are newly identified.

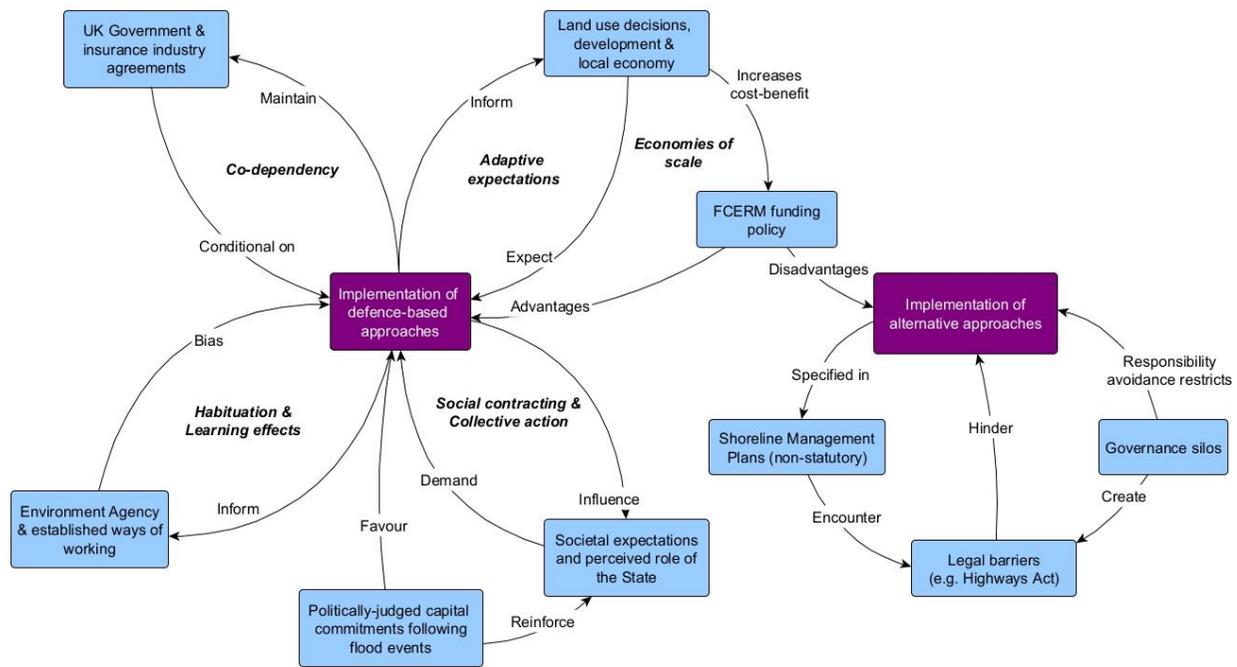


Figure 1: Systems flow diagram of lock-in mechanisms identified in coastal governance in England, U.K. [Arrows indicate feedbacks, blue boxes indicate entities and purple boxes indicate outcomes]

