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Shaping flood risk governance through science-policy interfaces: Insights from England, France and the Netherlands

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ABSTRACT

In the face of increasing threats from flooding, there are growing calls to strengthen and improve arrangements of flood risk governance (FRG). This endeavour requires an appreciation of the multitude of factors stabilising and driving governance dynamics. So-called catalyst flood events, policy champions and advocacy coalitions have tended to dominate this study to date, whilst the potential role played by Science Policy Interfaces (SPIs) has been somewhat neglected and often approached in a reductionist and fragmented way. This paper addresses this gap by drawing from in-depth policy analysis and stakeholder interviews conducted within England, France and the Netherlands under the auspices of the EU-FP7 STAR-FLOOD project. The analysis reveals four prominent ways in which SPIs shape FRG, by i) facilitating the diversification of Flood Risk Management (FRM) strategies; ii) increasing their connectivity, iii) facilitating a decentralisation of FRM and iv) fostering inter-country learning. It identifies different roles of specific interfaces (structures) and interfacing mechanisms (processes) in shaping governance dynamics. This way, the analysis reveals various 'entry points' through which SPIs can steer FRG, either along existing pathways, or towards new and potentially transformative change. The study shows that SPIs are a hitherto underexposed factor explaining dynamics in flood risk governance which merits additional systematic empirical study.

1. Introduction

In various European countries, efforts are ongoing to enhance societal resilience and implement effective flood risk governance to deal with increasing risks posed by urbanisation and the effects of climate change (Alexander et al., 2016; Kaufmann et al., 2016; Larrue et al., 2016; Hegger et al., 2014). However, countries have addressed this challenge in different ways. In France and the Netherlands, efforts are ongoing to complement traditional defence strategies with other approaches, such as proactive spatial planning, flood mitigation or emergency management to create 'fail-safes' (Larrue et al., 2016; Kaufmann et al., 2016). In England, such a diversified approach has a long legacy, but is being supplemented with a growing focus on long-term adaptation and the enhancement of community resilience (Alexander et al., 2016). Stability and change in governance are both supported and constrained by a multitude of factors (Raadgever and Hegger, 2018).

Flood Risk Management (FRM) literature has tended to focus on the influential role of 'shock' or 'catalyst' flood events which create policy windows for change (Liefferink et al., 2018). However, Science Policy Interfaces (SPIs) also appear to play an important role in FRM. Recent research in the field of water and flood risk management demonstrates how SPIs foster institutional learning and encourage the uptake of knowledge/technologies in practice (Quevauviller, 2011; Liefferink et al., 2018). The dominant thrust in these debates is that close interaction between scientists and policymakers is necessary at different levels of decision making (Quevauviller, 2011; Raadgever et al., 2012), a point which is also stressed in more general environmental governance literature (Hegger and Dieperink, 2014; Kirchhoff, 2013). However, existing literature is arguably reductionist and somewhat fragmented in the sense that empirical studies focus on highly specific SPIs while largely ignoring the context in which they emerge and function (Runhaar et al., 2016; Van Enst et al., 2014). Moreover, in the FRM literature there continues to be a lack of comprehensive empirical

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studies that characterise the nature of SPIs and the various pathways through which these shape, or are shaped by, FRG.

Addressing this gap, this article aims to critically assess the ways in which SPIs have influenced FRG using selected countries (England, France and the Netherlands) as examples. As a starting point, Section 2 reviews how SPIs are characterised in literature and identifies analytical categories to support systematic analysis. Section 3 outlines the research methods, including in-depth policy analysis, stakeholder interviews and cross-country comparisons. To contextualise the research, Section 4 outlines the main dynamics in FRG and provides an overview of SPIs established in the selected countries. Based on the analysis, Section 5 identifies four common themes concerning the role played by SPIs in terms of i) facilitating the diversification of FRM strategies, ii) connectivity between these, iii) the decentralisation of FRM and iv) inter-country learning. The findings demonstrate the suite of SPIs (mechanisms, processes and organisations) that bridge science and policy and help steer the direction of FRG, and raise a number of important implications for research and practice (discussed in Section 6).

2. Conceptual clarification on science-policy interfaces

To systematically analyse SPIs in FRG, conceptual guidance is needed in two respects. Firstly, different perspectives on the fundamental question of the relationship between science and policy need to be taken into account. This relationship has been widely debated from three discernible positions, i) science-led policy, ii) socially constructed science and iii) co-produced science-policy. The first perspective assumes that greater and better knowledge, in the long-run, will lead to better decision making. This perspective, in its most extreme manifestation, assumes that influence is one-directional: from science to policy. Several authors, including Beck (2011) have depreciatively termed this the 'linear model of expertise' and argue that this model is inadequate because it attributes too much independence and too much influence to scientists (Hegger et al., 2012:53). In contrast, a diametrically opposed position is that science is inherently socially constructed, thus, research incorporates values and many policy choices are already made in research (Latour, 1987). From this standpoint, the subject matter of research and research agendas arguably mirrors underlying values and power relations in policy and society. Seen in this way, science and policy are continuously co-evolving (Jasanoff and Martello, 2004). An alternative standpoint regards the coproduction of science and policy, whereby policy provides a steer for scientific inquiry and equally emerging scientific knowledge can inform policy (Hegger et al., 2012; Raadgever et al., 2012; Van den Hove, 2007). Adopting this latter perspective, this research critically reflects on the extent to which SPIs shape, and are shaped by, dynamics in FRG.

In addition to clarifying the theoretical relationship between science and policy, analyses of SPIs must consider the different components, features and characteristics of SPIs; in short, what makes-up an SPI? Literature in this field is highly diverse, with different disciplinary insights from science and technology studies (Guston, 2001; Jasanoff and Martello, 2004; Gieryn, 1983) as well as multi-disciplinary studies of environmental governance (Van Enst et al., 2014), with some relevant examples in water/flood risk management (Quevauviller, 2011). Van den Hove (2007:807) define SPIs as "social processes which encompass relations between scientists and other actors in the policy process and which allow for exchanges, coevolution and joint construction of knowledge with the aim of enriching decision making". While this definition emphasises processes, others are concerned with the role of specific actors (Guston, 2001; Van Enst et al., 2016), tools and other material resources (Gieryn, 1983; Hegger and Dieperink, 2014). To summarise these debates, Table 1 categorises the various elements of SPIs discussed in the literature and distinguishes SPIs encompassing concrete tools, resources and mechanisms that support the interfacing process (i.e. the verb), from specific organisations acting as specific interfaces (i.e. the noun).

2.1. Institutions that act as interfaces

Interfacing institutions are often referred to as boundary organisations (Van Enst et al., 2016). Although the term has various different definitions, it is generally understood as "intermediaries, which place themselves between the environmental science and policy-making arenas. Furthermore, following the empirical research on boundary organisations, they are predominantly considered to be scientific and/or governmental organisations/agencies" (ibid: 417). Boundary organisations collect and distribute scientific knowledge, structure research questions and knowledge demands, and develop and translate scientific reports for policymakers (Guston, 2001; Van Enst et al., 2014). Boundary organisations may be formally appointed as such, but their role as a boundary organisation may also emerge (e.g. Dannevig and Aall, 2015). Despite their crucial importance in establishing and facilitating science-policy interactions, there are limited empirical studies into how boundary organisations function (van Enst et al., 2016).

2.2. Science-policy interfacing processes and mechanisms

In terms of science-policy interfacing mechanisms, there is considerable emphasis in the literature on participatory processes of knowledge production to foster mutual learning and change strategic perspectives (Hegger et al., 2012; Raadgever et al., 2012; Van Enst et al., 2014). Such processes facilitate the exchange and negotiation of ideas, visions and knowledge. Insights into success conditions for such participatory knowledge production are emerging, such as the need for protected spaces in which people feel confident to participate (e.g. transdisciplinary innovation labs; Hegger and Dieperink, 2014) or specific 'communities of practice' (Déroubaix et al., 2017), and importance of achieving the appropriate balance between heterogeneity and homogeneity of involved parties (Boon et al., 2014). Participatory knowledge production may lead to knowledge which according to the actors involved could not have been produced in isolation (Hegger and Dieperink, 2014), as well as facilite mutual learning (Raadgever et al., 2012). Individual mediation- may facilitate bridging between science and policy through explanation and translation (Hegger and Dieperink, 2014; Van Enst et al., 2014). Another important mechanism is the presence of rules related to participatory knowledge production (e.g. regarding divisions of responsibilities between participating actors) (Hegger et al., 2012).

2.3. Science-policy interfacing tools and resources

Boundary objects have been recognised as means to facilitate knowledge exchange between scientists and policy makers (Hegger and Dieperink, 2014; Mattor et al., 2014; Star and Griesemer, 1989). They may include material objects and visual devices such as interactive flood maps (Meyer et al., 2012). It is claimed that boundary objects can be interpreted in different ways, hence different types of actors can relate to them and attach meaning to them (Hegger and Dieperink, 2014). For instance, so-called boundary concepts arguably constitute a specific type of boundary object (Gieryn, 1983). Concepts are used which are kept intentionally vague and therefore have meaning both in the worlds of science and governance (e.g. "tipping points", "resilience") (Hegger et al., 2012). Besides these tools, a richness of resources to facilitate science-policy interaction, including (administrative) support, availability of tools and capacities was found to be an important condition for facilitating such interfacing (Hegger and Dieperink, 2014; Mattor et al., 2014).

3. Methods

This research aims to assess the ways in which SPIs influence FRG in different contextual settings, using England, France and the Netherlands as case studies. The analysis draws from data collected

Table 1
categorisation of different components of science-policy interfaces.

Category	Type	Source(s)
Institutions that act as interfaces	Boundary organisations	Guston, 2001; Van Enst et al., 2014/2016
Interfacing processes and mechanisms	Forums for participatory processes of knowledge production and exchange	Hegger et al., 2012; Hegger and Dieperink, 2014; Van Enst et al., 2014
	Individual mediation	Van Enst et al., 2014/2017
Tools and resources supporting the interfacing process	Boundary objects	Star and Griesemer, 1989; Mattor et al., 2014; Hegger and Dieperink, 2014
	Boundary concepts	Gieryn, 1983
	Financial resources	Hegger and Dieperink, 2014
	Other resources: (administrative) support, availability of tools and capacities	Hegger and Dieperink, 2014; Mattor et al., 2014

within the EU FP7-funded "STARFLOOD" project (2012–2016) (http://www.starflood.eu/), derived from in-depth policy and legal analyses as well as semi-structured stakeholder interviews with policy makers and practitioners involved in all aspects of FRM, from national to local scales (61 in England, 64 in France and 45 in the Netherlands). While the data were initially collected to explain governance dynamics (Raadgever and Hegger, 2018) and evaluate current FRG more broadly (ibid)[1], SPIs emerged as a crucial, though implicit, part of the research. Therefore, these datasets have been reanalysed to provide further insight into the presence and influence of SPIs within national FRG. The typology of SPIs presented in the previous section provided sensitising concepts to help frame and support the analysis. Furthermore, in-depth cross-country discussions were held amongst the research team to interpret the findings. This led to the identification of four shared themes, which, while defined inductively for the purpose of the current study, correspond with important ongoing dynamics as discussed in Raadgever and Hegger (2018). It should be noted that while the original data collection was completed in July 2016, we have since performed additional desk-based analyses where required.

The development and performance of SPIs, like other societal processes, should be regarded as dynamic (Hegger and Dieperink, 2014). Therefore, this analysis adopts a longitudinal perspective and considers how SPIs as key elements of FRG have emerged or co-evolved with changes in FRG over time; whereby the presence of change is denoted by the emergence, change or disappearance of flood-relevant actors, discourses, rules and resources (Hegger et al., 2014). Although the complexity of societal processes makes it difficult to infer causality, the analysis focused on explicit evidence linking governance and SPIs (e.g. as stated by interviewees or within published reports or policies for example.

4. An overview of flood risk governance dynamics and SPIs in England, France and the Netherlands

This section provides a general overview of high-level changes seen in national FRG arrangements. The presence of particular SPIs within each country is summarised in Table 2. In all three countries, there has been a documented diversification of FRM strategies (see Fig. 1 for an overview of the strategies). Essentially, the strategies differ in their main focus on reducing the probability of floods (mainly flood defence); reducing the consequences (flood risk prevention; mitigation and preparation); or recovery. A detailed description of the strategies is provided in Raadgever and Hegger (2018).

France shows gradual change in FRM strategies from the beginning of the 1980s onwards, partly fuelled by a broader trend towards decentralisation (Larrue et al., 2016; Liefferink et al., 2018). While initially there was a strong emphasis on flood defence, since the 1980s flood prevention (through the designation of flood zones (PPRI system)), flood recovery (through the CAT-NAT solidarity mechanism), flood preparation, and to a lesser extent flood mitigation, have grown in importance. The role of the State is still strong in the implementation of the recovery system CATNAT and to a certain extent in the definition of the zoning areas (Barnier Law, 1995). Nonetheless the central state has progressively retreated from flood management and provided more room for action by local and regional authorities. With the Law MAPTAM (2016), local authorities – and in particular the communal and intercommunal level – are now given the responsibility in flood risk management for defense, prevention, mitigation and recovery. France is attempting to strengthen connectivity between different strategies. An important mechanism to do so is the development of Flood Risk Management Plans (FRMPs) as part of the implementation of the EU Floods Directive. Each plan provides the main objectives in terms of the reduction of vulnerability, disaster management and risk awareness and it provides the main tools to achieve those objectives (Zoning System for Flood prevention, the local Action Programmes for Flood Prevention – PAPI, the flood forecasting service, etc).

In the Netherlands there is a predominant focus on flood defence with probability-reducing measures, such as the construction and maintenance of dikes and dunes (dike rings), storm surge barriers and water storage locations. Although there were some smaller moves towards more nature-friendly and integrated water resources management in the mid-1980s, more profound changes within river management started to occur from the mid-1990s onwards with the implementation of the national *Room for the River* programme, accompanied with a discursive shift from 'a battle against water' to 'living with water' (Wiering and Arts, 2006; Kaufmann et al., 2016; Van der Brugge et al., 2005). Policy discourses on the need to implement additional FRM strategies such as flood mitigation and preparation received an additional impetus with the rise of the so-called 'multi-layered safety' approach in the National Water Plan in 2009. The Netherlands has a Calamities Compensation Act, although in general flood recovery is not prioritised. After all, due to the high safety standards, major flooding and the need for large scale recovery is rare. In the Netherlands, regional water authorities play a key role in generating and using knowledge on flood defence. To some extent, the high degree of institutionalisation of flood defence in the Netherlands has led to dominance of flood defence over other strategies.

Compared to the other studied countries, a diversified approach to managing flooding has a longer legacy in England, with all strategies established since 1947 (Alexander et al., 2016). However, it is only relatively recently that these strategies have been regarded as *equally* important, with progressive incremental changes leading to closer alignment and coordination, particularly over the past two decades. Although comprehensive, FRG in England has been criticised for being overly complex and fragmented, with correspondingly high transaction costs (Raadgever and Hegger, 2018). To remedy this, attention has been directed towards better integration of FRM activities and use of 'bridging mechanisms' to facilitate coordination and collaboration both

[1] For insight into the original findings from STAR-FLOOD, and national-level analyses of FRG, readers are referred to Alexander et al. (2016); Kaufmann et al. (2016) and Larrue et al. (2016).

Table 2
Key SPIs of relevance to flood risk governance in the Netherlands, France and England.

	Netherlands	France	England
Institutions that act as interfaces	-PBL the Netherlands Environmental Assessment Agency; Delta Programme; Consultancy Companies; dedicated Research Institutes	- Advisory Board on the Prevention of Major Natural Hazards (COPRNM); the Flooding Committee (CMI); General Board for the Environment and the sus tainable development (CGEDD) - Research Institutes: IRSTEA[1]; CEREMA[2] -Think tank of private insurance companies Mission of Natural Risk (MRN). - Associations: CEPRI[3], IRMA[4]	-Environment Agency; - Committee on Climate Change; - Joseph Rowntree Foundation
Interfacing processes and mechanisms	-Individual mediation (through Delta Commissioner; high-level experts). -Processes of participatory knowledge production (learning-action alliances at the local level; large research programmes)	-Individual mediation (through experts and consultancy agencies) -Processes of participatory knowledge production facilitated through local action plans for flood protection; specific river basin management plans	-Living With Environmental Change (LWEC), a partnership of 20 public organisations. This evolved into the RIDE Forum in 2016, comprised on 19 public sector member organisations to 'enhance the impact of UK's publicly-funded environmental change research'; -Defra/Environment Agency Research and Development Programme.
Tools and resources supporting the interfacing process	-Decision support tools; climate services; protected spaces (living labs) - Flood modelling, mapping, radar, forecasting	-Flood forecasting modelling, mapping, radar,	-Long-term investment scenarios. -Flood modelling, mapping, radar, forecasting.

1National Institute of Research for Environmental and Agricultural Technologies and Sciences (IRSTEA).
2Centre for the study and expertise on risks, environment, mobility and planning (CEREMA).
3European Centre for flood risk prevention (CEPRI).
4Institute of Major Risks (IRMA).

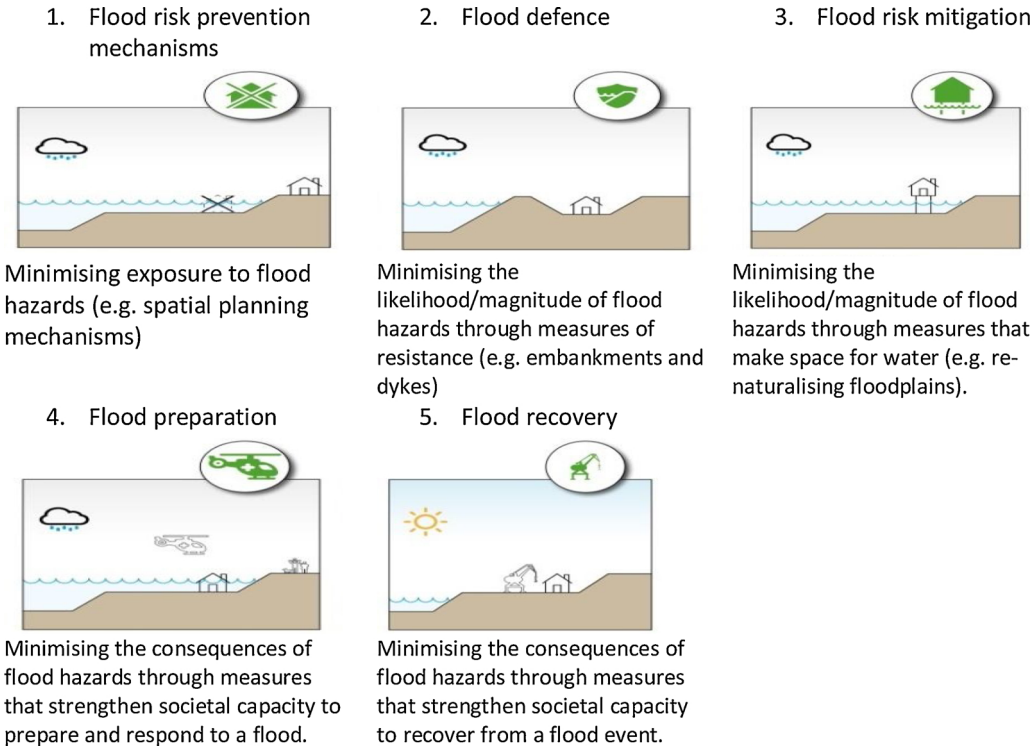

Fig. 1. Five FRM strategies (from Hegger et al., 2014 and with visualisations taken from Raadgever et al. 2016 and reprinted with permission).

within and between FRM strategies and different types of actors involved (Alexander et al., 2016). In addition, there has been a discursive shift towards managing floods at more local scales, with duties for managing local sources of flooding (including surface water) assigned to Lead Local Flood Authorities (under the Flood and Water and Management Act 2010) and greater efforts to involve local communities in FRM. These dynamics in FRG have been attributed to 'catalyst' flood events and subsequent inquiries (e.g. Bye Report 1998 and Pitt Review 2007); legislative changes in response to recognised gaps (e.g. the Flood and Water Management Act 2010); the influence of advocacy coalitions; advances in science and technology; as well as other economic and political drivers (see review in Alexander et al., 2016).

5. Analysing the relationship between SPIs and FRG

The assessment of the materials as described in the methods section have led to the identification of four common themes concerning the role played by SPIs in terms of i) facilitating the diversification of FRM

strategies ii) facilitating connectivity between these; iii) the decentralisation of flood risk management and iv) inter-country learning. These themes will be discussed in more detail below.

5.1. Facilitating the diversification of FRM strategies

As highlighted in the previous section, a key development in all three countries is a shift towards an integrated and risk-based approach to flood management, which in France and the Netherlands involves a diversification of FRM strategies and in England a more balanced emphasis of all types of strategies which are tailored to the specific place. Our analysis has revealed that, nested within a multitude of factors, SPIs played an important role in steering and facilitating the transition in each country. On a strategic level, boundary organisations and dedicated (knowledge and policy) programmes in particular have proved influential. Moreover, these appear to have diversified in parallel with the diversification of FRM strategies and actors involved in FRM.

5.1.1. Boundary organisations

In all three countries boundary organisations appear highly influential in terms of the emphasis placed on specific FRM strategies within the national policy agenda. However, these organisations differ in how they are constituted, at what scale they operate and, most importantly, how they work and what they produce.

Both in the Netherlands and France dominant and pervasive knowledge coalitions (Van Buuren and Edelenbos, 2004) related to flood defence played a significant role in stabilising FRG and maintaining the defence paradigm for several decades. Close cooperation between organisations producing knowledge on flood defence and organisations operating and maintaining these defences has led to the rise of well-developed defence expertise and practices. In France advisory boards and research institutes play a fundamental role in the definition and implementation of flood policy. On one hand, the production of scientific knowledge in this domain relies mostly on public agencies directly controlled the state through its Ministries (such as IRSTEA, CEREMA, CGEDD). On the other hand, other actors have started to support and acquire a capacity of producing knowledge through the financing of specific studies or dedicated institutions/associations (such as CEPRI and IRMA). Moreover the private insurance sector also acts as an expert in flood policy mainly through the Mission of Natural Risk (MRN). MRN acts as a think-tank to gather and analyse information on the whole risk management policy process and by providing technical details on prevention policies (knowledge on vulnerability, loss ratios, evaluation of the efficiency of the prevention measures, etc.).

In contrast, there is no weakening of the dominant defence-orientated knowledge coalition within the Netherlands. However, some dynamics in the internal logic displayed within this dominant coalition have been observed. Prior to the near flooding in 1993–1995 debates about diversification beyond the defence strategy towards water retention schemes emerged within knowledge institutes and amongst policy making actors (Driessen and De Gier, 1999). These shock events triggered the national policy programme Room for the River (ibid). As part of this programme, more resources for enhancing the knowledge infrastructure became available, including finances for modelling, which in turn provided input to the policy process and helped inspire non-defensive approaches such as nature-based solutions. However, the recipient of these resources remained the water management institutes, both those situated within Rijkswaterstaat as well as research institutes and universities (Wiering and Arts, 2006).

Contrary to France and the Netherlands, in England a multi-disciplinary approach has long been embraced since the dominance of engineering in the 1980s, however the weight assigned to different FRM strategies has increasingly levelled-out. In part, this can be related to the role of boundary organisations, though in the case of England, this might be better phrased as boundary partnerships. At the time of analysis, an important boundary partnership was established by the UK research councils, namely the Living With Environmental Change (LWEC) partnership. From 2007–2016, LWEC brought together 20 public sector organisation and was instrumental in driving the UK National Ecosystem Assessments[2] (RIDE Forum, No Date), amongst a range of other activities and specific FRM projects.[3] Reflecting on the success of LWEC members have commented on the valuable mechanisms provided through the LWEC partnership in steering shared strategic visions, including the UK flood research strategy which explicitly called for a multidisciplinary approach and identified research priorities across all aspects of FRM.[4] Additionally, LWEC established the UK Water Industry Research (UKWIR) which although was focussed more on water, it latterly lead to the creation of the Water Partnership which has a broader remit which includes flooding and has supporting research excellence as one of its four core aims and in 2017 the launch of the Flood Partnership initiative and the creation of a self-sustaining knowledge platform. The legacy of LWEC continues today as it evolved into the Research & Innovation for our Dynamic Environment (RIDE) Forum (from 2016), which similarly brings together representatives from UK governmental departments and agencies, local government and research councils. The Forum as it stands today adopts a strategic coordinating function to steer research activities, leverage resources, and maximise the impact of publicly-funded environmental change research, placing greater emphasis on the co-development of strategies and joint priority setting.[5] An explicit statement is made to articulate the network's role in bridging science and policy – "*it will also enable the UK academic community to form independent beneficial and impactful links to the policy and practice community*"[6] . While the RIDE Forum was not studied within this research, it is clear that it continues to play an important part in environmental governance more widely in the UK.

5.1.2. Knowledge and policy programmes

In England, the Netherlands and France, dedicated knowledge and policy programmes have played a key role in the diversification of FRM strategies. In England, the Environment Agency (EA) and Department for Environment, Food and Rural Affairs (Defra) jointly support a Research and Development (R&D) programme to bridge the gap between research and operational systems and policy needs. Research needs (both policy and operational) are identified and prioritised by three Thematic Advisory Groups (TAG) comprising leading academics, industrial and operational flood risk managers across various disciplines. This serves to inform the research agenda and provide knowledge for evidence-based decision-making from national to local scales. In this sense, the R&D programme acts as both a mechanism and resource to support the interfacing process between science and policy. It reinforces and is also served by the "*very good and strong relationship with the professional engineering sector*" (Interview with English policymaker). This programme has played an important role in establishing the need for risk-based management and embracing other disciplinary perspectives beyond engineering and the physical sciences associated with the defence-dominated approach that characterised English FRM in the 1950 s–1990 s. Furthermore, research implemented has helped to generate knowledge and close operational gaps, enabling the key FRM strategies to further evolve and align within an embedded approach to FRM. An English policymaker commented that a key benefit of this forum is "*the diversity of professionals generating ideas which can help*

[2] https://nerc.ukri.org/research/partnerships/ride/about/ride-forum/, accessed 22/06/2019).

[3] https://nerc.ukri.org/research/partnerships/ride/work/lwec-activities/, accessed 22/06/2019.

[4] https://nerc.ukri.org/research/partnerships/ride/lwec/fcerm/, accessed 22/06/2019.

[5] http://www.nerc.ac.uk/research/partnerships/ride/, accessed 22/06/2019.

[6] https://nerc.ukri.org/research/partnerships/ride/about/ (accessed 22/06/2019)

innovate…we had much success with shorter R&D projects to bridge the gap between research and the delivery of FCERM outcomes and lever additional resources" (pers. Comm.). Associated with the R&D efforts of the EA and Defra is the hosting of a longstanding (since the 1960s) 'Flood & Coast" conference which is described in the latest National Flood & Coastal Erosion Risk Management Strategy as "*an important part of bringing those who manage flood and coastal erosion together. It provides an opportunity to share lessons, celebrate success, showcase innovations and discuss ways to meet future challenges*" (EA, 2019; p46).

In France, the diversification of interventions and approaches has been triggered by local initiatives and by the affirmation of local actors in the management of the flood policy. In certain cases, the development of expertise managed to reorient the national doctrine in the domain of flood risk. The experience of the Plan Grandeur Nature on the river Loire in the 1990s has been crucial in order to reframe the national defensive doctrine towards the implementation of soft infrastructures (Fournier, 2010). In this case the discourse on vulnerability was reintroduced by new groups of experts and people, different from "established" scientists and engineers. This discourse was mainly supported by independent experts, working directly with the territory. A bottom-up logic characterised this experience and later obtained recognition from the central state. The technical mission for the elaboration of the Loire Plan was one of the first to officially promote the necessity of developing "soft protection" measures and the priority to give to vulnerability reduction of the territory (Larrue et al., 2016). This experience has provided an important turning point and has proved the capacity of local actors to produce knowledge and develop a more diversified approach to flood risk. Since other local programmes, such as Plan Egrian elaborated by the city of Nevers in 2007, was inspired by the experience and approach of Plan Loire.

In the Netherlands, the second Delta Programme (commencing in 2008), appears to have had a strong influence on the diversification of FRM strategies. This policy programme was informed by prominent knowledge institutes and research programmes, including the Knowledge for Climate programme (2008–2014) and Climate Change Spatial Planning. To some extent, the Delta Programme and associated knowledge development efforts strengthened flood defence. Debates on the compliance of flood defences with the already high safety norms combined with debates on a heightening of these norms feature prominently in this programme. At the same time, the programme incorporated knowledge related to e.g. nature-based solutions and governance and put the notion of 'resilience' on policy agendas. Hence, the programme contributed new ideas and fuelled discussion about better disaster management and spatial planning (Kaufmann et al., 2016; Van Buuren et al., 2016).

5.2. Increasing connectivity between FRM strategies

In all studied countries, diversification of FRM strategies is complemented with efforts to increase connectivity between strategies. While diversification is mainly pursued through boundary organisations and policy programmes establishing cooperation between policy actors at different levels, the enhancement of connectivity is taking place mainly through processes and mechanisms as well as tools and resources.

5.2.1. Processes and mechanisms

In England, post-flood inquiry processes have proved instrumental. The independent review into the Summer 2007 floods led by Sir Michael Pitt arguably acted as a form of SPI, for which evidence was invited from a range of stakeholders (Risk Management Authorities, government departments, academic and research institutions, business organisations, insurers, media, consultancies, voluntary sector and the general public). The Pitt Review raised 90 recommendations, many of which were translated into legislation (via the Flood and Water Management Act 2010), policy and practice. The Act was "*basically driven by Pitt and the 2007 floods…it was about having the right ideas and seizing the opportunity when floods happen to implement*" (Interview with English Policymaker). A number of recommendations specifically related to matters of coordination within and across FRM strategies. For example, interviewees highlighted the importance of the recommendations in steering the creation of a joint Meteorological Office/Environment Agency Flood Forecasting Centre (FFC) to improve the connectivity between those executing forecasting and emergency management. Moreover, the subsequent enactment of the Flood and Water Management Act solidified responsibilities for the Environment Agency as the coordinating authority for all types of flood risk, as well as establishing responsibilities for Lead Local Flood Authorities and other Risk Management Authorities, which included mandatory duties to coordinate activities. In this sense, the Pitt Review can be interpreted as driving significant change in FRG in England, utilising the Summer 2007 floods as a window of opportunity.

Enhanced connectivity in France has mainly taken place by establishing and strengthening collaborations between local authorities and local private or public expert agencies, or by the development of specific expertise within local authorities themselves. In these regards, recent Flood Risk Management Plans elaborated by local authorities and providing an integrated approach to FRM (especially through the specific Actions Plans for Flood Prevention (PAPI) - can be seen as important interfacing mechanisms (Larrue et al., 2016). In the framework of PAPI, the level of interconnectivity and balance amongst the different strategies is often a matter of debate: these programmes are often considered important source for financing mainly defence infrastructures.

In the Netherlands, the Delta Programme and its associated research initiatives introduced the concept of 'multi-layered safety', thus combining flood defence with spatial planning and emergency management into a holistic risk management framework. The concept was explored through national and regional pilot studies to examine the extent to which FRM strategies could be exchanged, in a sense that improved spatial planning and/or disaster management could limit the need for improving the primary flood defences (Kaufmann et al., 2016). However, most cases demonstrated the difficulty of substituting these strategies efficiently, either due to the physical situation (i.e. low lying polder areas are confronted with high sea and river water levels), or existing knowledge gaps and governance issues. Indeed, disaster management and spatial planning do not have legally appointed responsibilities and (legal) standards and tools for demonstrating their contribution to flood safety, unlike flood defences (Van Buuren et al., 2016). Therefore, although the connectivity between the strategies is recognised in national policy, they continue to be implemented largely separately from each other. Consequently, in the Netherlands, the actual degree of coordination and alignment of strategies achieved is comparatively lower than in England and France.

5.2.2. Tools and resources

In all countries, interfacing tools and resources have been fundamental in operationalising and delivering a more coordinated vision for FRM. In particular, technological and data improvements (e.g. flood modelling, mapping, radar, forecasting) have helped bridge different strategies within FRM. For instance, mapping underscores multiple strategies (e.g. spatial planning, defence/mitigation, insurance, emergency management) and has essentially helped to align these in all three countries. Examples in the Netherlands are the decision support tool "Blokkendoos", which was developed for selecting a combination of Room for the River measures that would sufficiently decrease extreme river water levels along the whole river; and later the "multi-layered safety tool" developed for selecting measures from different FRM strategies (interview with a civil servant from Rijkswaterstaat).

5.3. Decentralisation of FRM

Both in England and France, a trend towards managing floods at more local scales is observable which has been caused by a range of factors (Alexander et al., 2016; Kaufmann et al., 2016). In England, there has been a discursive shift towards managing floods at more local scales, with new duties for managing local sources of flooding (including surface water) assigned to Lead Local Flood Authorities (established under the Flood and Water and Management Act 2010). Several SPI tools and resources have helped facilitated this. In particular, flood maps underscore Strategic Flood Risk Assessments employed in spatial planning, as well as Catchment Flood Management Plans and Shoreline Management Plans which guide policy and the prioritisation of defence/mitigation programmes at the sub-national scale. Mapping is also a core component of the Multi-Agency Flood Plans that guide local flood emergency management. Simultaneously there is a growing expectation that local communities and at-risk households should become more actively involved in managing their personal risk (e.g. through the implementation of property-level measures or participation in community flood action groups). This agenda is actively promoted through policy and various supportive mechanisms (Defra/EA, 2011; EA, 2012). Somewhat acting as an intermediary, the National Flood Forum (a nationally-registered charity) provides support and advice for at-risk households and communities to enhance their preparedness to flooding. More broadly, the momentum towards community preparedness, as part of a multi-scale approach to resilience-building, can be partially attributed to the SPIs discussed in section 5.1, which have helped propagate this discourse within and between research and policy communities.

In France the decentralisation process in the flood domain started in the 1980s and culminated with the MAPTAM Law and the definition of a "Competence for Flood management and water environments" (GEMAPI), local authorities are in charge of. The decentralisation of responsibilities is matched with a decentralisation of SPI processes and tools. Local institutions represent the main interfacing body and mechanism in the sense that may involve and rely on regional/local R&D agencies/research centres to develop specific innovative tools, such as flood forecasting services for smaller rivers. Flood mapping tools are used to determine flood zones as part of the drafting of flood risk prevention plans. Knowledge production processes for these plans are being shifted to the local level through cooperation between local agencies or being developed internally by their own technical departments. Flood risk mitigation also gives an impetus to the development of local SPIs, since local authorities often develop the necessary expertise themselves or involve dedicated agencies. Water boards are the executive body of Catchment Committees which are in charge of the main plans for biodiversity, flood regulation and sustainable development of the river. These are important SPI institutions at local level as they promote mitigation projects while funding research programmes. The elaboration of emergency plans, which have become compulsory for municipalities, has triggered the cooperation between administrations and experts (private consultancy cabinets or public advisory boards). This is an example where the implementation of the SPI follows decentralisation rather than SPIs stimulating changes in governance.

In the Netherlands, the Room for the River programme, Delta Programme and associated research programmes have reinforced local research and development efforts. In local pilot studies in the Delta programme, various ministries, municipalities, provinces and water boards have been involved, with the support of knowledge institutes and consultancy companies. Driven by proactive policy entrepreneurs, several municipalities including Dordrecht and Rotterdam initiated additional studies, collaborating with other European cities and knowledge partners. For instance, "Rotterdam participated in the Dutch Delta Program and became a so-called 'hotspot' within the Knowledge for Climate Research Programme" (interview with local policy maker). These are also the cities that have strategies and plans for dealing with flood risks or climate adaptation more generally. Dordrecht has the ambition to become a 'self-reliant island' and Rotterdam has established the 'Rotterdam Climate Initiative'. Hence, in the Netherlands, many processes of participatory knowledge production are taking place at the regional/local level because of specific ambitions of local governments.

Furthermore, provinces and municipalities are increasingly involved in strengthening primary flood defences and spatial adaptation to climate change (including local flooding). Innovative examples of climate services are stimulating local approaches to FRM and climate adaptation more generally (Hegger and Dieperink, 2014). For instance, flood hazard and flood risk maps and the so-called Climate Effect Atlas have been developed. In a freely accessible knowledge portal, this Climate Effect Atlas can be viewed showing climate relevant information of an area (expected heat stress, water depth, soil subsidence etc.). These are examples of tools and resources that are increasingly applied at the local level.

5.4. Inter-country learning

SPIs have also supported inter-country learning. In this capacity, the European Commission (EC) can be seen as a boundary organisation promoting knowledge creation and translation to policy at the European level. Through its framework for funding research programmes, the EC has funded several international research projects on FRM, including FLOODsite on integrated flood risk analysis and management methodologies; WATCH on Water and Global Change; Corfu on flood resilience in urban areas and STAR-FLOOD on FRG (Quevauviller, 2011; Raadgever and Hegger, 2018). The Interreg project "Freude am Fluss" (2003–2008) associated Netherlands, Germany and France, in order to develop practical and transboundary mitigation solutions, by implementing a Joint Planning Approach. These projects have led to knowledge dissemination within and beyond the participating countries. Researchers participating in such projects exchange knowledge and experiences at an international level but often these insights precipitate at the national, regional or local level through contacts with stakeholders (ibid). A good example of this is evident in England where several publications from participating countries in the STAR-FLOOD project were referenced within the National Flood Resilience Review (HM Government, 2016).

At the EC level, the Working Group on Floods (WG—F) has facilitated the implementation of the EU Floods Directive (2007/60/EC) by stimulating international knowledge and policy exchange. International conferences (such as ECCA, PROVIA, FLOODrisk), particularly those held at regular intervals, also serve as fora to bring together the 'golden triangle': universities and knowledge institutes, companies, authorities and NGOs, to exchange knowledge and best practices.

Another mode of inter-country learning is through municipal interfacing processes and mechanisms. A prominent example is 'Connecting Delta Cities' in which, amongst other cities, Rotterdam, Paris and London participate. These programmes link cities active in implementing climate change adaptation and water management to support data, knowledge and policy exchange. There are additional networks established as part of EU funded INTERREG initiatives (e.g. FloodResilienCity, MARE) and via other structures for best practice exchange (e.g. OECD). Science-policy interfacing across international borders also occurs through the commercialisation and export of knowledge. Indeed, many consultancy companies specialising in water and flood management operate in the global market and as such are a conduit for both scientific advancement and policy exchange.

Inter-country learning has also been observed during or following flood events, where policymakers and flood risk managers recognise the need to seek alternative solutions to urgent or newly revealed flood problems. Action has often involved resolutions to practical problems (such as employing Dutch emergency pumping equipment during the

English Somerset levels floods in 2013), the use of specialist equipment (e.g. small-scale suction dredgers from the Netherlands being used in Lincolnshire, UK; Nicholson, 2017) or more wholesale learning of best practices from those with a longer or different tradition of management (e.g. the US learning from Dutch best practices following Hurricane Sandy; Aerts et al., 2013).

Joint scientific collaborations at the European (and wider) level have also facilitated SPIs. A key example of this relates to European flood forecasting and warning initiatives such as the European Flood Awareness System (EFAS) which includes the European Centre for Medium-Range Weather Forecasts (ECMWF). I-STORM (International Network for Storm Surge Barriers) is another such longstanding initiative which since 2006 has facilitated exchange of expertise and learning between England, the Netherlands, the US and Italy (https://www.i-storm.org/). The value of these, and other international learning networks, was also recognised by the Draft National Flood & Coastal Erosion Risk Management Strategy for England[7] . These joint programmes not only pool scientific knowledge and set research agendas but are also an operational service which has enabled the improvement of emergency preparedness and integration of better forecasting, warning and preparedness practice into policy arrangements.

Inter-country co-operation and knowledge exchange should be recognised as a significant element of science-policy interfacing. All three countries have both learnt from others and have transferred knowledge. In many situations a greater commitment of research programmes to delivering impact has reinforced knowledge transfer of science into policy, both within and external to the three countries. This has normalised international knowledge exchange on FRM which also makes it difficult to trace the influence of international knowledge exchange on dynamics in FRG.

In particular, the Netherlands has long recognised the potential market benefits of exploiting their long-standing water and flood management knowledge-base. They are seeking to expand it further, following the appointment in 2015 of a Special Envoy for International Water Affairs. In essence, this position is formalising the desire to instigate science-policy interfacing and aims to promote the international market position of this knowledge, further generating and facilitating the transfer of both scientific and policy expertise to other countries. Better exchange of best practice and joint working (such as on forecasting) can seek to generate more cost-effective solutions. However, care has to be taken to ensure that the physical, social and legal contexts are considered when transferring FRM solutions internationally to ensure their effectiveness.

6. CONCLUSIONS & DISCUSSION

The previous sections have provided a systematic overview of the types, functions and roles of SPIs in shaping FRG in England, France and the Netherlands. A first conclusion of this endeavour is that SPIs can be comprehensively analysed in terms of Institutions that act as interfaces, Interfacing processes and mechanisms, and tools and resources supporting the interfacing process. Secondly, we conclude the relation between science and policy as mediated by SPIs is co-produced and therefore bi-directional, as well as the relation between SPIs and the flood risk governance in which they are embedded. We have shown that flood risk knowledge and governance often alternate, stimulate each other and jointly lead to (usually incremental) change. Thirdly, evidence from England, France and the Netherlands shows that SPIs may facilitate change of FRG, and SPIs may also enhance lock-in situations (besides many other factors that may influence stability and dynamics).

The emergence of different types of SPIs should be understood by considering the wider context in which they emerge and function. The analysis has shown examples where dynamics in governance co-determined patterns of knowledge development. For instance, the decentralisation of both power and expertise regarding flood policies in France. In the Netherlands, despite the fact that ideas about resilience are increasingly embraced, there remains a strong tendency to direct resources towards engineering expertise and maintaining defence assets. These observations point to the fact that SPIs may function as path-dependency mechanisms that reinforce lock-in. Our findings show that new ideas and innovations brought about by SPIs are an important and maybe underestimated driver for changes in FRG (see also: Van Buuren et al. (2016); Liefferink et al. (2018); Izumi et al., 2019). While changes in FRM often manifest themselves after shock events, the central role attributed to them in FRM literature is increasingly nuanced and complemented with the observation that it is often a continuous development of new expertise and ideas that provides the seed for change by mobilising resources. This arguably takes place in interaction with catalyst events, an issue that deserves further scholarly attention.

Both commonalities and differences between England, France and the Netherlands are in place regarding how SPIs shape FRG, and vice versa. In all countries, the knowledge basis of SPIs in FRM has noticeably diversified in recent decades, while cross-country SPIs continue to play an important role. Furthermore, shifts in management paradigms (from defence to risk-based approaches) and partial devolution of FRM to local scales, have been somewhat propagated through SPIs in each of the studied countries. Differences include that in England the role of independent reviews and review committees has been proved highly influential. In France, dynamics in SPIs are closely related to more overarching trends in governance towards decentralisation. In contrast, in the Netherlands a dominant focus on flood defence remains and is reinforced by long-established, as well as more recent, SPIs.

Finally, the research identified four recent trends in the influence of SPIs on FRG that occurred to some extent in all three studies countries. These trends are the i) facilitation of a diversification of FRM strategies at the strategic level, predominantly through interfacing organisations and processes; ii) the facilitation of the coordination and alignment of strategies, involving processes and tools/resources; iii) the decentralisation of FRM, by empowering various types of local actors; and iv) inter-country learning, typically steered through interfacing organisations and processes.

This research provides an important foundation for future study and demonstrates the relevance and necessity of assessing SPIs in a holistic fashion to better understand the context in which SPIs emerge, function and interact with governance arrangements. More in general this study invites to a reflection on the understanding of “science” and “decision-making” in the flood domain, on their interaction in each context and the sense that this distinction may still have in technocratic democracies and approaches to risk management. While SPIs have been somewhat overlooked in the past, this research highlights the valuable role SPIs have had, and continue to have, in shaping FRG.

Moving forwards, SPIs have the potential to provide important pathways for changes in FRM and facilitate closer integration and alignment between and within FRM policies. In the face of mounting threats such as climate change and sea level rise, many have called for more radical transformative changes in governance to address so-called ‘wicked’ problems, while also asserting the value of incremental change or ‘small wins’ to inspire transformative governance (Termeer and Dewulf, 2018). Science policy interfaces could provide important ‘entry points’ for this in the future. Indeed, as this research has demonstrated, SPIs have influenced and continue to influence FRG and have acted as vehicles for incremental change in the past, as well as facilitating more fundamental paradigm shifts. However, further in-depth understanding is required of the contextual conditions that enable SPIs to drive governance change, or alternatively reinforce stability, path dependency and institutional inertia, and how this might vary between different types of SPIs operating at different spatial scales. In this regard, we would encourage scholars to elaborate and refine the theoretical

[7] https://consult.environment-agency.gov.uk/fcrm/national-strategy-internal/, Accessed 10.05.19

typology presented here and conduct additional case studies.

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