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Analyzing interdependencies between policy mixes and technological innovation systems: The case of offshore wind in Germany

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ABSTRACT

One key approach for studying emerging technologies in the field of sustainability transitions is that of technological innovation systems (TIS). While most TIS studies aim at deriving policy recommendations – typically by identifying system barriers – the actual role of these proposed policies in the TIS is rarely looked at. In addition, often single policy instruments instead of more encompassing policy mixes are considered. We address these shortcomings by applying a more comprehensive policy mix concept within the TIS approach. In doing so we analyze interdependencies between the policy mix and the TIS by shedding light on the role of the policy mix for TIS functioning and performance as well as how TIS developments influence the evolution of the policy mix. We explore these interdependencies for the case of offshore wind in Germany, using data from event history analysis and expert interviews. We find highly dynamic interdependencies with reoccurring patterns of systemic problems and adjustments of the policy mix, which are fuelled by high policy mix credibility and supportive actors. Our study constitutes a first step incorporating the policy mix concept into the TIS approach, thereby enabling a better understanding of real dynamics occurring in TIS.

1. Introduction

In order to prevent the costly consequences of climate change, a decarbonization of the energy system is needed. This transition requires the development and diffusion of low-carbon energy technologies, such as technologies based on renewable energies. However, without policy intervention these technologies will not be developed and will not diffuse at a rate and scale required for such a radical transition. A major reason for this is multiple failures in place, which require not just single policy instruments but rather a policy mix to address them (Lehmann, 2010; Weber and Rohracher, 2012). Besides comprising several interacting policy instruments, such policy mixes more recently have been highlighted to also include a policy strategy, policy processes and overarching policy mix characteristics (Flanagan et al., 2011; Rogge and Reichardt, 2013).

Emerging technologies, such as renewable energy technologies, are not only influenced by a policy mix but actually are impacted and shaped by an entire system, a so-called technological innovation system (TIS). Scholars on technological innovation systems study the evolution of such technologies as the outcome of complex interaction processes between actors, institutions (hard and soft rules) and physical artifacts (e.g. Negro et al., 2008; Suurs et al., 2010). This includes the analysis of the structure of the innovation system as well as its functioning (Bergek et al., 2008; Hekkert et al., 2007). In doing so, system failures or systemic problems are identified and, based on these, recommendations for specific policy interventions are derived.

While the literature on TIS has helped policy makers by developing the framework necessary for analyzing where policy intervention is needed and has offered a toolbox for such policy intervention (Bergek et al., 2008; Wieczorek and Hekkert, 2012), a more thorough understanding of the actual interlinkages between policies and the TIS they are embedded in, as well as a more differentiated treatment of policies are still largely lacking. There exist some TIS studies that analyze the role of policies to improve innovation system functioning, yet they are mostly limited to policy instruments. A recent example is Kivimaa and Virkamäki (2013), which analyzes the impact of several policy instruments on TIS functioning and in doing so detects design flaws in single policy instruments. Similarly, McDowall et al. (2013) explore how policy instruments influence system functioning, and addresses system weaknesses for the onshore wind innovation system in four countries. It concludes with lessons for

Abbreviations: BMVBS, Federal Transport Ministry; BMU, Federal Environment Ministry; BMWi, Federal Economics Ministry; BNetzA, Federal Network Agency; BSH, Federal Maritime and Hydrographic Agency; EEG, Renewable Energy Act; EEZ, Exclusive Economic Zone; EFL, Energy Feed-in Law; EnWG, Energy Economy Law; FIT, feed-in tariff; In.dp, demand pull instrument; In.sys, systemic policy instrument; In.tp, technology push instrument; OW, offshore wind; P.impl, policy implementation; PM, policy mix; P.mak, policy making; PS, policy strategy; RET, renewable energy technologies; TIS, technological innovation system; TSO, transmission system operator.

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a low-carbon instrument mix, e.g. the need to include systemic policy instruments alongside traditional demand pull and technology push. However, these studies do not consider features of a more encompassing policy mix, such as a policy strategy and policy processes.

In this article we incorporate a more comprehensive policy mix concept into the TIS approach by explicitly analyzing the role of a differentiated policy mix in the development of TIS. More specifically, we study the evolution of a technological innovation system and its corresponding policy mix and analyze interdependencies between the two. We thereby do not only examine the role of the policy mix for TIS functioning and performance but also investigate how particular TIS developments affect the coming about of the policy mix. By applying the policy mix concept within the TIS approach we enable a better understanding of the role of the policy mix in emerging innovation systems. Regarding the policy mix we rely on a recently proposed concept, which defines a policy mix as consisting of the four building blocks elements, processes, dimensions and characteristics (Rogge and Reichardt, 2013; see Section 2.2). We consider all of these building blocks, i.e. the policy strategy and the instrument mix as elements, policy making and implementation as policy processes, actors as an important policy mix dimension and the influential policy mix characteristic credibility.

We explore our research question of the interdependencies between the policy mix and TIS developments for the case of offshore wind in Germany, which we chose for the following reasons. First, the policy mix promoting the development and diffusion of this technology appears particularly rich and dynamic, comprising a policy strategy and an encompassing instrument mix, which have been adjusted several times. Second, offshore wind is an emerging renewable energy technology with great technological potentials expected to play a key role in the transition of the German energy system (BMWi and BMU, 2010), but is faced with a number of difficulties. In combination, these factors make offshore wind in Germany an ideal candidate to study the role of the policy mix for the development of the TIS.

We proceed as follows: Section 2 reviews the literatures on TIS and on policy mixes and derives our analytical framework, which combines these two approaches. Section 3 introduces the research case of offshore wind in Germany. While Section 4 outlines our method for analyzing TIS and policy mix developments over time, Section 5 describes these developments for the German offshore wind TIS between 1993 and 2013. Based on this description, Section 6 discusses the interdependencies between the TIS and policy mix developments, and Section 7 concludes.

2. Theoretical background

2.1. Technological innovation systems

The recent years have seen a fast growing literature applying the technological innovation systems framework for studying sustainability transition processes such as the transformation of the energy system (Jacobsson and Bergek, 2011; Truffer et al., 2012). A technological innovation system (TIS) can be defined as the network of actors, rules and material artifacts that influence the speed and direction of technological change in a specific technological area (Hekkert et al., 2007; Markard and Truffer, 2008a). The purpose of analyzing a TIS is to evaluate the development of a particular technological field in terms of the structures and processes that support or hamper the development and diffusion of novel technologies. The ultimate aim is to derive implications for policy makers and other actors so as to remedy ills in the functioning of such systems (Bergek et al., 2008).

The structural analysis of systems comprises mapping of its elements – actors, networks, institutions, and infrastructure – and evaluating their capacity to stimulate innovation. These structural elements, their presence or absence as well as their capacities are critical to the functioning of innovation systems (Wieczorek and Hekkert, 2012).

While different innovation systems may have similar structural elements, they may function in an entirely different way. Therefore, measuring the functioning of innovation systems constitutes another crucial step of analysis. Table 1 presents a list of key processes that need to be fulfilled for a TIS to build up and function well (Hekkert et al., 2007). These key processes are called system functions.

Structure and functions complement each other. While functions are more evaluative in character and allow for assessing of what works well and what does not within the TIS, the structure is what needs to be adjusted to enable better system functioning and thus should be the target of policy intervention. Put differently, functions that are badly fulfilled indicate problems in the structure. By identifying where the problems are within the system, these problems can more easily be addressed by policy makers. For example, if function knowledge diffusion is weak then the cause could be related to a lack of networks in which knowledge is exchanged (Wieczorek et al., 2013). Such problems are usually called systemic problems or system failures and can be defined as "factors that negatively influence the direction and speed of innovation processes and hinder the development and functioning of innovation systems" (Wieczorek and Hekkert, 2012, p. 79). Finally, the structure and functioning of a TIS have a direct influence on its performance, i.e. the development, use and diffusion of the technology under study (Bergek et al., 2008; Tigabu et al., 2015).

2.2. Policy mixes

Although policies are part of the institutional structures that make up a TIS and play an important role in TIS analyses, only few studies have focused on policies and their impact on the rest of the TIS (Foxon et al., 2005; Kivimaa and Virkamäki, 2013). Even fewer studies have focused on studying TIS-related policies from a policy mix perspective. At the same time the need for considering such policy mixes – both for researchers and policy makers – has been increasingly stressed in the

Table 1
Description of seven key system functions of a TIS.

Function number	Function name	Description
F1	Experimentation and production by entrepreneurs	Entrepreneurs are essential for a well-functioning innovation system. Their role is to turn the potential of new knowledge, networks, and markets into concrete actions to generate – and take advantage of – new business opportunities.
F2	Knowledge development	Mechanisms of learning are at the heart of any innovation process, where knowledge is a fundamental resource. Therefore, knowledge development is a crucial part of innovation systems.
F3	Knowledge exchange	The exchange of relevant knowledge between actors in the system is essential to foster learning-processes.
F4	Guidance of the search	The processes that lead to a clear development goal for the new technology based on technological expectations, articulated user demand and societal discourse enable selection, which guides the distribution of resources.
F5	Market formation	This function refers to the creation of a market for the new technology. In early phases of developments this can be a small niche market but later on a larger market is required to facilitate cost reductions and incentives for entrepreneurs to move in.
F6	Resource mobilization	The financial, human and physical resources are necessary basic inputs for all activities in the innovation system. Without these resources, other processes are hampered.
F7	Creation of legitimacy	Innovation is by definition uncertain. A certain level of legitimacy is required for actors to commit to the new technology and execute investments, take adoption decisions etc.

Source: adapted from Wieczorek et al. (2013).