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An analysis of 26 international cases

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Winkler-Portmann, Simon; Bauknecht, Dierk et al.

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Abstract

Regulatory experiments can be useful to guide complex transitions in the field of sustainable development. They help to understand the effects of policies and regulations and offer insights into the dynamics of social processes. Empirical studies analyzing heterogeneous samples of regulatory experiments are missing. This paper uses a qualitative content analysis to examine 26 international cases of regulatory experiments in the field of sustainable development. The results show the diversity of existing regulatory experiments in terms of their design. We use the results to formulate implications on how to use regulatory experiments that facilitate learning processes.

Content

1 Introduction 5
2 Background 7
2.1 Randomized control trials in development economics 7
2.2 Going beyond randomized control trials 9
2.3 Sandboxes and exemption clauses 10
2.4 Regulatory experimentation 12
3 Data and methods 13
3.1 Sample and data 13
3.2 Methods 15
4 Findings 18
4.1 Testing explicit hypotheses 18
4.2 Interaction between different actors 20
4.3 Causality 21
4.4 Monitoring, evaluation and learning processes 25
5 Implications for designing regulatory experiments 29
6 Conclusion 35
7 References 37
8 Appendix 41

1
Introduction

Societal transitions correspond to important shifts in the dominant way in which a societal function is fulfilled (Raven et al., 2010) and they have been conceptualized as major changes in socio-technical regimes (Geels et al., 2007; Geels, 2012). They imply changes of both physical and social structures (e.g. technology, infrastructure, norms and values, regulations, user practices, business models, etc.) (Elzen et al., 2004). Hence – and importantly for this paper – they are complex, which implies that transition processes do not have a single driver causing linear causalities.

Instead, transitions are long-term processes whose dimensions add up and reinforce each other, thus leading to circular causalities (Geels, 2005). Importantly, these complexities lead to high insecurity about the outcomes of policies and regulations, which are the focus of this paper. Sustainable development is a prominent example where societal transitions are crucial. Sustainable development constitutes a continuous process rather than a final state (Erdmann, 2005; Meppem and Gill, 1998; and Waas et al., 2011). It is characterized by path dependencies and insecure outcomes.

In order to maneuver these complex transitions in the field of sustainable development, experiments can provide valuable insights into the dynamics of social processes. Duflo (2006) highlights that experiments allow research questions to determine the data to be obtained, instead of the questions being determined by the content of existing large datasets. Moreover, experiments allow varying elements of a policy or a regulation in a way that permits testing hypotheses that cannot be answered in any other way (Banerjee and Duflo, 2009). Importantly, the knowledge obtained through experimentation can avoid the costs of introducing inefficient policies and regulations nationwide.

While there is already an abundance of empirical evidence on experimentation in the social sciences, until recently a framework to analyze heterogeneous regulatory experiments was missing (Bauknecht et al., 2020). Furthermore, empirical work on experimentation has focused on evaluating single experiments, whereas insights stemming from heterogeneous samples remain lacking. Finally, most empirical studies on experimentation are rooted in a specific scientific discipline, with the corresponding fixed set of criteria to differentiate experiments from non-experiments. We contribute to this literature by conducting a comparative analysis of 26 heterogeneous cases of regulatory experiments.

The aim of this paper is to analyze a heterogeneous sample that can be defined as regulatory experiments (Bauknecht et al., 2020) taking place in real-world contexts that may contribute to the UN Sustainable Development Goals (SDGs). We take a broad approach to experimentation and consider the generation of learning processes and the involvement of the regulator as the common denominator of a regulatory experiment. We then follow Bauknecht et al. (2020)

and analyze empirical examples of regulatory experiments along four aspects using a qualitative content analysis of publicly-available documents: 1) testing explicit hypotheses, 2) the existence of interactions between different actors, 3) causality, and 4) monitoring processes to ensure learning. We aim to understand how regulatory experiments function to foster sustainable development. While this will unavoidably lead us to reflect normatively on how they should be employed to generate learning effects, our analysis is primarily a positive one.

The remainder of this paper is structured as follows. Chapter 2 embeds our analysis of regulatory experiments in the existing empirical literature on experimentation in the social sciences. Chapter 3 describes the method and sample that we use to analyze regulatory experiments. Chapter 4 presents our qualitative insights into characteristics of regulatory experiments, which chapter 5 discusses in terms of their implications for designing such experiments. Chapter 6 concludes by presenting implications for policy-makers.

2
Background

Experiments in the social sciences are a heterogeneous research object and there are various definitions of social experiments (Lewitt and List, 2009). For the purpose of this paper, in line with Gisselquist and Nino-Zarazua (2015), we distinguish between experimental studies relying on randomized control trials and experiments that do not necessarily abide by strict design criteria. Common to both groups is the notion that academics have typically designed them to answer specific research questions. To this, we add a third group of experiments, namely regulatory sandboxes that – in contrast to the previous – are created by policy-makers.

Our starting point is that different forms of experimentation in the social sciences have their respective pros and cons, which we briefly discuss in this chapter. Subsequently, this paper follows Bauknecht et al. (2020) in taking an interdisciplinary approach to what we refer as regulatory experimentation.

2.1
Randomized control trials in development economics

As the name suggests, RCTs randomly allocate individuals to two or more groups, where some receive the intervention studied (treatment) and some not (control). Experimenters then compare the two groups with respect to a measured response of interest. Real-world RCTs are the type of experiments that most closely mimic laboratory experiments, with the difference that instead of using the typical student sample, they use experimental participants from the market of interest. Moreover, their primary goal is to inform public policy by experimenting with a broad set of actual public policy alternatives.

We chose to address RCTs in the social sciences by discussing experiments in development economics due to their widespread use in this field and their function as role model for policy experiments. According to Duflo (2006, p. 1), "there is a long tradition in development economics of collecting original data to test specific hypotheses. Over the last ten years, this expertise has merged with an expertise in setting up randomized field experiments". This type of experiments can be summarized as "the implementation and evaluation, by comparing different treatment groups chosen at random, of an intervention or a set of interventions specifically designed to test a hypothesis or a set of hypotheses" (Duflo, 2006, p. 3). Indeed, Duflo (2006) claims that the use of RCTs has no equal in other fields and highlights that this must be seen in the context of a lack of reliable large-scale data sets for such countries and the low cost (regarding program costs and data collection) of executing experiments. In 2008, half of the published or forthcoming papers in the Quarterly Journal of Economics on topics of development economics using microdata involved randomized assignment (Banerjee and Duflo, 2009). The same authors note that the interest in experiments stretches beyond academics in the social sciences, as the

World Bank had 67 ongoing program evaluations in 2009 in the African region alone, covering the topics of education, malaria, HIV/AIDS, accountability and transport.

In terms of design and implementation, these experiments are often developed working closely with implementing agencies (NGOs, private companies or governments). The interventions address specific problems embedded in these contexts (Duflo, 2006). Thematically, they cover both individual behavior and working mechanisms of institutions (Banerjee and Duflo, 2009).

In our view, the merits of RCTs are uncontestable, implying that any study of experimentation in the social sciences should address the issues randomization and control group. By relying on randomization and only varying one factor at a time, using a RCT experimental design significantly increases the chances of producing internally-valid insights into a specific question. Another advantage of RCTs in developing countries is that a large fraction of those who are intended to be in the treatment group are actually affected by the treatment. This means that the target population to test the hypothesis can be rather small (Banerjee and Duflo, 2009), which thus reduces the cost of experimentation.

Furthermore, experiments conducted in development economics yield at least two important general lessons. First, non-randomized studies might be dismissed when results are contrary to expectations, due to the likely occurrence of data or specification errors. In randomized studies, such dismissals are not easily possible. It can lead to the discovery of interesting nuances of existing evidence.[1] Second, and related, development economists have used sequential experimentation, where each set of results provides input to design new experiments. A variant of this are ancillary experiments where – as more RCTs become available in the social sciences – opportunities arise to use existing experimental data to investigate new questions. This allows experimenters to go beyond the initial hypothesis.

However, RCTs also have important drawbacks. One important shortcoming is the lack of external validity that arises because governance performance depends on various structural-, institutional-, cultural- and agent-focused factors that may vary greatly between different populations. Indeed, a number of existing replication studies in development economics show that while some results could be replicated, others could not (Banerjee and Duflo, 2009). On the other hand, relying on large datasets to evaluate nationwide policies to understand how to improve governance has been criticized due to lacking internal validity (Dehejia, 2015), but has high external validity since they cover a large segment of the population.

Furthermore, RCTs have been criticized for their limited scope. Key factors for governance such as modernization, social structure and national institutions are

[1] An experiment in Western Kenya examining the impact of learning on technology adoption in agriculture illustrates this (Duflo et al., 2005).

largely absent from RCT experimental research. It would be difficult to implement these variables in this experimental setting. It has been suggested in the literature that RCTs are probably most suited to study targeted interventions to improve governance whereas broader macro-structural shifts, national-level variation in institutions and other non-easily manipulable factors such as leadership would require experimental approaches outside of the RCT box (Gisselquist and Nino-Zarazua, 2015). Experiments are not only about testing hypotheses, but also about the (qualitative) developments taking place in the experiments itself and the contextual framework conditions.

Moreover, RCTs are often conducted for a limited time period and have a narrow focus. They rarely evaluate impacts of a given regulation or policy for more than a few years, whereas many governance processes are non-linear and evolve over decades. Furthermore, RCTs are particularly well suited to inform about the mean treatment effect, although heterogeneity in treatment effects can be useful for the policy-maker or regulator.

2.2
Going beyond randomized control trials

In their review of experimentation in the political sciences, Morton and Williams (2009, p.2) note that "the most common misconception is that the best experiment is one where a researcher manipulates one variable, called a treatment, while having an experimental group who receives the treatment and a control group that does not, and randomly assigning subjects across groups". According to the authors, merely striving for internal validity of experiments is outdated.

Nonetheless, Morton and Williams (2009) appear not to dispute the superiority of RCT design in terms of the validity of the results obtained, but rather the lacking fit for most questions of interest in political science. Hence, the authors (p. 3) conclude that "there is no perfect or true experiment. The appropriate experimental design depends on the research question, just as is the case with observational data". In contrast to development economists, they argue that the presence of a control group is not a necessary feature of an experiment. As an example of an experiment without control group, they sketch out an experiment investigating voting in a three-party election conducted by plurality rule versus proportional representation where the aim is to compare the outcome in the two treatment groups. Randomization on the other hand is considered valuable to deal with unobserved confounding variables.

Morton and Williams (2009) consider the defining feature of an experiment that the researcher intervenes in the data generating process although the authors include the case when the data is generated unintentionally, namely so-called natural experiments. The number of experimental articles published in the American Political Science Review, the American Journal of Political Science and

the Journal of Politics has developed similar to development economics. It increased from below 2,5 in the 1950s to over 45 in the 1990s before receding slightly to between 30 and 35 over the period 2000 to 2005.[2] They put forward the upcoming of cheap and easily programmable computer networking technology as the dominant explanation for this expansion and project that their use will continue to increase in the future.

Experiments in political science take place both in laboratories, in the field and online, while noting that survey experiments are an increasingly popular type of field (and sometimes internet) experiment within political science. They are used to test theories, search for facts, as a test bed for political methodologists and to communicate with policy-makers (Morton and Williams, 2009). For instance, in order to test theories on voting behavior, an experimenter can create an electoral institution and then pay subjects based on the outcomes of voting that induce a preference ordering over the candidates. Researchers have used experiments to see if voters do use polls and campaign contributions to coordinate (Rietz, 2003).

2.3
Sandboxes and exemption clauses

Sandboxes are experiments that usually rely on market or civil society initiatives – and are triggered by policy-makers.[3] The sandbox concept mainly originates from the financial sector and was first implemented in the United Kingdom (FCA, 2015), where it was also adopted by other domains like the energy sector (Ofgem, 2018). Today, there are sandbox initiatives in several sectors and countries – e.g. the financial sector in Denmark or the energy sector in Norway – which we analyze in the empirical part of this paper. As we have several cases of regulatory sandboxes in our sample, we focus the following explanations on the features of the sandbox concept of the German regulatory sandbox initiative.

What the German Federal Ministry for Economic Affairs and Energy refers to as regulatory sandboxes are experiments characterized by three elements: 1) regulatory sandboxes are test areas established for a limited time, covering a limited area, in which innovative technologies and business models can be examined in real life; 2) they make use of regulatory leeway; and 3) they entail an "interest in regulatory discovery" (BMWi, 2019: 7). Its work focuses on digital technologies but covers a range of sectors such as transport and logistics systems, the energy sector, the financial sector as well as questions of sustainability, the sharing economy and digital administration. The academic literature approaches sandboxes more broadly as "experimental spaces at the interface of

[2] Numbers based on a visual interpretation of figure 14.1 in Morton and Williams (2009).

[3] There are also some closely related concepts like real-world niches, real-world laboratories or urban laboratories with similar characteristics (for an overview, see Bauknecht et al. 2020).

science and society in which solutions are primarily sought for societal challenges and transition processes" (BMWi, 2019, p. 9).

Sandboxes mainly arise from experimentation or flexibility clauses in laws. Such experimentation clauses authorize the executive to deviate from the existing law by a predefined degree. They allocate legal flexibilities or financial support for socio-technical or administrative innovations (Schwarting, 2003), thus enabling the administration to carry out innovative projects, which may subsequently become a permanent part of the permanent governance framework (Maaß, 2003).

Experimentation clauses are suitable at various levels of legislation and for various regulatory techniques (BMWi, 2019). They can take the form of an exemption from a prohibition, an exemption from an approval requirement, an exemption from requirements to provide documentation or deploy certain equipment, or a catchall clause (BMWi, 2019). Furthermore, a defining feature is the existence of a time limit, introduced by either a predefined period on the experimentation clause itself, a time limit on the test phase of each regulatory sandbox or a general (not pre-determined) time limit on the test period (BMWi, 2019).

Nonetheless, experiments using experimentation clauses also have their limits, notably the possibility to properly evaluate their effects. In the case of sandboxes, the German Federal Ministry of Economic Affairs and Energy state that evaluations should "provide appropriate, transparent and objective information about the extent to which the goals of the regulatory sandbox have been achieved, and it should provide the partners with the information they are seeking" (BMWi, 2019, p. 53). The difficulty with this ambition is that one cannot identify which part of the goal attainment is due to the exemption clause and which part is due to other factors such as more frequent communication between stakeholders. Furthermore, while this approach assesses the goal attainment of a given regulatory sandbox, it does not evaluate the cost-effectiveness of the instrument itself (i.e. a given exemption clause). For this, one would have to find a way of adding (possibly with weights) the learning process including goal attainment for all regulatory sandboxes making use of a specific exemption clause and ultimately subtract any cost of the considered clause.

Moreover, while the experimentation clauses generating sandboxes are well suited to test specific socio-technological innovations, we suggest that it is helpful to take a broader view on experimentation to guide transition processes. Societal transition processes benefit from testing alternative governance options against one another. Furthermore, these are not linear processes and the design of governance structures should therefore facilitate changes when new technological developments occur. Experimentation for sustainable development therefore extends beyond the opportunity to test procedures to facilitate much broader systemic innovations including technical and social dimensions and new business models.

2.4
Regulatory experimentation

These diverse concepts of experimentation build up under the choice to take a broad approach to regulatory experimentation to unpack the most of what experiments can offer to guide societal transitions towards sustainable development. As such, the common denominator of what we refer to as regulatory experiments is the generation of learning processes. We adopt the understanding of learning in van den Bosch-Ohlenschlager (2010, p. 61) as "an active or interactive process of obtaining and developing new knowledge, competences or norms and values". Thus, learning enables the uptake of new practices and habits, and induces changes in cultures and structures.

While the literature generally differentiates between experimental and non-experimental techniques, this distinction makes little sense in our case. For us, it is unimportant which specific methodology an experiment uses, as long as learning processes occur and the regulator is involved in any way.

Following Bauknecht et al. (2020), we then consider four aspects important when analyzing regulatory experiments: 1) testing explicit hypotheses; 2) the existence of interactions between different actors; 3) causality; and 4) monitoring processes to ensure learning. These aspects are directly linked to the forms of experimentation discussed in the previous sections. While testing explicit hypotheses and implementing a control group are important to ensure learning in RCTs, we saw that learning process can also occur without explicitly randomizing subjects into treatment and control groups, e.g. in the form of natural experiments or sandboxes. In these cases, the interaction between different actors can be important to facilitate learning. What all forms of experimentation have in common is that some kind of monitoring is important to maximize knowledge gains from the experiment. Taking a broad approach to regulatory experimentation inevitably leads to the conclusion that the four aspects are not observable in all regulatory experiments. In fact, only a minority of regulatory experiments in our sample fulfill all four aspects. However, in order to examine the design of regulatory experiments as well as whether they can facilitate learning processes, we consider it helpful to discuss empirical cases of regulatory experiments along these four aspects.

3
Data and methods

This part of the paper describes our empirical approach used for analyzing regulatory experiments. First, we describe the theoretical sampling procedure based on Glaser and Strauss (1967/1998) that we used to collect our cases as well as the data thus obtained. We continue by explaining the methods we used the qualitative content analysis of Mayring (2010) to analyze the cases of regulatory experiments.

3.1
Sample and data

The previous chapter providing the background of regulatory experiments revealed that there exists a variety of experimental concepts and fields of application. To our knowledge, no comprehensive databases on regulatory experiments exist. Hence, the total population of existing regulatory experiments is large and heterogeneous. We used a theoretical sampling approach developed by Glaser and Strauss (1967/1998) to build our sample. The purpose of theoretical sampling is to collect cases, which help to generate theoretical insights instead of building a representative sample known from many other sampling techniques (Flick, 2011). We selected cases based on the theoretical concepts discussed in the previous chapter. We aimed to include experiments from diverse regions of the world as well as related to diverse SDGs. We are aware of the limitations of this procedure. First, our sample only contains cases with sufficient publicly-available online information. Second, the amount and type of information is case-specific, which makes a consistent analysis challenging. We addressed this issue by using a comprehensive and standardizing analysis framework discussed in the next chapter.[4]

We followed the approach in Glaser and Strauss (1967/1998) by analyzing data on already selected cases and collecting new cases for our sample in parallel using insights from already examined cases to select new cases with the highest potential to generate additional insights. We collected material on the selected cases from a variety of sources such as official websites, scientific publications, official documents and newspaper articles. At the end, our sample covers altogether 26 cases listed in table 1.

At this point, it is useful to distinguish between (a) exemptions from the existing regulatory framework – often referred to as 'regulatory sandboxes' – that are mainly directed at firms and (b) experimenting with new regulatory options and evaluate their effects on the behavior of relevant actors. In our sample of regulatory experiments, numbers 1-11 fall into the first group, whereas numbers 12-26 fall into the second group.

[4] See Appendix

ID	Experiment
	(a) Exceptions from the existing regulatory framework
1	Austria: Regulatory sandbox in the electricity sector (Energy.Free.Room)
2	Australia: Regulatory sandbox in the electricity sector
3	Singapore: Regulatory sandbox in the electricity & gas sector
4	Germany: Smart meter standardization
5	Netherlands: Regulatory sandbox in the electricity sector
6	United Kingdom: Regulatory sandbox in the electricity & gas sector UK
7	Norway: Exemption clauses in the energy regulation
8	Germany: Retroactive reimbursement in the electricity sector (SINTEG Ordinance)
9	Denmark: Regulatory sandbox in the financial sector
10	United Kingdom: Regulatory sandbox in the financial sector
11	European Union: Authorization scheme for the use of chemicals
	(b) Experimenting with new regulatory options
12	China: Trading scheme for CO_2 emissions
13	Germany: Tender procedure for promoting renewable energy systems
14	Pennsylvania, US: Promoting grocery stores in under-served neighborhoods (Fresh Food Financing Initiative)
15	India: Immunization access and incentives
16	Norway: Promoting electro-mobility
17	Berlin, Germany: Shared space pilot projects (Begegnungszonen)
18	Copenhagen, Denmark: Promoting biking
19	Germany: Occupational licensing in the crafts sector
20	Indonesia: Labor market consequences of school construction
21	Finland: Basic income experiment
22	Ontario, Canada: Basic income experiment
23	Seattle, United States: Minimum wage policy
24	Ontario, Canada: Minimum wage policy
25	Berlin, Germany: Solidary basic income experiment
26	Barcelona, Spain: Decentralized citizen-owned data ecosystem (DECODE)

Table 1: Overview of selected cases

3.2 Methods

In order to formulate implications about the experimental design and evaluation procedures of regulatory experiments, we follow the qualitative content analysis approach of Mayring (2010). The core idea of this approach is to avoid arbitrary qualitative empirical work by basing analysis of text documents on some theoretical foundations and proceeding in a rule-guided fashion. Hence, all decisions about the analysis process take into account the current state of research on the object of analysis. Every analysis step is based on a previously-defined rule, which allows others to follow all steps of the analysis.

This systematic procedure becomes apparent in the well-defined process model that every qualitative content analysis should follow (Mayring, 2010). This model describes all phases of the analysis and is displayed in figure 1. This illustration also includes explanations on how we approached every single analysis step for the examination of regulatory experiments. We have already described steps *1. Description of the material, 2. Origin of the material, 3. Characteristics of the material, 4. Direction of analysis and 5. Research question* in the previous chapters.

After these preliminary steps, this approach also requires the specification of the analysis technique used to analyze our material (*6. Specification of analysis technique*). Qualitative content analysis offers different techniques to summarize and structure material (for an overview see Mayring, 2010). As we are interested in specific features of regulatory experiments, we used a content structuring approach, which relies on a category system developed before the analysis based on theoretical consideration. Hence, we relied on both the interdisciplinary institutional analysis of Bizer and Führ (2015) and a comprehensive framework for analyzing regulatory experiments developed by Bauknecht et al. (2020) as our category system.

Bizer and Führ (2015) propose their approach of institutional analysis as a tool for the legislator to assess the impact of different regulatory options. Moreover, they suggest that this approach is also suitable for companies, associations or authorities to solve their own institutional design problems. We used a slightly modified version accommodating our research object of their seven analysis steps that together constitute the institutional analysis as the first part of the category system for our qualitative content analysis. The first step described the normative objectives of the regulatory experiment, while defining the actors participating in the experiment constituted the second step. In the third step, we described the behavior of actors in the experiment necessary to achieve the goal defined in the first step. In the fourth step, we analyzed factors relevant for the behavior of actors including the institutional context of the experiment. The aim of the fifth step was to describe the difference between the behavioral target and the individual behavior revealed in the previous step (defining the delta). This step was based on evaluation results. In the sixth step, we gathered

information on alternative design options that were not considered in the experiment. In the seventh step, we described the delta or knowledge gap that remains despite conducting the regulatory experiment.

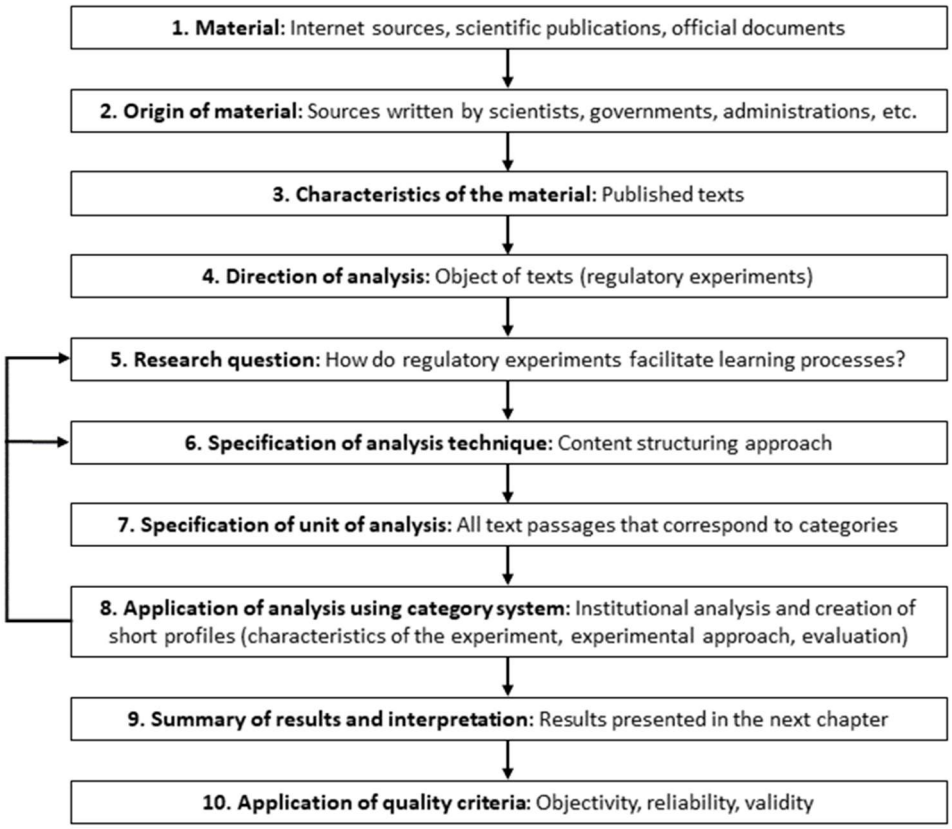

Figure 1: Process model of qualitative content analysis (own illustration based on Mayring (2010: 60))

The second part of our category system builds on the comprehensive framework for analyzing regulatory experiments suggested by Bauknecht et al. (2020). This framework yields so-called short profiles that cover various elements of regulatory experiments organized into the categories of 1) testing explicit hypotheses, 2) interactions between different actors, 3) causality, and 4) monitoring and learning processes. These categories are then further divided into twenty sub-categories (see Bauknecht et al. (2020) for a detailed description of the framework).

We summarized the information on each regulatory experiment in our sample applying this category system, which corresponds to step *7. Specification* of unit of analysis and *8. Application of analysis using category system* of Mayring's

(2010) content analysis approach. Hence, for each regulatory experiment, we conducted an institutional analysis and completed a short profile.[5] In the next chapter, we bring together the results of this work, which corresponds to step *9. Summary of results and interpretation*.

Ensuring a high level of objectivity, reliability and validity after a first unilateral application of the category system to the material by different researchers, one of the authors reviewed all of the material and streamlined the interpretation and explanation of the category system. Commented results were redistributed to the researcher of the specific cases and the category system was applied to the material once again. This procedure ensured a similar analysis of all experiments, which is necessary to compare them and formulate overall conclusions according to Mayring's (2010) step *10. Application of quality criteria*. This completed our analysis of altogether 26 heterogeneous regulatory experiments.

[5] The appendix lists the sources that we used to gather information for the institutional analyses and short profiles. The institutional analyses and short profiles for each case are available upon request.

4
Findings

The exploratory analysis of the 26 cases revealed insights that help to understand how regulatory experiments work. As a main result, the analysis showed that regulatory experiments serve various aims and elicit learning in a multitude of ways. This underpins our approach to regulatory experimentation described in chapter 2 of this paper. In the following, we outline our findings based on the four main categories of the analytic framework by Bauknecht et al. (2020): "testing explicit hypotheses", "interaction between different actors", "causality", "monitoring and learning processes". The findings from the institutional analyses of the 26 cases are integrated in this structure wherever they are supplementing the insights from the category system.

4.1
Testing explicit hypotheses

In order to analyze aspects of regulatory experiments related to the testing of hypotheses, the first part of the applied profile sheet includes the variables "aim", "object of the regulatory experiment", "SDG orientation", "controllability of regulatory experiment process" and "test of theories/hypotheses". Our analysis shows that regulatory experiments often do not possess the characteristics of formal experiments that test explicit hypotheses.

Finding 1: The same regulatory experiment can serve a multitude of aims

By 'aim', we refer to the overall purpose of the experiment as defined at its onset. Based on McFadgen and Huitema (2018), the framework we use to profile our cases differentiates between the aims to 'gather scientific information', 'test policy options', 'test a pilot project' and 'promoting innovations'. 19 of 26 cases have aims that can be sorted in at least two of these categories.

All experimental sandboxes or similar experiments providing exceptions from the current regulatory framework (group a) are created to promote innovation, often by testing pilot projects (6 of 11 cases) while sometimes providing additional insight on policy options (4 of 6 cases). For regulatory experiments of group b, experimenting with new regulatory options, there is a greater share of cases with a single aim (5 of 15). The focus seems to be more on testing pilot projects (12 of 15 cases), with some cases (6 of 12) additionally trying to gather scientific information.

Gathering scientific information generally does not seem to be a high priority for most regulatory experiments, as only seven cases in our sample have aims that can be sorted in that category ([4], [15], [20], [21], [22], [25], [26]). All of these cases additionally aim at testing a pilot project and the majority (4 cases) also aspire on testing a policy option. It is therefore hardly surprising that almost all (6) of the cases in our sample that aim to obtain scientific information are

from the second group of regulatory experiments (testing specific regulatory options). In addition, most (5 of 7) cases are specific experiments, while two cases are frameworks for several regulatory experiments.

When testing policy options, experimenters not only try to assess whether the political goals are attained and how the policy option affects stakeholders, but also how the policy should be implemented. Experimenters aim at policy testing in fourteen cases in our sample, often in combination with testing a pilot (9 of 14 cases) or promoting innovation (9). The latter combination appears more often for experiments of the exemption group (7 of 9 cases), although policy testing is equally important for both groups of regulatory experiments (7 cases each). The majority of regulatory experiments in our sample (16 cases) aims on promoting innovation, most of which are the regulatory experiments of the first group providing exemptions from current regulation (11 cases). Regulatory experiments even more often aim to test a pilot project (18 cases in our sample of 26), often coupled with the aim of promoting innovation (10 of 18). This aim appears more often for regulatory experiments of the second group that are focused on new policy (12 of the 15 cases in that group).

Finding 2: In many cases regulatory experiments do not test several design options

Testing several design options has only occurred in cases of our sample experimenting with new regulatory options (group b) and not those of group a (providing exceptions from the existing regulatory framework). Several experiments in the sample hint at increased learning through testing several design options ([12], [13], [14], [15], [18]). For instance, from the immunization control trial in India [15] one learns that although providing immunization camps does increase vaccination, providing them in conjunction with a food reward is even more effective. The Chinese emission-trading pilot scheme can be seen as a best practice for concurrently testing out several design options, as the authorities simultaneously started seven pilot projects, each of which were given substantial leeway in the design of the regional emission-trading schemes [12]. It shows how experimenting with a multitude of pilot projects provides more possibilities to learn during the experiment and constantly improve the instrument tested.

However, flaws in the experimental framework from a scientific perspective can reduce the regulatory learning potential by hampering a conclusive comparison of the design options. For example, the pilot tenders for promotion of renewable energy in Germany [13] only tested the different pricing models on a different number of occasions and under different circumstances.

Finding 3: Regulatory experiments usually do not appear as formal experiments

Explicit hypotheses as usually formulated in laboratory experiments or RCTs are quite uncommon in our sample. Experimenters only formulated ex-ante hypotheses in four cases, all of which focused on experimenting with new regulatory options ([15], [21], [22] and [25]). Consequently, these are also the only five cases that the variable "controllability of regulatory experiment process" identified as formal experiments. Experiments providing exceptions for testing innovation omit the formulation of explicit hypotheses. However, some experimenters formulate expectations in reference to the experimental aims.

4.2
Interaction between different actors

The second part examines which actors participated in initiating, planning and implementation of the regulatory experiment and analyzes how they interacted. For this purpose, it refers to the variables "impulse of the regulatory experiment", "participating actors at the beginning of the regulatory experiment" and "change in the composition of actors". While the impulse to experiment often comes in a top-down direction, the regulatory experiments are often co-developed by heterogenous group of actors.

Finding 4: The impulse for new regulatory experiments is mostly top-down

The experiments in our sample were mostly (18 out of 26) initiated in a top-down manner, although in some cases (7 out of 26) the impulse had a bottom-up direction. The latter concerned experiments from group (a) (e.g. [6], [8]) as well as group (b) (e.g. [16]). We note that the regulator appears to be attentive to impulses from societal actors as several experiments in our sample originated from the efforts of individuals, initiatives and interest groups with the regulator taking over the impulse at a later stage (e.g. [8], [18]). It is even likely that we under-observe bottom-up impulses as they may appear as a top-down impulse when they only become visible after the regulator takes action.

Finding 5: Regulatory experiments with a different impulse also differ in their aims

One might expect that experiments with a top-down impulse would more often be directed on policy testing. However, within our sample the experiments initiated by a bottom-up impulse aim at testing policy options more often than the experiments with a top-down impulse. Of eighteen cases with a clear top-down impulse, eight aimed at testing policy options, while the same applies for five out of seven cases with a bottom-up impulse. For gathering scientific information, one cannot make such a clear distinction, as five of top-down cases and two of bottom-up cases had this aim. Two-thirds (twelve) of top-down impulse cases aimed at testing a pilot project, while five bottom-up impulse cases did. The same share of bottom-up impulse cases also aimed at promoting

innovation, compared with only one-third of top-down cases. Overall, bottom-up experiments more often have several aims compared with top-down experiments, which might relate to a broader inclusion of stakeholder interests.

Finding 6: Regulatory experiments are co-developed by a heterogeneous group of actors

In seventeen experiments within our sample, a heterogenous group of actors was involved in developing the experiment. This includes the legislator, the regulator, government agencies and enterprises (e.g. [7], [5]), as well as research institutions (e.g. [21]), NGOs [18], and sometimes even individuals/philanthropists (e.g. [16]). The composition of actors remained static in half (13 cases) of the experiments in our sample (e.g. [14], [17], [20]). However, in some experiments (9 cases / 34%), the composition of actors changed during the experimentation period (e.g. [7], [18], [26]), sometimes due to changes of government ([22], [24]).

4.3
Causality

The variables "geographical scope", "timeframe", "target group", "control group", "randomization" and "external validity" in this part of the profile sheet applied analyze whether the regulatory experiment is designed in a way that allows measuring causal effects. The strong variation in most of these factors suggests that considerations about internal and external validity are currently underrepresented in regulatory experiments.

Finding 7: There is major variation in the geographic scope of regulatory experiments

A delimited geographical framework is required to draw causal conclusions in comparison with external circumstances. Based on our sample, it is evident that regulatory experimentation is flexible concerning its geographic scope. It appears to be an instrument that can be applied at the street (e.g. [17]), community (e.g. [23], [26]), regional (e.g. [14]), national (e.g. [10])) and supranational levels (e.g. [11]). In addition to their area of application, the experimental frameworks in our sample also have variable geographical scopes depending on the actors taking advantage of the leeway to experiment (e.g. [2], [3], [5], [6]).

Finding 8: The time frames of regulatory experiments vary broadly and are not entirely predictable ex ante

As highlighted in part 2, one limitation of RCTs are their short window of analysis. By contrast, some experiments in our sample show a wide range concerning their duration, from one to ten years, with most lasting for up to three years. Experiments with a similar objective were planned with various duration. For example, the basic income experiment in Ontario [22] lasted for one year, while

similar experiments lasted two years in Finland [21] and five years in Berlin [25]. Similarly, the energy sandboxes and similar derogations provide a timeframe for experimental projects ranging from two years in the UK [6] to five years in Norway [7] and ten years in the Netherlands [5]. As for cases experimenting with new regulatory options, the tender procedure for promoting renewable energies in Germany [13] was tested for two years, while the CO_2 emission-trading scheme in China [12] was tested for three years.

Some experiments in our sample have no limited time frame. This applies especially to the natural experiments in the sample, e.g. those concerning minimum wage in Ontario [24] and in Seattle [23] as well as the mobility experiments Copenhagen [18] and Norway [16]. In addition, frameworks for regulatory experiments are not always ex ante limited in time, e.g. the sandboxes for the finance sector in Denmark [9] and the UK [10] and the REACH Authorization [11]. However, the derogation within the Dutch energy legislation [5] was limited to four years, as was the energy sandbox in Singapore [3]. The UK Energy sandbox [6] and the reimbursements of the SINTEG Ordinance in Germany [8] were limited to three years, the energy sandbox program in Austria [1] is limited to five years.

In some cases, experiments end prematurely when circumstances change. The basic income experiment in Ontario [22] was canceled due to a change in government. The experimental tenders in Germany [13] were originally planned for three years but were transferred into general law due to increased political pressure.

Finding 9: Regulatory experiments vary in the specificity of their target groups

While the target group inevitably depends on the legal scope of the regulatory experiment, the level of precision with which the target group is narrowed down varies. Relatively formal experiments (e.g. the basic income experiment in Finland [21]) have a very specific target group, whereas more informal experiments are broader based. Some experiments address specific industry sectors (e.g. sandboxes for the energy sector: [1]-[3], [5], [6] or the financial sector: [9], [10]) or sub-sectors (e.g. renewable energy [13]), often further defined by specific factors (e.g. local / regional electricity supply projects of homeowner associations in [5]). Other experiments consider economic actors conducting specific activities (e.g. the use of certain chemicals that are subject to the REACH Authorization in [11]).

Regulatory experiments can also affect actors who are not in the target group. The regulatory sandbox in the Netherlands [5] aimed at enabling small-scale energy community projects to organize their own energy supply. The distribution network supplier is obliged to provide these projects with a grid connection and thereby is indirectly affected by the experimental framework.

Finding 10: Target group participation is not necessarily voluntary in regulatory experiments and shows several obstacles

The way regulatory experiments designate the participation of the target group actors in the experiment differs broadly within our sample. While group (a) experiments often allow interested parties to apply for voluntary participation and select participants from applicants based on predefined criteria, some cases experimenting with new regulatory options affect actors that cannot avoid participating. The traffic reduction experiment in Berlin [17] provides an excellent example for this option. It turns almost all regular users of the selected roads (residents, businesses, delivery services) into participants in the experiment.

The experiments in our sample with voluntary participation have shown several measures that aim to incentivize stakeholders to participate. The energy sandbox in Singapore [3] provides a perspective for the time after the experiment by offering that relaxations might be transferred to the legal framework so the tested innovations can be introduced on a larger scale. The experimental framework integrates a decision procedure and predefines transition conditions for the end of the experiment.

The analysis also identified several obstacles in experimental frameworks for participation. The Dutch energy sandbox [5] only allowed actors with small energy consumption to participate and required that companies only represent 20% of participants within an experiment. Many interested parties could not comply with these requirements. Similarly, in the Singapore case [3], detailed knowledge of the legal framework is required to identify those provisions that should be relaxed during the sandbox experiment. In some cases, experimenters have tried to minimize the hurdles for participation. In order to address financial risks, the SINTEG Ordinance in Germany [8] reimburses actors for economic disadvantages caused by participating in the experiment.

Finding 11: Defined control and treatment groups are rare, randomization procedures are even rarer

Overall, the analysis of our sample suggests that control groups are seldom part of regulatory experimentation. In only three cases, experimenters defined explicit control and treatment groups ex ante ([15], [21], [22]). Furthermore, randomization was only used in three cases ([19], [21], [15]).

The Finnish basic income experiment used randomization procedures to form treatment and control groups and tested explicit hypotheses regarding the effects of basic income on several variables [21]. The basic income experiment in Ontario did not use randomization procedures when creating treatment and control groups and participation was voluntary. However, the experiment was conducted with individuals in a few pilot sites representative for the population of Ontario [22]. The basic income experiment in Berlin formed a control and a treatment group without randomization procedures [25]. For the immunization

experiment in India, group-based randomization presented a good alternative to individual-based randomization [15].

For fourteen experiments in the sample, control group could be built ex post or implicitly ([3], [5], [7], [11]-[14], [19], [20], [23]-[25]). Other cities, countries or states that have not put in place the same instrument may serve as a control group, although we identified several particularities in institutional contexts that one should take into consideration by such comparisons.

In natural experiments, the surrounding environment naturally divides the population into a treatment and control group. In the natural experiment of the German crafts deregulation [19], evaluators additionally used synthetic control estimation and other alternative evaluation methods and robustness checks to assess whether the designated control group indeed is a good counterfactual.

Finding 12: Regulatory experiments are limited in their external validity by institutional, geographical and temporal factors.

It often appears difficult to transfer the results from regulatory experiments to other contexts. Only eleven cases in our sample are designed in a way that simplifies the transferability of the results. Features that make transferability difficult include institutional, geographical and temporal factors.

Regulatory experiments are integrated in a specific institutional context that influences the behavior of participants. For instance, national electricity markets are highly regulated. Concerning the Singapore energy sandbox [3], one should note that the Singapore energy market was only recently liberalized in May 2019, with the grid operation remaining with the state-owned SP Power Assets. This results in a limited number of actors on the market. The Dutch electricity sector presents a more diverse range of actors, presenting a different basis for the sandbox [5]. Consequently, results of the two electricity sandboxes are difficult to compare. Our analysis identified such institutional factors hampering the transferability of results for 19 of 26 cases.

Geographical particularities can also create barriers for external validity. Berlin as the largest city in Germany may not be representative for the whole country when evaluating effects of the basic income experiment [25]. Similarly, Copenhagen's high population density and flat geography favor bike riding, while its cold winters have the opposite effect [18]. The regulatory sandbox for the finance sector in the UK limits the test periods to 6 months, creating a temporal barrier for external validity as long-term effects are difficult to assess. External validity can also be hampered when experiments are canceled prematurely, like with the basic income experiment in Ontario, Canada [22].

Replications also appear to be very rare for regulatory experiments, as only one case in our sample was replicated [14]. The Fresh Food Financing Initiative served as a model for similar programs in other states of the US. Furthermore,

the analysis revealed that it is not possible or highly unlikely to replicate the regulatory experiment for twelve cases.

At the same time, there is ample reference data for regulatory experiments. For most (23) regulatory experiments, there are experiments that address similar policy issues in a different form or context.

4.4
Monitoring, evaluation and learning processes

Under this title, our framework allows analyzing how and by whom the regulatory experiments are monitored, evaluated and how the results are used. It includes the variables "Conducting evaluation", "Information collected", "Costs of the RE", "Type of learning", "Availability of results" and "Publications". Our analysis suggests that regulatory experiments result in various forms of learning. The cases in our sample also show widespread use of evaluation and monitoring mechanisms, but costs of the regulatory experiments are often neglected or not revealed.

Finding 13: Evaluation processes are very common. In most experiments, the results are publicly available and published.

The sample provides some insight into how regular official evaluations can provide robust means for experiments to ensure learning processes. All experiments in our sample conduct some form of evaluation. In many cases, several publications are available in addition. In one case, specific indicators for evaluation are defined ex ante that measure the success of the experiments and assess the need for regulatory optimization [1].

The experiments differ regarding who is responsible for the evaluation. In some cases such as the solidary basic income experiment in Berlin, independent research facilities will conduct the planned evaluation. In other cases, such as [15] and [19], researchers have evaluated the experiment at their own initiative. There are several experiments, in which the government agency that carries out the experiment also conducts the evaluation (e.g. [13], [21]). In [5], the ministry initiating the experiment evaluates the experiment in cooperation with the government agencies carrying out the experiment. While the widespread evaluation practice is very positive, one should keep in mind the availability bias of our research as we could only analyze experiments for which information was available.

In addition to ex-post evaluations, some experimenters put in place monitoring mechanisms to react to developments during the experiment. For example, the energy sandbox in Singapore [3] requires applicants to report to the regulator on the experiments progress. If the regulator EMA loses confidence that the tested innovation fulfills its purpose, or if EMA detects a substantial deficiency that cannot be corrected, the experiment can be terminated. This also applies to cases where the applicant breached conditions of the sandbox. Applicants

for the REACH Authorization [11] also have to conduct monitoring activities. The results of these monitoring activities can lead to a review of the authorization.

Another example of monitoring practices is the so-called 'Bicycle account' in the experiment promoting biking promotion in Copenhagen [18]. They are official evaluations published regularly by the local regulator and contains information about the main targets of the experiment such as the number of kilometers traveled by car and bike in the city, modal splits, facts about the current biking infrastructure and user surveys. Furthermore, the Chinese emission-trading experiment [12] used results from ongoing evaluation to already adapt the tested policy instrument during the experiment. The experimenters changed the reserve price of allowances to increase the flexibility of enterprises of when and where to purchase emission allowances and improve the liquidity of the market.

Finding 14: Financial aspects of regulatory experiments are often neglected (or remain undisclosed)

From 26 regulatory experiments in our sample, only eleven have publicly declared or estimated costs in evaluations. Mapping out the costs of regulatory experimentation is no straightforward task. The funds devoted to the experiment in public budgets is a start, yet other costs may occur that are more difficult to anticipate. In cases where the costs are published, they are often confined to public expenses and specific aspects of the experiment, e.g. subsidies or administrative costs. In the case of regulatory sandboxes, the regulator mainly provides the framework and applicants test themselves, and hence we expect that the majority of costs lies with the economic and societal actors (which is often not surveyed).

Even the public costs of regulatory experiments are difficult to compare, as the size of the experiment and the specific experimental subject influence the costs. For example, the overall costs of experiments with subsidies are quite high, such as 30 million US dollars for the Freshfood Financing Initiative [14]. For larger natural experiments that focus on financial incentives, the costs can amount to one billion Euro per year, such as the costs for the tax revenue for promoting electric mobility in Norway [16]. By comparison, the 189,000 € administrative costs for the SINTEG regulation [8] seem very modest. The comparison shows that a more detailed breakdown of costs is essential for further research.

Experimenters and scholars alike have identified several measures to reduce the costs of experimentation. Banerjee and Duflo (2010) highlight that given the fixed costs of experimenting and the fact that experiments necessarily require some time, multiple experiments at the same time on the same population help to evaluate alternative potential variants of the program. Regulatory experiments have various options available to reduce the costs of experimentation. In the vaccination program in India [15], one part of the population simultaneously

serves as control group for two treatment groups. Similarly, the REACH Authorization [11] allows "grouped" applications to reduce the costs. The Fresh Food Financing Initiative [14] provided a different option by choosing a financing model with a high degree of cooperation between public and private stakeholders. The experimenters calculated around 120 million US Dollar of TRF investments.

Finding 15: Experiments vary broadly in their specific type of learning

All experiments generate at least one type of learning, eleven cases generating as much as four and one experiment [26] generating all of the five types of learning defined in the framework (epistemic, political, social, interactive, entrepreneurial). Hence, the regulatory learning obtained through the experiments in our sample is diverse.

Epistemic learning, i.e. learning that results in scientific knowledge, seems to be particularly rare for those experiments providing exceptions from the current regulatory framework (group (a)), where it only occurs in one experiment of the eleven in our sample. For those experiments experimenting with new regulatory options (group (b)), epistemic learning occurred in 10 of 15 of the cases. It is noteworthy that in half of them, the experimenters were not aiming to gather scientific information ([12], [17], [19], [23], [24]). One example of this is the German crafts deregulation [19], where the efforts of researchers to gage the effects of removing occupational licensing has led to a fruitful scientific debate, although this was not the aim as the reform passed parliament in 2004.

Regulatory experiments also seem to be successful in promoting innovation, as all but one experiment [13] with that aim have initiated changes in learning processes in firms that enable innovations, thereby generating entrepreneurial learning. Overall, sixteen cases in our sample show learning of that type, including all eleven experiments exempting current regulation.

As one might expect, political learning – i.e. knowledge that affects the preferences and goals of political actors – is common in regulatory experiments, with only three cases in our sample being unable to affect the political process in that sense ([7], [8], [15]). Almost two-thirds of the experiments in our sample – seventeen cases overall – have generated knowledge that affects the preferences and goals of societal actors. This social learning seems to be more likely to occur in group (a) experiments (11 of 15 cases) than those in group (b) (6 out of 11 cases). Interactive learning – i.e. changes in the behavior of actors regarding information, communication and cooperation – is also created in seventeen cases in our sample. Similarly, it appears in ten cases of experiments testing future regulation and seven cases of experiments exempting current regulation.

The types of learning occur in several combinations in regulatory experiments. Two experiments showed only one type of learning (political learning in [14] and entrepreneurial learning in [8]). Generally, in most experiments, learning

appears in combination with three or four types. Political learning, appeared in combination with social and interactive learning in twelve cases. Apart from the DECODE experiment [26] with five types of learning, five cases additionally initiate entrepreneurial learning ([2], [6], [11], [16], [18]), while five others show epistemic as a fourth type of learning ([17], [21], [23]-[25]).

The identified specific learning effects also vary broadly within the sample. For example, the Berlin traffic reduction experiments [17] showed that experiments may incite a public discourse on the future regulation ("discursive effect"). It appears that some measures are retained, some are not, and some (untested) measures are added. The solidary basic income experiment in Berlin [25] illustrated how interaction between several actors (in this case, the regulator, the public employment service, employers, employees and unemployed individuals) potentially leads to interactive learning.

5
Implications for designing regulatory experiments

The main finding presented in part 4 showed that learning in regulatory experiments arises in multiple ways. This is good news for policy-makers and regulators wanting to engage in regulatory experimentation. Our analysis of the findings indicated first implications regarding how regulatory experiments can maximize learning and which impediments experimenters have to address.

Implication 1: Preparatory measures before the experiment are useful to experimenters to determine whether a regulatory experiment (and what kind) would be useful

Cases in our sample suggest that regulatory experiments may not prove useful for all applications and for all aims. The UK Electricity and Gas Sandbox [6] e.g. showed that affected businesses tend to be more in need for advice on possibilities within the existing legal framework rather than applying for a regulatory sandbox, as they are mostly unaware of what they are already legally allowed to do. Similar situations occurred within the Dutch energy sandbox [5].

Depending on the perspective of the various actors, several arguments may speak against an experiment: regulators and legislators may not want to create expectations regarding future leeway in laws and regulations, [8] while companies – especially start-ups – want to be able to signal low dependence on regulatory assistance in their innovative activities to investors [6]. It is therefore important to define criteria for which cases regulatory experimentation may be beneficial. In order to facilitate the decision on whether or not to conduct a regulatory experiment, legislators can survey and assess its needs and potentials, as done for the energy sandbox in Austria [1]. This assessment can also reduce obstacles for potential participants, as the future framework can be designed to meet specific needs in a problem-oriented manner.

Preliminary measures that ensure the integration of stakeholders are especially relevant when regulatory experiments testing legislation are not apolitical and not necessarily welcomed by all stakeholders. As the Berlin traffic reduction experiment [17] showed, regulatory experiments easily become part of political battles of interest. In this case, some actors demanded the premature termination of the experiment as they criticized the costs, the design and the effects of the experimental traffic reduction measures. Accordingly, the course and results of the experiment are not necessarily awaited as actors who are against the measures or even the general objective of the experiment might fight against it.

Implication 2: A heterogeneous group of participants is beneficial (or even a prerequisite) for learning from regulatory experiments

Representative and robust results depend on the size and composition of the participating actors. Including heterogeneous stakeholders with distinct knowledge sources can contribute to learning. (Luederitz et al., 2017; van

Mierlo and Beers 2020). Lewitt and List (2009) see collaboration with private parties in experiments in an effort to learn more about the workings of the economy more generally as an untapped source of benefits. We extend this statement to all stakeholders involved or affected by governance processes. If the objective of the regulatory experiment is to test how it affects various stakeholders – including unintended side effects – and how processes between stakeholders function. A heterogeneous group of participants may be considered a prerequisite.

The experimental framework should therefore effectively incentivize relevant stakeholders to participate. If participation is voluntary, it mostly depends on the prequalification requirements and selection criteria within the experimental framework (e.g. [6], [2], [8]). Extensive application requirements, e.g. the detailed knowledge of the legal framework to identify possible impediments ex ante [3], may hinder participation as the barrier is too high for actors to invest in an application. If the prequalification requirements are very strict, the regulator has to reject applications from actors who might have been relevant for the overall success of the experiment (see e.g. [5]). At the same time, experimenters have to take several influencing factors into account when defining these criteria, including overlapping frameworks, e.g. the research program in the case of the SINTEG Ordinance [8] or EU consumer protection in the Dutch electricity sandbox [5]. The experimental framework should also provide clarity on questions such as ownership after the experiment and take financial burdens such as taxes in considerations ([3], [5], [8]).

Experimenters might guide actors through the application process, as done in the Dutch sandbox [5]. Similarly, the REACH Authorization scheme [11] has shown that it might not suffice to simply "leave the door open" as the composition of participants might not be representative as a result. Instead, experimenters should invite relevant actors to take part in the experiment. [6]

Regulatory experiments that define or necessarily affect a group of relevant actors that cannot avoid participating, e.g. the traffic reduction experiment in Berlin [17], may allow for more representative results. This might be especially true for findings on compliance and acceptance in experiments testing restrictive regulation. In that context, one should keep in mind that forcing the target group to participate does not serve the aims of all experiments. Experiments aiming to foster innovative activities such as regulatory sandboxes will not profit if actors are forced to participate. Furthermore, involuntary participation can be in conflict with superordinate legal norms. Electricity network projects of the Dutch energy sandbox, e.g. would violate European consumer protection legislation if they would force consumers in their community to purchase electricity

[6] In the example case of the REACH Authorization scheme [11], observers have proposed that the regulator asks competitors, research institutes and NGOs to submit information and statements to the application for authorization.

from them. It may also entail difficult legal questions, e.g. concerning discrimination in comparison to actors in non-affected areas as well as loss of income or profit due to the experiment. In addition, involuntary participation might intensify existing political conflicts (see implication 1).

Implication 3: Where applicable, control groups and randomization measures should be used more intensively to gain more representative results

Holland (1986) noted the fundamental problem of casual inference that exists in policy evaluation: since one cannot observe the outcome under treatment and non-treatment for the same individual, it is necessary to compare distinct units receiving different levels of the treatment. Such a comparison can involve different physical units or the same physical unit at different times. Using the incorrect counterfactual eliminates the internal validity of the experiment, i.e. obtaining causal effects within the considered population. Even if we take a broad approach to regulatory experimentation, it remains an important aim of an experiment to test for causality.

For experiments testing regulatory instruments, establishing such causality requires control and treatment groups and randomization procedures. Our analysis showed that forming a control and treatment group is a prerequisite for testing explicit hypotheses (e.g. [25]). As one of few experiments in our sample, the randomization procedures to form treatment and control groups in the Finnish basic income experiment [21] allowed causal inferences about the tested instrument and the set hypothesis. The treatment and control groups were selected from a target group of the entire Finnish population aged between 25 and 58 years who received a labor market subsidy or basic unemployment allowance. By comparison, the basic income experiment in Ontario [22] defined a similar target group, but only for the population of three specific pilot locations. Volunteers from the target audience – who had to apply – formed the treatment and control groups. In the Berlin experiment [25], individuals can apply to receive the solidary basic income if they have been unemployed for at least one year and a maximum of three years. The remaining long-term unemployed individuals receiving basic unemployment benefits (ALGII) but not solidary basic income serve as an implicit control group. Through nationwide randomized sampling, the Finnish experiment was able to create representative results that are more easily applied to different contexts, while the same is less likely for the Ontario or the Berlin experiment.

The finding that randomization is seldom used in regulatory experiments is likely to reflect the notion that it is often difficult for the regulator to argue why specific individuals are assigned to treatment and control groups. This supports the concerns in Greenstone (2009, p. 17) that "some consider randomized experiments unethical, because they relegate a significant number of people to the control group when there are non-experimental reasons to believe that the treatment will prove beneficial".

For sandboxes and similar regulatory experiments, control groups are especially difficult to assign, as participation is often voluntary. Interested actors might see the possibility of ending up in the control group as a burden, when considering the efforts required to apply and participate. In addition, actors might withdraw their application when they see themselves in an unfavorable situation vis-a-vis competitors in the treatment group. Studies have shown an attrition bias whereby there are systematic differences between the treatment and control group in the loss of participants throughout the experiment (Hausman and Wise, 1979). However, as experiments derogating from the regulatory framework are rather trying to provide niches for innovation and indicate impediments in the current framework, it may suffice for causality to define the control group ex post (e.g. by comparing with those actors who do not participate). A lack of causality might therefore rather relate to derogations from several legal provisions at the same time (or unidentified impediments in case of a failed experiment).

There are also problems related to randomization that one should consider. One potential problem is so-called randomization bias, describing a situation where the sample population is different from the true population precisely due to randomization, as persuading individuals to participate in randomized studies is difficult and those who choose to take part possess specific characteristics (Levitt and List, 2009). A related issue is that the population that takes part in small-scale experiments may not be representative of that affected by full-scale programs. Due to these biases – but mainly because randomization is so seldom used – it makes sense to look for other examples of design elements in the sample that can contribute to internal validity.

Implication 4: The time frame highly affects the success of regulatory experiments

The pilot tenders for the promotion of renewable energy in Germany [13] and the basic income experiment in Ontario [22] have shown that the effects of a tested policy cannot be adequately evaluated if the period of an experiment is too short. In the former cases, the evaluator was unable to assess the realization rate of successful bids. In the latter case, the experiment was canceled prematurely due to a change in government. Experimenters therefore not only have to set up an adequately time frame when designing the regulatory experiment, but also must ensure broad support to reduce the vulnerability of experiments towards the political cycle.

At the same time, regulatory experiments, as real-world experiments, cannot be conducted in complete isolation from broader societal changes. In order to minimize the influence of such factors that hamper a causal interpretation, it is necessary to limit the duration of regulatory experiments. In addition, rising costs due to the long duration can become a barrier for conducting the regula-

tory experiment. Long regulatory experiments also entail the risk of discontinuation for political reasons, as described above for the basic income experiment in Ontario [22].

Implication 5: Costs can present a barrier to experimentation

Orcutt and Orcutt (1968) emphasize costs as an important barrier to experimentation. Some scholars have questioned whether expensive experiments such as RCTs are worth the cost (Heckman and Smith, 1995). Our analysis shows that not only are costs a barrier to the emergence of an experiment, high costs are also often a reason why experiments are cut short or not prolonged (e.g. [22], [14]). In cases of financial incentives, insufficient attention is given to the long-term phasing-out of financing [16], [21]. Some experiments seem to address this issue with predefined exit scenarios [3] or long experimentation periods [5].

Furthermore, in those experiments testing new policy instruments, it may be important to assess the costs of the experiment in relation to the potential costs of a full introduction of the tested instrument, including costs of potential unintended side effects. Such cost estimations are certainly even more complicated and show greater uncertainty, although common in the legislation process. As our analysis has shown, the costs of regulatory experiments often remain neglected or unpublished, making it difficult to assess these claims.

Implication 6: Testing several design options in regulatory experiments increases learning

A complex mix of laws and regulations such as industry norms, charges, codes and licenses often hinders innovative projects. An experiment focused on facilitating innovation by adapting one law or regulation therefore may not address all obstacles to innovation. As a result, it may be necessary to go beyond experimenting with a single instrument, and instead use a mix of instruments.

Furthermore, when experimenting with future legislation, not testing several alternative design options may reduce policy-makers' ability to build an appropriate legal framework. In the basic income experiment in Finland [21], the regulator decided to only test one partial basic income model with monthly income of 560€, although the research group around the Finnish social insurance institution Kela suggested testing several concepts of basic income. As a result, the instrument tested can only be compared with the status quo, rather than the effects of an alternative option. By contrast, the Chinese emission-trading pilot [12] increased learning by testing a different regulatory option in each of the experimental regions, serving as a best practice on that matter. Adapting the experimenting conditions during the experiment based on constant evaluation has shown positive results in our sample. For cases focused on experimenting with new regulatory options, e.g. [18] and [12], this proved beneficial to see the full potential of the instrument tested. For experiments providing exceptions

from the exiting regulatory framework, adaptations addressed impediments for target group participants (e.g. [3]).

Implication 7: Lessons learned cannot easily be transferred to other contexts, but there are several ways to improve the external validity of regulatory experiments

As highlighted in chapter 2 of this paper, experiments are criticized for the lack of external validity, i.e. the ability to extrapolate the results to other populations (see e.g. Gisselquist and Nino-Zarazua, 2015). Our explorative analysis finds arguments supporting this criticism. The external validity of the experiments in our sample is questioned by differences in the institutional contexts and distortions in the experimental setting. The experimental framework may distort the behavior of actors, e.g. when participants are reluctant to invest in light of uncertain regulatory continuity after the experiment (see above on the time frame and financial aspects of experiments). Institutional contexts influence individual behavior and thus behavioral target attainment.

In our analysis, we also suggest that the external validity of an experiment depends on the sector of interest. While experimentation of basic income schemes are likely to be highly transferable to other settings, the same is more complicated for experiments in the highly regulated energy sector, where several of our sample cases are located [1]-[8]. Effects here are likely to depend on the institutional context, such as the taxation or institutional support for the technology, product or service. When the German federal government tested a tender procedure for promoting renewable energy systems in pilot tenders for free-field photovoltaic systems [13], e.g. the legislator could transfer the findings regarding the pricing model to other technologies for the following legal amendment. Findings on the realization of successfully tendered projects could not be transferred due to different technology-specific circumstances and prequalification requirements.

According to Banerjee and Duflo (2009), replication studies with additional experiments in different locations with different experimenters are necessary to address concerns of external validity. If a theory predicts where the effects might be different, one should focus on replications there. Otherwise, the location for replication should be chosen at random. The difficulty in practice depends on what kind of replication one would like to do. Reanalyzing the original data or designing new experiments are more easily done than copying the original experiment on a different pool of subjects (Levitt and List, 2009). The construct of replications, while fitting to social experiments, might not be easily applied to regulatory experiments. However, as an approximation, experimental frameworks such as regulatory sandboxes provide room for several experiments under equal conditions, but at different locations and conducted by different project managers (e.g. [5],[6]). Experimenters might also approximate replication studies with additional tools such as computer-based models to address external validity issues.

6
Conclusion

Regulatory experiments have become increasingly popular to inform regulators and policy-makers. As a tool for reflexive and adaptive governance of innovation, they potentially guide societies towards sustainable development. Experiments help to avoid the large-scale introduction of inefficient policies and regulations as well as by reducing lock-in effects that may permanently hinder societal transitions. Nonetheless, while a large pool of empirical data on real-world experiments is available, studies that examine large, heterogeneous samples of regulatory experiments are lacking.

This paper is a first step to filling this gap in the literature. We took a broad approach to what we refer to as 'regulatory experimentation' that focuses on achieving learning rather than any ex-ante strict criteria for the experimental design. We examined a heterogeneous sample of 26 such regulatory experiments all connected to contribute to the SDGs. We followed the approach of Mayring (2010) for qualitative content analysis and used a comprehensive framework developed in Bauknecht et al. (2020) as well as the institution analysis in Bizer and Führ (2015) to collect, standardize and analyze the relevant information of these cases.

Based on this sample, we noted a number of interesting features of real-world experimentation and formulated normative considerations regarding appropriate experimental designs. These findings can serve policy-makers interested in regulatory experimentation as a first indication to consider when designing such experiments. Policy-makers should determine whether regulatory experiments can address the identified problems. This may include discussions in advance with stakeholders on existing barriers for innovation in the existing regulatory framework. Furthermore, as part of the preparations, experiments should identify and address diverting perspectives on the experimental object, which may be transposed onto the regulatory experiment.

When policy-makers proceed with the experimental design, they need to take heterogeinity of participants into account. If the experimental setting allows it, experimenters can define a representative sample of the (heterogeneous) target group. However, they have to address legal issues, e.g. concerning anti-discrimination laws, and possible side effects such as intensifying political conflicts. In case participation is voluntary, they should address impediments such as financial insecurities.

In addition, the experimenters should ensure that they choose a suitable time frame for the regulatory experiment so that it can provide robust insights into stakeholder behavior. This includes to promote broad support for the regulatory experiment among political actors and societal groups, so it will not be discontinued following electoral changes in government. In order to support public legitimacy, the costs of experimentation should be transparent. In addition,

costs for experimentation should be presented in relation to potential benefits through innovative activities of actors or estimated costs of unintended side effects by introducing a regulatory option without experimentation.

In case policy-makers plan to experiment with new regulatory options, they should establish treatment and control groups and randomized selection processes to achieve representative results and generalize the outcomes. In order to increase the learning, policy-makers should use the regulatory experiment to test several design options and their effects on the behavior of the target group. For the external validity of the results, it might be beneficial to create a framework that allows several experiments under equal conditions at different locations. In addition, other methods such as computer-based models help when transferring the results to other contexts.

Future research should extend beyond reviewing officially-available documents and rely on means such as interviews with stakeholders to gain further insights about policy design and implementation in practice. Such an approach would also allow covering important issues such as stakeholder participation and learning processes. Furthermore, examining additional cases might allow clustering regulatory experiments with respect to their main characteristics.

7
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8
Appendix

A.1 Background material for the interdisciplinary institutional analysis (Bizer & Führ 2015) and the analytical framework of Bauknecht et al. (2020)[7]

Austria: Regulatory sandbox in the electricity sector (Energy.Free.Room)

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