Routledge
Taylor & Francis Group

Journal of Environmental Planning and Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cjep20

Regulating eco-innovation in the European Union

Alberto Quintavalla & Orlin Yalnazov

To cite this article: Alberto Quintavalla & Orlin Yalnazov (11 Oct 2023): Regulating eco-innovation in the European Union, Journal of Environmental Planning and Management, DOI: 10.1080/09640568.2023.2263636

To link to this article: https://doi.org/10.1080/09640568.2023.2263636

Published online: 11 Oct 2023.

Journal of Environmental Planning and Management, 2023
https://doi.org/10.1080/09640568.2023.2263636

Regulating eco-innovation in the European Union

Alberto Quintavalla[a]* and Orlin Yalnazov[b]

[a]*Erasmus School of Law, Erasmus University Rotterdam, Rotterdam, the Netherlands;* [b]*Faculty of Business, Law and Politics, University of Hull, Hull, UK*

(*Received 10 January 2023; final version received 19 September 2023*)

This article develops a framework to guide the EU in the choice of legal form for the regulation of eco-innovation. The framework distinguishes between uncertain and risky applications of eco-innovation. An uncertain eco-innovation, which poses an incalculable risk, is more difficult to regulate because the EU legislator needs to accumulate information in order to plug gaps in knowledge. In that context, directives are superior to regulations because they are conducive to experimentation and information accumulation. Risky eco-innovations, conversely, should be covered by regulations; otherwise, the cost of legal heterogeneity would outweigh the benefits of information accumulation. We also show that there are ways of conceptualising the choice between directives and regulations that are more productive than the sovereignty-versus-competition model that predominates in current legal thinking.

Keywords: eco-innovation; EU law; data accumulation; precautionary principle; uncertainty

1. Introduction

Recent international policy and legislative instruments have emphasised the role of eco-innovation in society and its influence on sustainable development (UNEP 2014; see also the UN sustainable development goals). This view is echoed at lower levels of governance, where eco-innovation has begun to play a prominent role in the making and execution of policy. For instance, the EU now acknowledges that sustainable green growth requires eco-innovation (see, e.g. European Commission 2013; European Union 2022) and has developed an eco-innovation action plan (European Commission 2011).

An eco-innovation is an ecological innovation that leads to "progress towards the goal of sustainable development through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources" (European Commission 2011, 2). Eco-innovation is not limited to environmental technologies (Kemp and Foxon 2007, 12). Any innovative processes or product that results in the prevention, reduction, or mitigation of ecological harm, be it directly or incidentally, is an eco-innovation (Fussler and James 1996; Kemp and Pearson 2007; OECD 2009). In this contribution, we use the term "eco-

*Corresponding author: E-mail: quintavalla@law.eur.nl

innovation" in line with the latter definition, which is also commonly employed in the literature and by policymakers.

Given the high relevance of eco-innovation to sustainability targets, scholars have focused on its determinants (Dewick, Maytorena-Sanchez, and Winch 2019, 39). Numerous studies have identified and analysed a wide array of factors that may influence the development and adoption of eco-innovation (see del Río González 2009; del Río, Peñasco, and Romero-Jordán 2015; Hojnik and Ruzzier 2016; Horbach 2016; Cai and Li 2018). These factors have been grouped into categories. In developing those categories, scholars have built on the demand pull–supply push dichotomy from the economics-of-innovation literature (Peñasco, del Río, and Romero-Jordán 2017, 57). The demand side (i.e. market pull, such as end-market characteristics) and the supply side (e.g. technological capability) are the first two categories that influence eco-innovation (Di Stefano, Gambardella, and Verona 2012); the political-institutional framework has been acknowledged as the third (Horbach 2008; Belin, Horbach, and Oltra 2011; Horbach, Rammer, and Rennings 2012; Triguero, Moreno-Mondéjar, and Davia 2013).

Regulation has recently benefitted from considerable attention in that literature (Mickwitz, Hyvättinen, and Kivimaa 2008; Demirel and Kesidou 2011; Horbach, Rammer, and Rennings 2012; Ramanathan *et al.* 2017; You, Zhang, and Yuan 2019). Most contributions point to specific characteristics that regulation should possess if it is to be effective, such as stringency, flexibility, and enforceability (Kesidou and Demirel 2012; Horbach, Rammer, and Rennings 2012; Auld *et al.* 2014; Hojnik and Ruzzier 2016; de Miranda Ribeiro and Kruglianskas 2015). Some have also focused on the governance level at which eco-innovation should be orchestrated. Their efforts have revealed that national regulation is more conducive to eco-innovation than its international counterpart (Huber 2008; Popp, Hafner, and Johnstone 2011; Peñasco, del Río, and Romero-Jordán 2017).

The extant literature clearly does not neglect regulation. However, the problem of legal form has been overlooked. Little has been written on the type of law that would promote eco-innovation most effectively. Compartmentalisation may account for this lacuna – legal form tends to be seen as a matter of blackletter law. Striking a balance between being proactive and reactive is particularly important for designing laws on innovation. However, the implications of legal form for action and reaction are poorly understood outside of legal circles (Rizzo 1980; Rubin 1977; Zywicki 2003; Epstein 2006; Ponzetto and Fernandez 2008); to the best of our knowledge, there has been no serious attempt to determine what form regulations for eco-innovation should take.

The aim of this article is to integrate the literature on eco-innovation and regulation with theoretical legal scholarship in order to close the gap that we described in the preceding paragraph. To that end, we develop a model for the regulation of eco-innovation at the EU level. The model is based on the distinction between risk and uncertainty. Although the empirical literature has shown that regional regulatory frameworks exercise a less profound influence on eco-innovation than domestic ones (Popp, Hafner, and Johnstone 2011; Peñasco, del Río, and Romero-Jordán 2017), the former are important in the EU context for two reasons. First, regulation at the national level is tightly intertwined with regulation at the EU level due to the principle of subsidiarity (Article 5(3) of the Treaty on the European Union). Both governance levels shape eco-innovation (Rogge, Schneider, and Hoffmann 2011). Second, the EU is currently focusing on eco-innovation. It would be regrettable if the realisation of its objectives were to be thwarted by neglect of jurisprudential arcana such as legal form.

EU legal measures tend to take one of two forms: directives and regulations. Directives usually describe policy objectives and leave their actuation to Member State authorities. Regulations specify both goals and implementation measures, and municipal adaptations are prohibited. Our main argument is that regulations are better for regulating risky eco-innovations, while directives are superior when the novelty that is being regulated is uncertain. This is so because directives advance policy goals while also encouraging regulatory experimentation. Information about the impact of regulatory solutions facilitates social learning (van den Bergh 2002, 29). As learning accumulates, uncertainties become risks. However, regulatory experimentation can become too costly, either due to inertia or because the innovation has already become risky. In such instances, the costs of regulatory heterogeneity outweigh the marginal benefits of learning, and regulations tend to be superior. The proposed framework also coheres with the precautionary principle, a cornerstone of EU risk regulation that aims to protect EU citizens from unknown (environmental) risks.

The exposition is structured as follows: Section 2 introduces our methodology. Section 3 outlines the literature on Knightian uncertainty by distinguishing between uncertainty and risk and by showing how uncertainty becomes risk. Section 4 describes our model for the choice between directives and regulations. Our synthesis of the literature yields three policy prescriptions, which we present in Section 5. Section 6 explains the relationship between our model and two general features of the practice of environmental regulation in the EU, namely reliance on the precautionary principle and the need to address socio-political concerns about technocratic rule. Section 7 concludes.

2. Method and material

We developed this paper as a critical review for social scientists (Grant and Booth, 2009, 93). We do not examine a large set of academic articles to summarise the state of the art or to identify patterns and trends. Instead, our aim is to provide a critical analysis of different strands of scholarship in order to produce a theoretical model. This decision calls for an explanation. The aim of the model is to improve the effectiveness of EU policymaking by solving a problem of legal doctrine. Problems of legal doctrine cannot ordinarily be solved by testing hypotheses against data (Rubin 2007; Hesselink 2009), which is why we cannot say in good faith that this is a scientific paper. However, our argument is that the problem of legal form can be solved *through the use of* social scientific literature. We are thus methodologically closer to Feyerabend (1975) than to Popper (1959), in that we marshal concepts from the social scientific literature strategically and with a view to persuading the reader.[1] In other words, our method is more inductive than deductive.

We made this methodological decision for two reasons. First, there are no empirical data on the implications of the choice between regulations and directives for the accumulation of information. Second, nobody has formulated any testable hypotheses about them. Useful data on law are hard to come by. It is usually unethical to run legal experiments, and legal instruments tend to be embedded in different interpretative traditions in different polities (Mattei 1997; Zwiegert and Kötz 1998), which means that they operate differently even when they are worded identically.

We start by analysing the importance of information for regulation. To that end, we draw on the literature on Knightian uncertainty. Consistent with our previous

contribution to the field (Kołacz, Quintavalla, and Yalnazov, 2019), we conclude that the distinction between risk and uncertainty is instrumental for the regulation of technology. Subsequently, we discuss the problem of legal form and the choice between directives and regulations in EU law. In that part of the analysis, we build on economic analyses of the optimal precision of legal texts. Finally, we identify three prescriptions that would enable the EU legislator to solve the problem of legal form in a manner that is conducive to eco-innovation while also protecting EU citizens from various perils.

We use two expositional devices to make the text more accessible. We rely on several hypotheticals to illustrate important theoretical distinctions, such as that between uncertainty and risk. Since the hypotheticals are illustrative, they are also highly reductive, which is why we do not derive any of our prescriptions from them. We also develop several examples from actual regulatory practice, such as the passage of the Regulation 1907/2006 ("REACH") and the operation of the precautionary principle. Those worked examples are considerably more convoluted than the reductive hypotheticals, and their presentation is intended to demonstrate how our model can be used to improve real laws and the manner in which they are made. We believe that the hypotheticals and the examples, when taken together, make a strong case for the adoption of our model.

The critical review that we present here is intended to contribute to the integration of the legal literature with the social scientific one. Currently, the problem of legal form in EU law is thought to be purely, or at least chiefly, doctrinal (Harrison 1996; Harbo 2010; Craig and de Búrca 2020), which precludes the possibility of using more traditional social scientific methods to solve it. Conversely, the solution that we propose is intended to result in the formulation of testable hypotheses and in the accumulation of data that would enable them to be tested. It is for this reason that we believe that the text may be of interest to scientists.

3. The role of information gathering in regulation

3.1. Risk and uncertainty

The distinction between risk and uncertainty is a distinction between two different types of information scarcity. Humans use information to make causal inferences and predictions. Culture depends on those faculties, and the history of their refinement is the history of science. The more our inferences and predictions proliferate, the more our material conditions improve. Unfortunately, our powers of prognosis, both individual and collective, have serious limitations. Our predictive impotence takes two general forms. One is risk, the other is uncertainty. The term "risk," in Knight's (1921) terms, captures problems of prediction whereby one can assign an actuarial probability to all possible outcomes of one's choices. For example, if we toss a coin, we cannot say whether it will land heads or tails – we do not know the weight of the coin, we do not know how to measure or moderate the force which we apply to it with our thumbs, and we know little about the laws that govern its motion once it is in the air. Why, then, do we toss coins? We compensate for our ignorance of mechanics through our knowledge of statistics. We know the possible outcomes of a coin toss and the probabilities with which they occur. The problem of coin tosses is one of risk, and information about risk is much easier to acquire than information about mechanics. This

notion of risk has uses in virtually all areas of concerted human action, including eco-innovation.

Not all ignorance can be reduced to risk. Suppose that we show you an opaque urn and tell you that it contains black balls and white balls. We then say that we will draw one ball from the urn and ask you to try and guess what colour it is.[2] Statistics are useless to you because you know neither the total number of balls in the urn nor their distribution. Consequently, you cannot calculate any probabilities. You can still make predictions if you like, but they would have no rational basis.

Knight (1921, 197) would say that the hypothetical urn exemplifies uncertainty in apposition to risk. Problems of prediction are uncertain when we cannot assign probabilities to all of the possible consequences of our choices. Many, if not most, problems are uncertain. We cannot assign exact probabilities to the possible outcomes of the next General Election, the health outcomes of vaping, or reincarnation upon the dissolution of the body.

Risk is easier to regulate than uncertainty. We expect regulation to be rational (Bruff 1984). Regulators practice rationality when they conduct strategic environmental assessments and environmental impact assessments. Suppose, hypothetically, that a municipal authority is considering a plan to construct a hydropower plant. The savings from cheaper and cleaner energy are assured to be £5,000,000. However, there is a 20% probability that the plant will disrupt the natural habitat of salmon living in the area. The current salmon population is worth £20,000,000 to the local fishing industry. Should the municipal authority allow the hydropower project to go ahead? If real life were so simple, it would be possible to make that decision rationally and categorically: the regulator would merely need to balance the £5,000,000 in savings against the expected cost of the project, which is 20% of £20,000,000, or £4,000,000. The result of this simple calculation would demonstrate conclusively that the plant should be constructed – it would generate a gain of £1,000,000 for society.

A real hydropower project would obviously pose issues that are much more complex than the ones that we described above. The planning process is usually shaped and driven by uncertainty. Imagine that our earlier estimate of the probability of the salmon population being eradicated is compromised and that the probability of all salmon in the area dying transpires to be incalculable. In this situation, which is also highly hypothetical, the regulator may reason as follows: "the savings from cheaper energy will be one-quarter of the current total value of the habitat of the salmon. Therefore, the hydropower project should only be built if the probability of habitat destruction is lower than 25%." Since that probability is in fact completely unknowable, the regulator cannot make a reasoned choice. Still, she must choose. Her choice can only be based on convictions. For example, she may say that society in general should be averse to uncertainty and that the hydropower project should therefore be scrapped. Alternatively, she may say that eco-innovation drives progress and that the project should go ahead for this reason.[3] The choice between the two outcomes and the subjective attitudes that underlie them cannot be made rationally. Propositions like "uncertainty should be avoided" or "eco-innovation should be encouraged" are "oughts" in the sense in which Hume ([1739] 1888, 469–70) used that term – they cannot be proven. Risk can be managed by reasoning; the same is not true of uncertainty. When we regulate, therefore, we should prefer risk to uncertainty.

3.2. The conversion of uncertainty into risk

Uncertainty forces regulators to make choices that they cannot make well. The future is more uncertain than risky (Polasky *et al.* 2011). How do we make progress? We observe reality and draw inferences from our observations. The knowledge that we acquire through inference converts uncertainty to risk. To give a very simple example, the link between anthropogenic greenhouse gas emissions and climate change was uncertain decades ago (see, e.g. World Meteorological Organisation 1979, 2–3). Even if some exceptionally perspicacious regulator had directed her mind to that link, she would have been unable to procure dependable estimates of the influence of anthropogenic greenhouse gas emissions on large-scale climate change. Over time, data revealed the correlation (see, e.g. World Meteorological Organisation 1988 and the assessment reports by the Intergovernmental Panel on Climate Change). We now know that an increase in carbon dioxide that is caused by human activities elevates global temperatures. In response, regulators have made manmade greenhouse gas emissions expensive. When uncertainty became risk, therefore, we were in a position to begin improving our regulations.

Regulators are not passive beneficiaries of knowledge accumulation. It is in their power to convert uncertainty into risk (Diver 1983; Kaplow 1992; Korobkin 2000; Friedman and Wickelgren 2014). This might sound unusual: the government is not often associated with the direct creation of new knowledge. Since information tends to be monetisable, private individuals sometimes produce it for rewards (Arrow 1962; Demsetz 1969). At other times, they do not. In such cases, information production must start with the state if it is to start at all. When it comes to the knowledge needed for the specific purposes of regulation, the case for government intervention is difficult to resist. Regulatory information is a public good (Head and Shoup 1969; Shavell 1984), and the market underproduces it. The market ignored the correlation between anthropogenic greenhouse gas emissions and climate change. Even if some private company had discovered that anthropogenic greenhouse gas emissions contribute to climate change at the regional and the global level, it would not have been able to charge the government for that knowledge. Since the discovery of this correlation would have involved considerable and likely irrecoverable costs, in the broad economic sense of that term (see Buchanan 1969), market actors largely skirted the issue.

Admittedly, the promoters of new products and technologies usually have information in their possession which would be of tremendous use to the regulator. For example, ExxonMobil must have known that the use of fossil fuel causes global warming (Supran and Oreskes 2017). However, the regulated have little reason to disclose such information to regulators. Few would claim seriously that industrialists publicise evidence of their harmful activities freely and without compunction. It follows, then, that in the context of regulation, the market will not convert uncertainty into risk (Hirshleifer 1971) – the government must act. To predict human behaviour under a certain regulatory regime, we need observations. The regulator can generate such observations by running experiments (Cowen 1992; Greenstone 2009). For example, almost half of all carbon emissions within the EU are now regulated through a trading system (Directive 2003/87/EC). There is a cap on the total amount of emissions of certain types. Subject to this cap, emissions are traded on markets (Arts 10–11 of Directive 2003/87/EC). This works, in that the EU has reduced the total number of emissions allowances over time – certain industrial activities pollute less now than they did in the past. The usefulness of that mechanism was proven experimentally.

Regulators established a carbon market. They were then able to observe reductions in carbon emissions volumes, increases in investment in low-carbon technologies, and decreases in pollution. The hypotheses of the economists were confirmed.

We should note here that regulatory experiments impose large costs on society. For instance, in universal basic income experiments, funds are allocated to randomly selected members of the public.[4] Their economic behaviour is then monitored and compared to the behaviour of those who are not selected. The procedure yields very robust data. It is also unethical and inefficient. If those who are selected to receive the basic income do not use it to engage in productive activity, social resources are dissipated. Moreover, if the welfare of those who are selected improves, the control group forgoes a benefit for wholly arbitrary reasons. Since experimentation is unfair and inefficient in these ways, regulators seldom experiment intentionally and explicitly. However, reform can be based on observation of past legal regimes even if those past legal regimes were not designed as experiments. For instance, much of our knowledge about the effectiveness of cap and trade derives from the experience of the United States (Schmalensee and Stavins 2017). The United States did not establish cap and trade to prove or disprove hypotheses. It just so happened that it was the only country which had replaced command-and-control regulation with a market-based mechanism for combatting air pollution and acid rains. This gave everyone an opportunity to draw comparisons. Those comparisons informed our environmental policy and that of the Americans. Information production is thus often a byproduct of legislative choices that are made without experimental intent.

4. A model for the choice of legal form: regulations versus directives

Let us now, at last, turn to the problem of legal form. For the most part, EU law is contained in directives and regulations. Unlike regulations, directives tend to be vague. They instruct Member States to pursue certain ends, but they leave the choice of means to each national government. The emissions trading scheme is regulated through a directive (Directive 2003/87/EC). That directive stipulates that Member States must issue allowances, monitor and record emissions, and report to the Commission every year. It is mandatory for all 27 Member States to issue allowances. However, each Member State government is free to determine how to use the resultant income (e.g. to develop renewable energy, to promote low-emissions public transport, or to finance activities to tackle climate change) and to set penalties for non-compliance (Article 16 and Article 19 of Directive 2003/87/EC). Under that regime, the same policy objective, reducing carbon emissions, is pursued across the EU, but the regulatory means that the Member States employ vary. A regulation, conversely, is a mandatory measure that specifies both regulatory objectives and regulatory means. In the carbon emissions example, a regulation would contain detailed rules on both the application of income from the sale of allowances and on enforcement procedures; as a result, those policy domains would be beyond the reach of Member State governments.

In academia and practice alike, the choice between directives and regulations is treated as a choice between sovereignty and prosperity (Hunt 2010; Weber 2013). Directives preserve sovereignty partly, but at the cost of regulatory heterogeneity. This heterogeneity causes market fragmentation, with the attendant losses for producers and consumers. If a regulation is chosen, the laws of all Member States are synchronised

immediately. Competition intensifies. *Ceteris paribus*, aggregate social welfare increases. However, national sovereignty is undermined.

How much sovereignty to cede in the name of material abundance? The question has excited considerable academic and electoral controversy (Alesina and Perotti 2004; Maduro 2003). No consensus is likely to ever emerge. We believe that the directive-regulation dichotomy can be analysed in more productive ways. Directives tend to foster experimentation; regulations tend to foreclose it. Experimentation is essential to social learning and to the regulation of innovation (Bischoff *et al.* 2020). It enables regulators to collect evidence that can be classified and evaluated in order to assess alternative regulatory approaches that were not, or could not be, tested at the time at which the original measure was promulgated. It is not possible to predict the impact of any policy accurately prior to its implementation (Greenstone 2009). The quasi-experiments[5] that are performed in different places, such as the Member States of the EU, result in the accumulation of information on the effects of the implemented policy and the manner in which it affects economic and environmental behaviour.

For instance, under the Emission Trading System Directive, the EU can reduce carbon emissions while also observing the consequences of the different regulatory schemes that the Member States adopt. The observations yield information, and the accretion of information results in the conversion of uncertainties into risks. The EU will thus, at some point in the future, be able to discriminate rationally between alternative schemes. A new, Union-wide regulation would emerge from the information that the experiments will generate.

Directives are not always preferable; sometimes, they increase legal uncertainty.[6] A business cannot anticipate the content of the law that a national government will enforce against it by examining the text of an EU directive. In addition, directives obviously leave open the possibility that the same regulatory goal will be pursued in 27 different ways, which, absent some countervailing consideration, is unfair on those who must labour across borders and comply with unclear and disparate regulations for the benefit of an inquisitive bureaucracy. Such sacrifices are only justifiable if the gains from superior information exceed the costs of experimentation. Very often, that condition is not satisfied. In those cases, a regulation is preferable.

Therefore, the choice of legal form entails a trade-off between information production and regulatory heterogeneity. Once a regulation is in place, it is harder to experiment and observe. Conversely, a directive, while it may cause domestic laws to differ, facilitates experimentation and allows the regulator to convert uncertainties into risks. This conversion eventually paves the way for measures that are rational, specific, and uniform.

5. Prescriptions

The reformulation of the problem of legal form along these lines would have important implications for legal theory. Typically, that problem is cast as a trade-off between national sovereignty and free trade. We replace those notions with information production and heterogeneity. This is important because sovereignty means all things to all people (Keohane 2002), whereas information and heterogeneity are somewhat less emotive. More importantly to the present ends, the underlying model yields three prescriptions that can guide regulators even if they do not hold any strong views on legal

theory. It is those prescriptions that are most likely to be of interest to social scientists, too, which is why we propose to elaborate on them on the pages that follow.

5.1. Uncertain eco-innovations should be regulated through directives

Our first prescription is that uncertain eco-innovations should be regulated through directives. Why so? Uncertain eco-innovations, so long as they remain uncertain, cannot be regulated in a wholly rational manner. A regulator can neither advance rational justifications for her decisions nor avoid deciding – inaction may expose the public to danger, while overregulation may thwart innovation (Todt and Luján 2014). In the absence of information, both action and inaction can only be justified by some ideological conviction, and ideological conviction is a notoriously unreliable frame of reference in governance.

Directives can ensure the attainment of essential policy objectives without requiring the regulator to commit to concrete measures. Vague instructions on policy desiderata – the reduction of waste, the preservation of life, and such like – suffice for a directive to become legally effective. The Member States then devise specific rules. Once each Member State has implemented its rules, the EU can observe behaviour in national markets. The co-existence of diverse approaches causes economic waste. However, once regulatory experimentation has produced reliable data, uncertainty is converted into risk. At that point, a uniform law for the EU can be identified rationally. Therefore, the EU should favour directives when it regulates uncertain eco-innovations.[7]

We must acknowledge that the process of converting uncertainties into risks may not be as straightforward as we have made it seem. Additional information may simply reveal new uncertainties. However, this does not affect our prescription – the collection of further information would still advance knowledge by facilitating both the analysis of alternative regulatory approaches and the adaptation of existing regulatory systems (McDaniels and Gregory 2004).

5.2. The EU should regulate risky eco-innovations through regulations

Our second prescription is that the EU should regulate risky eco-innovations through regulations. Recall that an eco-innovation is risky if all of the outcomes of its adoption are identifiable and if it is possible to assign an actuarial probability to each outcome. If these conditions are satisfied, then the prognostic problem before the regulator is easy to solve. Suppose that we are told that if some eco-innovation is adopted, there is a 1% probability of harm that would be worth £1,000,000 and a 50% probability of gains that would be worth £100,000. The expected value of the adoption of the eco-innovation would be £40,000. A concrete and rational decision about regulation can be made immediately. The adoption of a directive and the attendant experimentation may still appear useful, for example because they may confirm the accuracy of the original estimates or result in their refinement. However, these gains in accuracy would be banal relative to the economic benefits of regulatory homogeneity. Therefore, regulations are preferable.

We do not, of course, mean to imply that the use of regulations forecloses the possibility of experimentation. The distinction between directives and regulations, though useful, is blurry. The EU has recourse to tools that enable it to learn from regulations,

too. These include requests for data production and retrospective evaluation instruments, such as reporting obligations and *ex post* impact assessments (Mickwitz 2013). In the last decade, these tools have grown more popular (European Commission 2015). As the European Commission (2010, 3) has stated, "implementing existing legislation properly and amending it in the light of experience is as important as the new legislation" (see also European Union 2002, 14).

REACH Regulation, which aims at a policy of "no data, no market," is a suitable illustration of this tendency. That complex legislation imposes a general registration requirement on those who produce and market chemicals. To that end, economic operators must submit technical data that allows the health and environmental risks that a chemical poses to be assessed. In practice, failure to register results in the exclusion of the chemical from the market. One of the main rationales of REACH was to generate new information and to address the knowledge gaps that had emerged under the previous regulatory framework. Under that regime, reporting duties for existing chemicals oftentimes went unfulfilled, and new chemicals were not used because the notification process was costly and cumbersome (Heyvaert 2007, 205; European Commission 1998). It was, thus, information production that resulted in the ultimate adoption of the regulation.

5.3. In the long run, directives should be replaced by regulations

All other things being equal, the long-term tendency should be towards the substitution of directives with regulations. Eco-innovations tend to be uncertain when they first emerge. The regulator, when faced with such eco-innovations, has two choices. First, she may adopt an EU-wide regulation. That regulation would necessarily reflect the ideological preferences of the regulator. Second, the regulator may adopt a directive. Then, she can wait for the uncertainty to be converted into risk. In a rationalist social order, we would always prefer the second option to the first.

Once the eco-innovation becomes risky, our putative regulator faces a new choice: retain the directive, which would produce more information, or pass a regulation, which would optimise trade. The second option dominates the first. The gains from legal homogeneity tend to be high. What has to be foregone to achieve legal homogeneity is experimentation. Experimentation, like all human activity except prayer, exhibits diminishing returns.[8] At the point at which uncertainty has been converted into risk, the regulator already has enough information to regulate effectively. It follows, then, that a rational regulator should switch from directives to regulations over time.

6. The model and contemporary EU environmental regulation

We now propose to show how our model would fit into the current EU regulatory framework. We begin by highlighting its main strength, which is that it would dovetail into the precautionary principle. Thereafter, we elaborate on some of the political difficulties that its adoption would pose.

6.1. The precautionary principle

The EU adopted the precautionary principle to legitimise the adoption of precautionary measures and to ensure a high level of, among others, environmental protection, even

when the scientific evidence is incomplete. The precautionary principle, which is set out in Article 191(2) TFEU, requires the EU legislator to take prudent decisions that reduce the potential for irreparable environmental harm in the absence of scientific consensus (European Commission 2000). Its purpose is to protect society by guaranteeing that the procedures and standards that are implemented ensure that risk is appraised accurately and managed well (Fisher 2009). Extensive research has shown that the precautionary principle is applied flexibly and contextually (Scotford 2017). That principle does not affect the regulation of all risky and uncertain technologies. The regulator may fail to identify any negative consequences, or it may deem the potential harm acceptable. In such instances, the precautionary principle is not applied (Christoforou 2003, 206–7; Case C-77/09 2010, paras 75–6).

Some commentators have called the decision whether to apply the precautionary principle "political" (Von Schomberg 2012). The precautionary principle can be interpreted weakly, moderately, or strongly (Garnett and Parsons 2017). Aside from the strongest formulation, which always leads to the prohibition of new applications of eco-innovations, all other interpretations require the regulator to develop some novel set of regulatory measures (Garnett and Parsons 2017, 506).

Our model complements the precautionary principle in two ways. First, its adoption would enable the EU to regulate risky and uncertain eco-innovations whose environmental impact is deemed acceptable and which, therefore, do not trigger the application of the principle. By following our prescriptions, the EU could discriminate between cases in which further knowledge must be accumulated (in our terms, uncertain eco-innovations that call for directives) and cases in which legal homogeneity and free trade ought to be prioritised (in our terms, risky eco-innovations that call for regulations). Second, our model facilitates the application of the precautionary principle by identifying the most appropriate legal form that precautionary measures should take. The principle serves as a "rationale for action" (Von Schomberg 2012), but it is wholly silent on the question of form (Lee 2014, 6). The Commission communication on the principle is limited to the proposition that the final instruments adopted should not *necessarily* produce legal effects (European Commission 2000, 15).

An example might be helpful at this juncture. Suppose that the use of membrane filtration technology in water treatment is gaining popularity, but the scientific evidence is incomplete. The EU must then decide whether to invoke the precautionary principle, that is, it must decide whether the use of membrane filtration technology is liable to cause irreparable and unacceptable harm to the environment. If it decides that the principle is inapplicable, the EU could still regulate membrane filtration technology by means of a directive or a regulation, depending on whether that technology is uncertain or risky. If the EU decides to invoke the precautionary principle, it could adopt measures with or without legal effect. If it chooses the former, our prescriptions can guide the choice of legal form.[9]

It follows, then, that our model would not only respect, but also enrich, the precautionary principle. It would also accord with the tenets of risk management that are associated with that principle (European Commission 2000, 17). For example, the model posits that using directives for uncertain technologies ensures that scientific evidence is collected over time and, accordingly, that existing measures can be reviewed continuously. In fact, such reviews are mandatory under our model because its adoption implies that directives should be replaced by regulations in the long term. Furthermore, the use of regulations for risky eco-innovations is premised on the idea

that the EU should attain its objectives by generating as little legal heterogeneity and economic disruption as possible. Adherence to that prescription from our model would therefore strengthen the integration of proportionality into the cost-benefit analysis that the precautionary principle requires (Von Schomberg 2012, 150).

6.2. *Political implications of the model*

Our model is also liable to run into difficulties in the current socio-political climate. The conversion of uncertainty into risk can take decades. The same is true of the formulation of legislative proposals to convert a directive into a regulation. During this period, society would need to accept the potentially unjustified use of regulatory experimentation for information gathering and knowledge acquisition. Such acceptance is far from given – our proposal smacks of technocratic overreach.

The model does not, of course, purport to replace the political component of EU policymaking. It merely identifies the conditions under which further knowledge ought to be sought. Ultimate decision-making authority still rests with bodies that are accountable to the public, not with anonymous experts. Still, assurances of this kind have not proven particularly effective in the past. A more practical political advantage of the model is that it favours the use of directives when uncertainty is high. Directives allow non-scientific and socio-cultural factors to be considered at the local level. That each Member State can choose between several ways of implementing a directive means that the rules that are ultimately implemented should reflect the preferences of domestic electorates. For instance, in the European directive on GMOs, the exact meaning of the phrase "adverse effects on human health and the environment," which is clearly relevant to the application of precautionary measures and also likely to excite political controversy, was left to the Member States (Von Schomberg 2012, 153).

Another meaningful strategy for mitigating the aforementioned concerns, at least partially, would be to make decision-making processes about legal form more participatory (Kingston, Heyvaert, and Čavoški 2017, 29; Lee 2014, 178). Although public participation is certainly not unproblematic (Lee 2011), it has been shown that public scrutiny and procedural flexibility can mitigate scepticism and strengthen dialogue between experts and the public (Kingston, Heyvaert, and Čavoški 2017, 468–471; Gunningham and Grabosky 1998). Participation has also been shown to foster knowledge creation in the context of risk assessment and management (Everson and Vos 2009).

There is one last possibility on which we must remark briefly. The preceding paragraphs may make it seem as if we are worried that the public would reject our model because it is too technocratic. However, in actuality, the risk of subversion by politicians and administrators is much higher. Because we are writing theoretically, we have treated risk and uncertainty as epistemological absolutes. This they are not, at least in practice. Everything depends on how one delineates situations, problems, and technologies. Whether a coin will land tails up is a matter of risk. Whether gambling will ruin your life is uncertain. The same is true of eco-innovations: whether enough information has been accumulated to convert an uncertainty into a risk depends very much on perspective and compartmentalisation. This feature of the problem need not be fatal to our proposal, insofar as all reality is to some degree fabricated. It does, however, leave the regulatory scheme that we propose vulnerable. That the EU legislator infuses all

kinds of ideologies, preferences, and agendas into contemporary cost-benefit analyses is well documented (Heyvaert 2011), and our scheme can also be hijacked in this way (van Asselt and Vos 2006). It would doubtless be better to redesign European institutions in a way that forecloses the possibility of subversion. Under such a system, the directive-regulation dichotomy might not exist or matter. However, our own expertise confines us to the current institutional framework, and our proposal is merely intended to improve its operation while we await the emergence of a superior alternative.

7. Conclusion

Regulation occupies an important position in the literature on eco-innovation. That literature enumerates the various characteristics that regulations should ideally possess, but it has little to say about their optimal legal form. The present contribution is an attempt to close that gap by integrating the legal literature into its social scientific counterpart.

We reviewed the literature on Knightian uncertainty, legal form, and the choice between directives and regulations. That review yielded a model that may guide the EU when it regulates eco-innovation. Specifically, we argued that directives are preferable to regulations when an uncertain eco-innovation is being regulated, that regulations are superior when the eco-innovation in question is risky, and that regulations should replace directives in the long run.

Adopting this model would have three more general advantages. First, the regulation of eco-innovation in the EU, that is, at the regional level of governance, would improve. The existing literature indicates that national regulation currently has a more significant impact on eco-innovation (Popp, Hafner, and Johnstone 2011; Peñasco, del Río, and Romero-Jordán 2017). Evidently, improving regional-level regulation in Europe would be desirable. Second, the regulation-directive dichotomy is usually conceptualised along sovereignty-versus-free-competition lines. Departing from that model would benefit both legal theorists and those who rely on their output to make laws. Finally, the model is intended to promote the accumulation of information and the testing of hypotheses. At least in the environmental domain, there can be little doubt that the application of scientific rather than ideological principles would benefit all.

Notes

1. Paradoxically, the solution that we arrive at by using this method is highly Popperian.
2. The example is based on Ellsberg (1961).
3. The dilemma is explicit in Ellsberg (1961) and Keynes (1921, 75).
4. For an overview of basic-income experiments, see Schjoedt (2016).
5. The term ‘quasi-experiments’ is used when ‘the assignment of individual subjects to the treatment or control group is determined by nature, politics, an accident, or some other factor’. See Greenstone (2009, 117).
6. Obviously, not all directives are equally uncertain, and some directives are very certain. However, all directives entail at least *some* uncertainty, and the average directive is less certain than the average regulation.
7. There is also much to commend a regime which delegates ideologically loaded decisions, such as those on the governance of uncertain technology, to democratically elected legislatures. A directive obviously achieves that aim more effectively than a regulation by virtue of allocating most regulatory decisions to the Member States.
8. As noted earlier, regulatory inertia may cause the returns from experimentation to become negative.

9. Here, we should note that the uncertainty that is relevant to the precautionary principle is not the same as Knightian uncertainty. The precautionary principle can apply under conditions of both Knightian uncertainty and risk. For example, a risk can be said to be uncertain in the precautionary-principle sense ('the absence of complete scientific certainty') even when we know the likelihood of it materialising but not the time at which it will occur.

Acknowledgements

We would like to thank Michael Faure and the two anonymous reviewers for their extensive comments on the previous drafts of this paper. We are also grateful to Neil Powe and Sarah Cherrill from the *Journal of Environmental Planning and Management* for their assistance throughout the publication process.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Alesina, A., and R. Perotti. 2004. "The European Union: A Politically Incorrect View." *Journal of Economic Perspectives* 18 (4): 27–48. doi:10.1257/0895330042632780.

Arrow, K. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by NBER, 609–634. Princeton, NJ: Princeton University Press.

Auld, G., A. Mallett, B. Burlica, F. Nolan-Poupart, and R. Slater. 2014. "Evaluating the Effects of Policy Innovations: Lessons from a Systematic Review of Policies Promoting Low-Carbon Technology." *Global Environmental Change* 29: 444–458. doi:10.1016/j.gloenvcha.2014.03.002.

Belin, J., J. Horbach, and V. Oltra. 2011. *Determinants and Specificities of Eco-Innovations – an Econometric Analysis for the French and German Industry Based on the Community Innovation*. Groupe de Recherche en Economie Théorique et Appliquée (GREThA).

Bischoff, T. S., K. von der Leyen, S. Winkler-Portmann, D. Bauknecht, K. Bizer, M. Englert, M. Führ, et al. 2020. "Regulatory Experimentation as a Tool to Generate Learning Processes and Govern Innovation." https://www.sofia-darmstadt.de/fileadmin/Dokumente/Diskussion/2020/Netzversion__Portmann_Regulatory.pdf

Bruff, H. H. 1984. "Legislative Formality, Administrative Rationality." *Texas Law Review* 63: 207–250.

Buchanan, J. 1969. *Cost and Choice: An Inquiry into Economic Theory*. Chicago: Chicago University Press.

Cai, W., and G. Li. 2018. "The Drivers of Eco-Innovation and Its Impact on Performance: Evidence from China." *Journal of Cleaner Production* 176: 110–118. doi:10.1016/j.jclepro.2017.12.109.

Case C-77/09. 2010. *Gowan* ECLI:EU:C:2010:803.

Christoforou, T. 2003. "The Precautionary Principle and Democratizing Expertise: A European Legal Perspective." *Science and Public Policy* 30 (3): 205–212. doi:10.3152/147154303781780443.

Cowen, T. 1992. "Law as a Public Good: The Economics of Anarchy." *Economics and Philosophy* 8 (2): 249–267. doi:10.1017/S0266267100003060.

Craig, P., and G. De Búrca. 2020. *EU Law: Text, Cases, and Materials*. Oxford: Oxford University Press.

de Miranda Ribeiro, F., and I. Kruglianskas. 2015. "Principles of Environmental Regulatory Quality: A Synthesis from Literature Review." *Journal of Cleaner Production* 96: 58–76. doi:10.1016/j.jclepro.2014.03.047.

del Río González, P. 2009. "The Empirical Analysis of the Determinants for Environmental Technological Change: A Research Agenda." *Ecological Economics* 68 (3): 861–878. doi:10.1016/j.ecolecon.2008.07.004.

del Río, P., C. Peñasco, and D. Romero-Jordán. 2015. "Distinctive Features of Environmental Innovators: An Econometric Analysis." *Business Strategy and the Environment* 24 (6): 361–385. doi:10.1002/bse.1822.

Demirel, P., and E. Kesidou. 2011. "Stimulating Different Types of Eco-Innovation in the UK: Government Policies and Firm Motivations." *Ecological Economics* 70 (8): 1546–1557. doi:10.1016/j.ecolecon.2011.03.019.

Demsetz, H. 1969. "Information and Efficiency: Another Viewpoint." *The Journal of Law and Economics* 12 (1): 1–22. doi:10.1086/466657.

Dewick, P., E. Maytorena-Sanchez, and G. Winch. 2019. "Regulation and Regenerative Eco-Innovation: The Case of Extracted Materials in the UK." *Ecological Economics* 160: 38–51. doi:10.1016/j.ecolecon.2019.01.034.

Di Stefano, G., A. Gambardella, and G. Verona. 2012. "Technology Push and Demand Pull Perspectives in Innovation Studies: Current Findings and Future Research Directions." *Research Policy* 41 (8): 1283–1295. doi:10.1016/j.respol.2012.03.021.

Directive 2003/87/EC Establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community, OJ L 275/32.

Diver, C. 1983. "The Optimal Precision of Administrative Rules." *The Yale Law Journal* 93 (1): 65–109. doi:10.2307/796245.

Ellsberg, D. 1961. "Risk, Ambiguity, and the Savage Axioms." *The Quarterly Journal of Economics* 75 (4): 643–669. doi:10.2307/1884324.

Epstein, R. 2006. "Intuition, Custom, and Protocol: How to Make Sound Decisions with Limited Knowledge." *New York University Journal of Law and Liberty* 2: 1–27.

European Commission. 1998. *Report on the Operation of Directive 67/548/EEC, Directive 88/379/EEC, Regulation (EEC) 793/93, Directive 76/769/EEC', SEC(1998) 1986 final, 18 November 1998*. Brussels: EC.

European Commission. 2000. "Communication on 'the precautionary principle'." COM(2000) 1 Final, 2 February 2000. Brussels: EC.

European Commission. 2010. "Turning Europe into a True Innovation Union." Memo 10/473 Accompanying the Innovation Union Communication, 6 October 2010. Brussels: EC. https://ec.europa.eu/commission/presscorner/detail/nl/MEMO_10_473

European Commission. 2011. "Communication on 'Innovation for a Sustainable Future: The Eco-innovation Action Plan (Eco-AP)'." COM (2011) 899 final, 15 December 2011. Brussels: EC.

European Commission. 2013. *Directorate-General for Environment. Eco-Innovation: The Key to Europe's Future Competitiveness*. Brussels: EC Publications Office.

European Union. 2002. "Decision No 1600/2002/EC Laying Down the Sixth Community Environment Action Programme." *OJ L* 242/1: 1–15.

European Union. 2022. "Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030." *OJ L* 114/22: 22–36.

Everson, M., and E. Vos. 2009. "The Scientification of Politics and the Politicisation of Science." In *Uncertain Risks Regulated*, edited by E. Vos and M. Everson, 1–18. Abingdon: Routledge.

Feyerabend, P. 1975. *Against Method: Outline of an Anarchistic Theory of Knowledge*. London: Verso.

Fisher, E. 2009. "Opening Pandora's Box: Contextualising the Precautionary Principle in the European Union." In *Uncertain Risks Regulated*, edited by E. Vos and M. Everson, 21–45. Abingdon: Routledge.

Friedman, E., and A. Wickelgren. 2014. "A New Angle on Rules Versus Standards." *American Law and Economics Review* 16 (2): 499–549. doi:10.1093/aler/aht013.

Fussler, C., and P. James. 1996. *Eco-Innovation: A Breakthrough Discipline for Innovation and Sustainability*. London: Pitman.

Garnett, K., and D. J. Parsons. 2017. "Multi-Case Review of the Application of the Precautionary Principle in European Union Law and Case Law." *Risk Analysis: An Official Publication of the Society for Risk Analysis* 37 (3): 502–516. doi:10.1111/risa.12633.

Grant, M. J., and A. Booth. 2009. "A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies." *Health Information and Libraries Journal* 26 (2): 91–108. doi:10.1111/j.1471-1842.2009.00848.x.
Greenstone, M. 2009. "Toward a Culture of Persistent Regulatory Experimentation and Evaluation." In *New Perspectives on Regulation*, edited by D. Moss and J. Cisternino, 111–126. Cambridge: Tobin Project.
Gunningham, M., and P. Grabosky. 1998. *Smart Regulation: Designing Environmental Policy*. Oxford: Clarendon.
Harbo, T. 2010. "The Function of the Proportionality Principle in EU Law." *European Law Journal* 16 (2): 158–185. doi:10.1111/j.1468-0386.2009.00502.x.
Harrison, V. 1996. "Subsidiarity in Article 3b of the EC Treaty – Gobbledegook or Justiciable Principle." *International and Comparative Law Quarterly* 45 (2): 431–439. doi:10.1017/S002058930005908X.
Head, J., and C. Shoup. 1969. "Public Goods, Private Goods, and Ambiguous Goods." *The Economic Journal* 79 (315): 567–572. doi:10.2307/2230383.
Hesselink, M. 2009. "A European Legal Method? On European Private Law and Scientific Method." *European Law Journal* 15 (1): 20–45. doi:10.1111/j.1468-0386.2008.00449.x.
Heyvaert, V. 2007. "No Data, No Market. The Future of EU Chemicals Control Under the REACH Regulation." *Environmental Law Review* 9 (3): 201–206. doi:10.1350/enlr.2007.9.3.201.
Heyvaert, V. 2011. "Governing Climate Change: Towards a New Paradigm for Risk Regulation." *The Modern Law Review* 74 (6): 817–844. doi:10.1111/j.1468-2230.2011.00874.x.
Hirshleifer, J. 1971. "The Private and Social Value of Information and the Reward to Inventive Activity." *American Economic Review* 61 (4): 561–574.
Hojnik, J., and M. Ruzzier. 2016. "What Drives Eco-Innovation? A Review of an Emerging Literature." *Environmental Innovation and Societal Transitions* 19: 31–41. doi:10.1016/j.eist.2015.09.006.
Horbach, J. 2008. "Determinants of Environmental Innovation: New Evidence from German Panel Data Sources." *Research Policy* 37 (1): 163–173. doi:10.1016/j.respol.2007.08.006.
Horbach, J. 2016. "Empirical Determinants of Eco-Innovation in European Countries Using the Community Innovation Survey." *Environmental Innovation and Societal Transitions* 19: 1–14. doi:10.1016/j.eist.2015.09.005.
Horbach, J., C. Rammer, and K. Rennings. 2012. "Determinants of Eco-Innovations by Type of Environmental Impact: the Role of Regulatory Push/Pull, Technology Push and Market Pull." *Ecological Economics* 78: 112–122. doi:10.1016/j.ecolecon.2012.04.005.
Huber, J. 2008. "Pioneer Countries and the Global Diffusion of Environmental Innovations: Theses from the Viewpoint of Ecological Modernisation Theory." *Global Environmental Change* 18 (3): 360–367. doi:10.1016/j.gloenvcha.2008.03.004.
Hume, D. (1739) 1888. *A Treatise of Human Nature*. Reprint. Oxford: Oxford University Press.
Hunt, J. 2010. "Devolution and Differentiation: Regional Variation in EU Law." *Legal Studies* 30 (3): 421–441. doi:10.1111/j.1748-121X.2010.00164.x.
Kaplow, L. 1992. "Rules versus Standards: An Economic Analysis." *Duke Law Journal* 42 (3): 557–629. doi:10.2307/1372840.
Kemp, R., and P. Pearson. 2007. "Final Report MEI Project about Measuring Eco-Innovation." *UM Merit* 10 (2): 4–11.
Kemp, R., and T. Foxon. 2007. "Typology of Eco-Innovation." *Project Paper: Measuring Eco-Innovation* 5 (1): 10–23.
Keohane, R. O. 2002. "Ironies of Sovereignty: The European Union and the United States." *JCMS: Journal of Common Market Studies* 40 (4): 743–765. doi:10.1111/1468-5965.00396.
Kesidou, E., and P. Demirel. 2012. "On the Drivers of Eco-Innovations: Empirical Evidence from the UK" *Research Policy* 41 (5): 862–870. doi:10.1016/j.respol.2012.01.005.
Keynes, J. M. 1921. *A Treatise on Probability*. London: Macmillan & Co.
Kingston, S., V. Heyvaert, and A. Čavoški. 2017. *European Environmental Law*. Cambridge: Cambridge University Press.
Knight, F. 1921. *Risk, Uncertainty, and Profit*. Boston, MA: Houghton, Mifflin.
Kołacz, M. K., A. Quintavalla, and O. Yalnazov. 2019. "Who Should Regulate Disruptive Technology?" *European Journal of Risk Regulation* 10 (1): 4–22. doi:10.1017/err.2019.22.

Korobkin, R. 2000. "Behavioral Analysis and Legal Form: Rules vs Standards Revisited." *Oregon Law Review* 79: 23.
Lee, M. 2011. "Risk and beyond: EU Regulation of Nanotechnology." *European Law Review* 35 (6): 799–821.
Lee, M. 2014. *EU Environmental Law, Governance and Decision-Making*. Oxford: Bloomsbury.
Maduro, P. 2003. "Contrapunctal Law: Europe's Constitutional Pluralism in Action." In *Sovereignty in Transition*, edited by N. Walker, 501–538. Portland: Hart.
Mattei, U. 1997. "Three Patterns of Law: Taxonomy and Change in the World's Legal Systems." *The American Journal of Comparative Law* 45 (1): 5–44. doi:10.2307/840958.
McDaniels, T. L., and R. Gregory. 2004. "Learning as an Objective Within a Structured Risk Management Decision Process." *Environmental Science & Technology* 38 (7): 1921–1926. doi:10.1021/es0264246.
Mickwitz, P. 2013. "Policy Evaluation." In *Environmental Policy in the EU: Actors, Institutions and Processes*, edited by A. Jordan and C. Adelle, 267–286. London: Routledge.
Mickwitz, P., H. Hyvättinen, and H. Kivimaa. 2008. "The Role of Policy Instruments in the Innovation and Diffusion of Environmentally Friendlier Technologies: Popular Claims versus Case Study Experiences." *Journal of Cleaner Production* 16 (1): S162–S170. doi:10.1016/j.jclepro.2007.10.012.
OECD. 2009. *Sustainable Manufacturing and Eco-Innovation: Towards a Green Economy. Policy Brief*. Paris: OECD.
Peñasco, C., P. del Río, and D. Romero-Jordán. 2017. "Analysing the Role of International Drivers for Eco-Innovators." *Journal of International Management* 23 (1): 56–71. doi:10.1016/j.intman.2016.09.001.
Polasky, S., S. Carpenter, C. Folke, and B. Keeler. 2011. "Decision-Making Under Great Uncertainty: Environmental Management in an Era of Global Change." *Trends in Ecology & Evolution* 26 (8): 398–404. doi:10.1016/j.tree.2011.04.007.
Ponzetto, G., and P. Fernandez. 2008. "Case Law Versus Statute Law: An Evolutionary Comparison." *The Journal of Legal Studies* 37 (2): 379–430. doi:10.1086/533421.
Popp, D., T. Hafner, and N. Johnstone. 2011. "Environmental Policy vs. Public Pressure: Innovation and Diffusion of Alternative Bleaching Technologies in the Pulp Industry." *Research Policy* 40 (9): 1253–1268. doi:10.1016/j.respol.2011.05.018.
Popper, K. 1959. *The Logic of Scientific Discovery*. London: Routledge.
Ramanathan, R., Q. He, A. Black, A. Ghobadian, and D. Gallear. 2017. "Environmental Regulations, Innovation and Firm Performance: A Revisit of the Porter Hypothesis." *Journal of Cleaner Production* 155: 79–92. doi:10.1016/j.jclepro.2016.08.116.
Regulation (EC) No. 1907/2006 on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and Establishing a European Chemicals Agency [2007] OJ L136/3 (REACH Regulation).
Rizzo, M. 1980. "The Mirage of Efficiency." *Hofstra Law Review* 8 (3): 641–658.
Rogge, K. S., M. Schneider, and V. H. Hoffmann. 2011. "The Innovation Impact of the EU Emission Trading System: Findings of Company Case Studies in the German Power Sector." *Ecological Economics* 70 (3): 513–523. doi:10.1016/j.ecolecon.2010.09.032.
Rubin, E. 2007. "What's Wrong with Langdell's Method, and What to Do About It?" *Vanderbilt Law Review* 60: 609–665.
Rubin, H. 1977. "Why is the Common Law Efficient?" *The Journal of Legal Studies* 6 (1): 51–63. doi:10.1086/467562.
Schjoedt, R. 2016. "India's Basic Income Experiment." *Pathways Perspectives on International Development* 1 (21): 1–8.
Schmalensee, R., and R. N. Stavins. 2017. "The Design of Environmental Markets: What Have We Learned from Experience with Cap and Trade?" *Oxford Review of Economic Policy* 33 (4): 572–588. doi:10.1093/oxrep/grx040.
Scotford, E. 2017. *Environmental Principles and the Evolution of Environmental Law*. Oxford: Bloomsbury.
Shavell, S. 1984. "Liability for Harm versus Regulation of Safety." *The Journal of Legal Studies* 13 (2): 357–374. doi:10.1086/467745.
Supran, G., and N. Oreskes. 2017. "Assessing ExxonMobil's Climate Change Communications (1977–2014)." *Environmental Research Letters* 12 (8): 084019. doi:10.1088/1748-9326/aa815f.

Todt, O., and J. L. Luján. 2014. "Analyzing Precautionary Regulation: Do Precaution, Science, and Innovation Go Together?" *Risk Analysis: An Official Publication of the Society for Risk Analysis* 34 (12): 2163–2173. doi:10.1111/risa.12246.

Triguero, A., L. Moreno-Mondéjar, and M. A. Davia. 2013. "Drivers of Different Types of Eco-Innovation in European SMEs." *Ecological Economics* 92: 25–33. doi:10.1016/j.ecolecon.2013.04.009.

UNEP. 2014. *The Business Case for Eco-Innovation*. Nairobi: United Nations Environment Programme.

van Asselt, M., and E. Vos. 2006. "The Precautionary Principle and the Uncertainty Paradox." *Journal of Risk Research* 9 (4): 313–336. doi:10.1080/13669870500175063.

van den Bergh, R. 2002. "Regulating Competition for Harmonization? Guidelines for the European Regulation." Ch. 1 in *The Economics of Harmonizing European Law*, edited by A. Marciano and J.M. Josselin. Cheltenham: Edward Elgar.

Von Schomberg, R. 2012. "The Precautionary Principle: Its Use Within Hard and Soft Law." *European Journal of Risk Regulation* 3 (2): 147–156. doi:10.1017/S1867299X00001987.

Weber, F. 2013. "European Integration Assessed in the Light of the 'Rules vs. Standards' Debate." *European Journal of Law and Economics* 35 (2): 187–210. doi:10.1007/s10657-011-9259-2.

World Meteorological Organisation. 1979. *Declaration of the World Climate Conference*. Geneva: IOC.

World Meteorological Organisation. 1988. *The Changing Atmosphere: Implications for Global Security*. Geneva: IOC.

You, D., Y. Zhang, and B. Yuan. 2019. "Environmental Regulation and Firm Eco-Innovation: Evidence of Moderating Effects of Fiscal Decentralization and Political Competition from Listed Chinese Industrial Companies." *Journal of Cleaner Production* 207: 1072–1083. doi:10.1016/j.jclepro.2018.10.106.

Zwiegert, K., and K. Kötz. 1998. *An Introduction to Comparative Law*. 3rd ed. Oxford: Oxford University Press.

Zywicki, T. 2003. "The Rise and Fall of Efficiency in the Common Law." *Northwestern University Law Review* 97 (4): 1551–1634.