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Company Strategies for Responsible Research and Innovation (RRI): A Conceptual Model

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Abstract: Responsible research and innovation (RRI) has become an important topic in the academic community and in policy circles, but it has not yet been systematically included in the innovation process of companies. We discuss how companies can integrate RRI into their corporate social responsibility (CSR) policies and business strategy. To this end, we developed a conceptual model that links a company's RRI strategy to its context, and that helps to translate the RRI strategy into activities that result in RRI outcomes. We also propose a process for developing company-specific RRI key performance indicators (KPIs) that can support companies to measure RRI outcomes.

Keywords: responsible research and innovation (RRI); corporate social responsibility (CSR); business strategy; key performance indicators (KPIs); ethics; acceptance; pilot; industry; code of conduct; innovation

1. Introduction

In the past few decades, many companies have assumed social responsibilities beyond what is legally required of them. This has taken many forms, from local charitable activities to the branding of new socially responsible products and services. In this article, we are particularly interested in how companies integrate social and moral considerations and values into the innovation process of new products and services. In particular, we are interested in how companies can develop strategies and employ tools to make their innovation processes more responsible. We study this in the PRISMA project, which pilots responsible innovation strategies in eight companies. In order to be able to compare the development of responsible research and innovation (RRI) strategies and the deployment of RRI tools in these eight pilots, we developed a conceptual framework for responsible innovation in industry. We present the framework in this article.

The term responsible innovation, or responsible research and innovation, has come into vogue in the past few years, not least because the European Union (EU) has made RRI a cross-cutting theme in its Horizon 2020 program. The Rome Declaration on Responsible Research and Innovation in Europe defines RRI as an "on-going process of aligning research and innovation to the values, needs and expectations of society" [1]. RRI has also been defined as a "transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to

the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products" [2]. It requires attention to be paid to the process of innovation, which should meet such criteria as being anticipatory, reflective, deliberative, and responsive [3]. It also requires that the products or outcomes of innovation meet deeply held moral values [4].

While the RRI concept is well known in the EU policy arena, many companies have not yet heard about it, and are unaware of the scientific and governance discourse that has developed around it. Some studies in this special issue therefore address what incentives are required for companies to take RRI on board [5]. However, companies themselves feel that the RRI discourse is not always sufficiently attuned to them [6]. Moreover, many of them already undertake activities that resonate with RRI, albeit using different terms, like sustainable innovation, participatory design, open innovation, stakeholder dialogues, scenario development, circular economy, and risk assessment [7]. RRI is also congruent with what has become known as corporate social responsibility (CSR), which is a more established concept in business and industry. Valuable lessons can be learned by comparing all these diverse, often ad hoc, activities through the lens of RRI.

To make such comparisons possible, we developed a conceptual model for RRI in companies. This model builds on the state of the art in RRI and CSR, and also extends it by more systematically relating the RRI strategy and activities of a company to its context and to RRI outcomes. We present this model in Section 3. First, though, we describe the relevant theoretical background and discuss corporate social responsibility (CSR), its relation to RRI, and the need to pilot RRI in industry.

2. Theoretical Background

2.1. Corporate Social Responsibility (CSR)

The European Commission has defined CSR as "the responsibility of enterprises for their impacts on society" [8]. Insofar as enterprises have a large impact on society through the innovative products they bring to the market, RRI certainly comes under the broad umbrella of CSR. Over the years, CSR has become a well-established term in the business world, and more and more companies are committing themselves to CSR. For example, currently the number of enterprises (larger companies as well as small and medium enterprises) that have signed up to the 10 CSR principles of the United Nations Global Compact is currently 9733 companies [9]. The ninth principle of the UN Global Compact relates to technological development and calls for encouraging "the development and diffusion of environmentally friendly technologies" [10], which, from the viewpoint of RRI, may be broadened to include responsible technologies.

However, there is also critique of CSR, as some companies use it merely for symbolic or instrumental reasons, rather than substantive ones [11,12]. This critique may also apply to RRI. As Owen et al. write: "If RRI risks becoming a new label for business-as-usual, it also risks being used instrumentally, to smooth the path of innovation in society, and/or to achieve precommitted policies" [13] (p. 757). Thus, as in CSR, the motivations behind RRI can influence the accountability of the activities one undertakes and the outcomes one aims for and achieves, ranging from merely wanting to gain acceptance to actually embedding various forms of knowledge (expert, lay people's, stakeholders') throughout the development or innovation process, and collectively addressing societal problems and needs.

A survey among UK nanotechnology companies suggests that in their CSR policies, most of these companies "focus on goals of regulatory compliance and supporting commercialization, rather than on wider issues regarding the need to seek from stakeholders some form of informed consent to bear risks and uncertainties, or regarding the need to shape innovation in accordance with agreed-upon societal priorities" [14] (p. 547). A CSR strategy that is developed to include RRI aspects would require companies to move beyond such reactive, defensive, or accommodative policies to deal with social, environmental, and ethical issues, and adopt a more proactive posture. This would imply that they actively anticipate the issues that may affect their processes, products, or services, which groups

of people they may impact on or what environmental footprint they will have, that they assume responsibility for this, and that they aim not only, conservatively, at doing no harm to society, but also, progressively, at doing good (cf. [15]).

Although several companies, mainly large ones, have assumed responsibility for many parts of their operations through CSR, they have only done so to a limited extent for their R&D and innovation processes. Figure 1 shows the various phases of the product development and life cycle. Current CSR efforts that relate to this product development and life cycle usually focus on later phases, for example the manufacture, use, and disposal of products. RRI emphasizes the earlier phases of R&D, innovation, and design when addressing responsibility in product development and its life cycle phases. This is important for industry, too, because the outcome of the innovation, namely its limitations and its effects on users and wider society, depends on decisions made in these earlier phases of the life cycle. Changing the product at later phases of the product development is likely to induce higher development costs, and delay the innovation process and eventual market entry. It is therefore important to think about what social challenges and what values need to be included during the early product development phases, which can lead to the development of products that better meet such challenges and values, and are, as a result, socially, environmentally, and financially more successful. Hence, RRI strategies can help companies reach the well-known triple bottom line of people, planet, and profit from the very beginning of innovation activities [16].

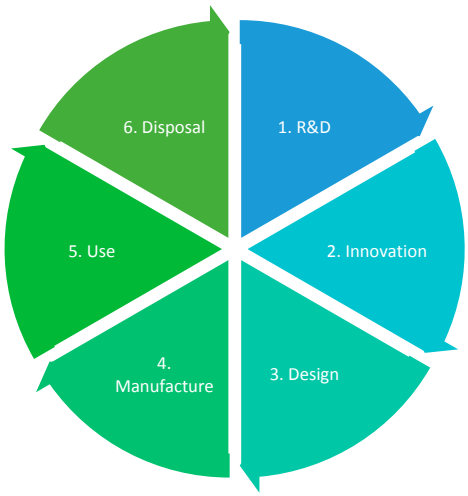

Figure 1. Product development and life cycle phases.

At the same time, the foreseeability of social and ethical impacts increases as the life cycle proceeds. Therefore, some benefits, values, risks, and concerns are hard to foresee in the early phases. This poses the well-known Collingridge dilemma: In the early phases of technological development and innovation, technology is still malleable and the costs of change are limited, but social effects are hard to foresee; at the later stages, the social effects are better known, but the technology may be so well embedded that it is hard to change or can be changed only at high costs [17].

What is needed to resolve this dilemma is a balance between foreseeability and the cost of change. This brings RRI into the equation. The goal of developing an RRI strategy is to identify early in the product development and life cycle process of new innovations, what potential social effects are associated with the invention and how to accommodate these before the technology's embedding is irreversible or can only be undone at high costs and with delays in market launch.

2.2. Responsible Research and Innovation for Companies

The aim of a CSR strategy is to ensure that business operations are principle-driven and ethically sound both at home and abroad, expressing genuine regard and care for the interests and needs of

all legitimate stakeholders of the firm. Responsible research and innovation is more specific and concerns the early phases of technology development. RRI may be defined as an "on-going process of aligning research and innovation to the values, needs and expectations of society" [1]. A central idea is that social and ethical issues brought about by new innovations are anticipated and integrated in the innovation and design process from the very start.

RRI may have clear advantages for companies and contribute to competitive advantage [18–20]. It helps them to better know and understand their clients and stakeholders, and thus to identify their needs and concerns and translate these into the development of products that will be better accepted and more socially acceptable. This process creates more value for both users and society. Furthermore, because this process encourages timely consideration of potential issues that products may raise, it sidesteps or mitigates scenarios in which companies face public criticism. More generally, it may help to build a relation of trust with society, which may make companies less sensitive to resistance or protest [21]. In addition, it may help them to show governments that they take their responsibility seriously, and thus be allowed to make voluntary agreements rather than being regulated. As indicated above, this may also result in mere window-dressing if companies do not at the same time seriously take on board a proactive responsibility to develop more responsible technologies.

Porter and Kramer argue that CSR is often disconnected from corporate strategy [22,23]. Some companies undertake CSR activities in areas that are not central to their core business activities. For instance, a chemical company that supports local social initiatives but does not invest in making its production process more sustainable. Moreover, Porter and Kramer maintain that a lot of the debate about the responsibility of companies focuses on the tension between business and society, rather than on their interdependence. They argue that a broader perspective shows that companies need society as a nurturing environment, for example for the acceptance of their products or to find good personnel, while in many cases society needs companies to achieve certain goods. Therefore, both CSR and RRI should aim at creating shared value together with social actors [22].

In terms of developing an RRI strategy, this means that companies should establish in which areas they can have an added value for society. These areas vary depending on the company; for example, how a company can add value depends on the technological area, the type of market, and the company's resources and capabilities. It also means that RRI strategies should be closely attuned to the more general corporate business strategy of the company. Companies should be selective in their RRI strategy and look for those areas where they can add value to society while making a profit. Such RRI strategies are typically focused not only on avoiding harm, but also on doing good.

An example of how an RRI strategy may be closely attuned to corporate strategy and may create competitive advantage for the company as well as added value for society is the Fairphone company [24]. Fairphone started out as a movement for fairer electronics, but in 2013 it became an independent company. Its aim is to have a "positive impact across the value chain in mining, design, manufacturing, and life cycle, while expanding the market for products that put ethical values first" [24]. The company developed a mobile phone using "conflict-free" minerals and a modular design so that parts can be repaired and replaced.

The Fairphone case is obviously a quite specific one and not an example that can be followed by every company. It nevertheless shows that RRI and CSR can be closely aligned with corporate strategy to make a business. How best to do this may differ from sector to sector, or even from company to company. One of the things that is needed to further enable this are positive examples and engaging narratives that show how to put RRI into practice in a company context. Within the PRISMA project we aim to contribute to this by means of eight pilots with RRI in companies.

2.3. The Need to Pilot RRI: The PRISMA Project

Although growing attention is being paid to RRI in corporate settings, the actual experience is still very limited. Only very few companies have developed a deliberate and explicit RRI strategy. There is therefore a need for experience with, and examples of implementing, RRI in companies. This requires

experimenting and piloting with RRI in companies, as we do in the PRISMA project and as is done in a number of other European projects, for example Compass and Smart-map [25–27]. It is fair to assume that whereas some of these experiments and pilots will be successful, others will turn out to be relative failures. From a broader perspective, failure may be as important as success, as it may point out crucial factors for making RRI a success in a business context. We often learn more from failure than from success [28,29].

The PRISMA project specifically focuses on the R&D and innovation phase of transformative technologies. Transformative technologies have the potential to alter the very societal values that companies engaged in research and innovation contribute to, since they might transform existing modes of production, communication, and social organization, and might change companies' relations with the users of their products, with suppliers, or with other stakeholders. Such transformative technologies can make important if not indispensable contributions to a sustainable society and to the economic competitiveness of Europe. Examples are synthetic biology and its impact on the bio-economy by reorganizing the chemical industry, and the Internet of Things, which can transform everything from the personalization of health care and energy use, to data analytics for evidenced-based investment in transportation, energy distribution, and manufacturing processes. Table 1 presents the PRISMA pilot projects and the key technology sectors, pilot types, and locations. We selected these categories for comparisons since we believe that the implementation of RRI strategies depends on the type of technology, the availability of resources within companies, and their prior experience of conducting innovation.

Table 1. Technologies and pilots.

Company Case No.	Technology Sector	Pilot Type	Location
1	Nanotechnology	SME	Italy
2		SME	Italy
3	Synthetic Biology	Start-up	UK
4		SME	US
5	Automated cars/drone	Start-up	UK
6		SME	Netherlands
7	Internet of Things	Start-up	UK
8		SME	Netherlands

Note: Pilots take place between April 2017 and October 2018.

In the pilots, we help the companies to articulate an RRI strategy, make the business case for RRI, and embed RRI principles and practices in their organization and workflow. Each pilot focuses on one or more specific products or transformative technologies developed by the company. The pilots are aimed at evaluating the applicability of a number of RRI approaches and tools to the company and to the development process of the product or technology that is central to the pilot.

3. Developing a Conceptual Model for RRI in Industry

3.1. State of the Art

Responsible research and innovation has been discussed among policymakers and academics mainly as a new paradigm for innovation governance with a view to the inclusion of ethical values [2]. In these discussions, four main dimensions of RRI have surfaced, namely anticipation, inclusiveness, reflexivity, and responsiveness [3,30]. In relation to companies, these dimensions can be described as follows:

- *Anticipation*: Are possible ways of using the technology and possible impacts (risks and benefits) of the technology anticipated by the company and integrated into the research and innovation process and other relevant business processes in the company?

- *Inclusiveness*: Does the company engage in dialogues with relevant stakeholders, and are insights from such dialogues integrated into the research and innovation process and other relevant business processes in the company?
- *Reflexivity*: Does the company reflect on its impacts on society, its purposes, motivations, and values, and are the purposes and values integrated into the research and innovation process and other relevant business processes in the company?
- *Responsiveness*: This has two aspects: Is the research and innovation process (1) responsive to social needs and (2) organized such that it can respond to new insights and developments (including surprises)?

Most of the discussions are at the policy or the academic level and are aimed at supporting and stimulating more research programs to contribute to the wellbeing of society, and few studies have investigated how RRI is implemented in the private sector [31,32]. Several studies have built on the CSR literature and investigated responsible leadership among CEOs [32]. According to these studies, the business objective shifts to optimizing the economic, social, and environmental values in order to create sustainable value for business and society. The main challenge that managers face is making long-term projections, which are more difficult to make than short-term projections due to increasing uncertainty, and thus tend to be less accurate [33]. In order to reduce the uncertainty, various methods and models have been developed, in particular in the field of constructive technology assessment (CTA). In CTA, social issues are included in the technology development and design practices in the early phase of innovation development [34]. Such models are based on feedback loops that inform the actual construction of new technologies. Similarly, in foresight and future studies, researchers have used methods to forecast the various types of impacts that technology will have on future societies. These methods help to signal early warnings and build scenarios in order to accommodate the direction in which society evolves [35]. In general, industry has developed methods, based on CSR, to investigate the effects of new technology on society and to develop strategies to ensure that the technology has a greater likelihood of acceptance once brought to the market. Studies have found evidence that when managers attend to environmental and social practices, the trust that people have in the firm increases [36,37]. The inclusion of stakeholders in the strategic decision making concerning the development of new activities, induces followers to consider the leaders of such firms inspirational [38].

While these studies have provided a variety of methods, RRI requires a method that includes more reciprocity between the innovating firm and the wider stakeholder arena, in particular from the initial phase of the product development and life cycle phases. Drawing on the input–output model of von Schomberg [2], researchers have developed a seven-stage process of responsible innovation [16], whereas others have developed measurement tools to gauge the various dimensions of RRI [7]. These studies, however, pay little attention to the complex external environment in which the innovation takes place. The assumption of these studies is that the external information is transparent and can be obtained by a thorough analysis of external stakeholders. However, we emphasize the non-linear development of innovation and that its direction is often difficult to predict. As a result, the inclusion of relevant stakeholders becomes more difficult and may vary over time, and as such the context has a major impact on the usefulness of RRI activities and strategies. We therefore need a conceptual model for RRI in industry that places the company in its environment.

3.2. A Conceptual Model for RRI in Industry

We now present a conceptual framework for RRI in industry. Central to this model is the RRI strategy of a company. This strategy is a reflection of the specific context in which the company operates. This RRI strategy is translated into certain RRI activities and the employment of certain RRI tools. These in turn will result in certain RRI outcomes, for which RRI key performance indicators (KPIs) can be developed so that company managers can monitor outcomes and progress.

The framework is shown in Figure 2. It distinguishes four main elements, namely context, the strategic level, the operational level, and RRI outcomes. In doing so, and in further elaborating these elements, it builds on the above-described state of the art, as well as moves beyond the state of the art in three specific ways:

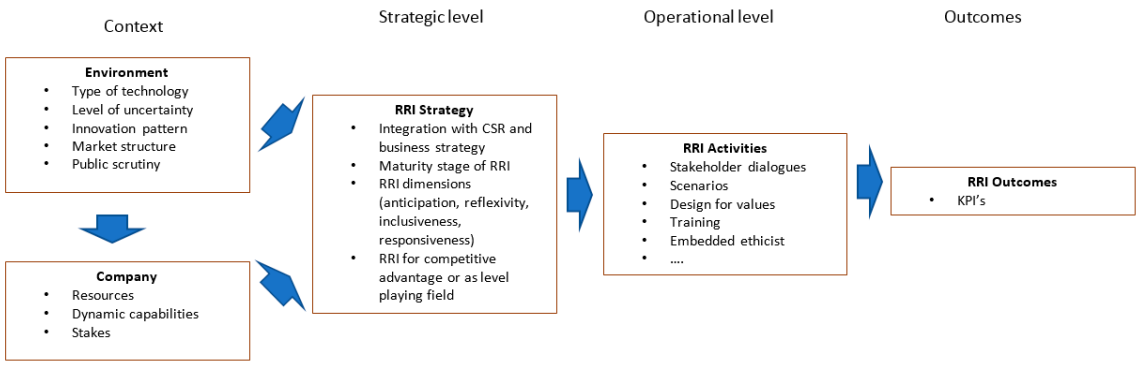

Figure 2. A conceptual model for RRI in industry.

First, it places the RRI strategy and activities of a company in the broader context in which it operates, whereas most models focus on RRI activities and pay less or no attention to context. However, the context should be taken into account, because the strategy a company can follow depends on, for example, its resources and the type of market in which it operates, both of which are contextual variables.

Second, it makes a distinction between the strategic and the operational level of RRI. This distinction is particularly important to prevent moving too quickly to the formulation of RRI activities without formulating an RRI strategy. As stressed in Section 2.2, the RRI activities of a company in the ideal case follow from a deliberate RRI strategy that aligns with the more general strategy of the company, and that involves deliberate decisions concerning where and how the company intends to add value to society.

Third, it explicitly pays attention to RRI outcomes and the possibility to monitor these through RRI KPIs. Toward the end of this paper, we describe the process through which companies can develop a more specific set of RRI KPIs for their RRI strategy and activities.

Below, we describe the various parts of the model in more detail. It should be noted that the components included in the boxes are exploratory rather than exhaustive. This means that the model can be further refined and extended. It nevertheless offers a basic structure that helps one to think more systematically about RRI in a company context.

3.2.1. Context

To define the context in which a company operates, we first define a number of contextual variables, distinguishing between variables that relate to the company and those that relate to the environment. For both, we propose a number of main variables on the basis of the relevant literature. However, as said, these variables should not be seen as exhaustive but may need to be extended or refined in further developing the model.

Environment

(1) Type of Technology

Different types of technology raise different types of RRI issues and may therefore require different types of RRI strategies. Here, we briefly discuss some of the issues that are often associated with the four main technologies in the PRISMA project (i.e., nanotechnology, synthetic biology, self-driving cars and drones, and the Internet of Things).

Nanotechnology raises concerns about health and environmental risks—risks that are still largely uncertain or contested and that may only become less uncertain in the long term [39]. Beyond that, nanotechnology raises concerns and provides possible benefits in terms of sustainability (e.g., environmental remediation) and human health (nanomedicine), human enhancement, dual use, and issues of privacy and civil liberties [40–42].

Synthetic biology also raises issues of risk and safety, for example in the case of an unintended release of modified organisms into the environment [43]. A main concern is also biosecurity, namely the intentional misuse of synthetic biology to create, for example, a deadly virus; another issue that is quite specific to synthetic biology is its possible effect on biodiversity. In addition, it raises a number of larger issues like "playing god," or tinkering with nature, which, according to some, is unwarranted, and it has been criticized for widening the gap between rich and poor countries, for example through issues of intellectual property rights [44,45]. Unlike some of the other transformative technologies described here, synthetic biology is already the topic of a highly polarized debate, which poses a challenge of its own.

Whereas nanotechnology and synthetic biology raise different but overlapping RRI issues, drones and self-driving cars raise other specific issues. One issue specific to these technologies is human control and responsibility, fueled by a fear that these technologies will diminish human control and lead to undesirable consequences for which nobody is responsible, see e.g., [46]. Also issues relating to privacy, data ownership, surveillance, and spatial and city planning arise here. In the case of drones, the fear of diminished human control has led to discussions about humans in or on the loop and the proposal of notions like "meaningful human control" [47,48], which might also be useful in the case of self-driving cars. In the case of self-driving cars, it has led to discussions on how these cars should be programmed to behave in the event of an accident, e.g., [49]. In addition, these technologies also raise more traditional safety and risk issues, as well as issues of trust and of compliance with existing regulatory frameworks.

The Internet of Things directly raises issues of privacy, surveillance, and civil liberties. Obviously, it also raises issues of security and reliability. In as far as it is connected with artificial intelligence and decision algorithms, also accountability, transparency, and democracy are at stake.

As this brief overview illustrates, RRI issues may be quite different for different technologies. Moreover, issues will also depend on the specific application, as becomes clear in our PRISMA pilots. Another thing is that a company may change its technology area. For example, one of the PRISMA pilots concerns a producer of cleaning agents that has now embarked on the Internet of Things as an area for further innovation. Typically, at a company level, technological applications may raise certain concerns (like the ones listed above), but also may add value for society. It is important to focus both on the expected social benefits and on the possible issues of concern in a company RRI strategy.

(2) Market Structure

Market structure includes such variables as the size distribution of firms, entry conditions for new firms, and the degree of differentiation between products. Market structure affects the way companies can gain a competitive advantage over competing firms and may also affect RRI strategies. For example, in monopolistic or oligopolistic markets, which are difficult for new firms to enter, companies may have more latitude to spend resources on RRI without losing market share. At the same time, this might mean that there is little incentive to develop RRI strategies and to add social value.

Opportunities for RRI are also different in markets where there is strong price competition compared to markets in which competition focuses more on the quality of products. If there is competition over quality rather than price, RRI strategies may be a means to develop and market qualitatively different products and thus gain a competitive advantage, while if there is only price competition it may be more difficult for an individual company to spend resources on RRI. Policies to develop a level playing field for a whole sector can mitigate the differences in incentives, and with respect to RRI it can prevent companies from gaining a competitive advantage by being less responsible.

(3) Innovation Patterns

The notion of innovation pattern refers to the pattern by which innovations usually come about in a certain sector. Pavitt [50] distinguishes different types of innovating firms. On the basis of this, van de Poel [51] distinguishes four basic types of innovation patterns: supplier-dependent, user-driven, mission-oriented, and R&D-dependent. These innovations patterns are characterized by different dependency relations between innovating firms, users, suppliers, research institutes, and government. The different innovation patterns offer different opportunities for and put different constraints on transforming existing patterns of technological development [51], and therefore offer different opportunities for and put different constraints on responsible innovation. Consequently, companies' RRI strategies will depend on the innovation pattern in a certain sector.

(4) Level of Uncertainty

Different sectors are characterized by different levels of uncertainty. Apart from the uncertainty that is inherent in a market economy, technology is also a main source of uncertainty, in particular in the case of potentially transformative technologies. Not only are the social impacts of technology uncertain, but technologies may also affect market structures in unknown ways; and how the public will react to new technological products is often also uncertain.

It is important to be aware that in many cases there are not just differences in the level or degree of uncertainty, but also different types of uncertainty. Here, we propose the following distinctions (cf. [52–54]):

- Statistical uncertainty: We speak of statistical uncertainty if we know what might happen (the scenarios) and we know the probability of each scenario. We do not know with certainty, however, which scenario will happen as we only know the likelihood of each scenario.
- Scenario uncertainty: We speak about scenario uncertainty if we know the scenarios that might occur, but cannot meaningfully attach probabilities to each one. In the case of scenario uncertainty, we thus know the possible outcomes but not their probabilities.
- Recognized ignorance: In the case of recognized ignorance, there are certain things we do not know (e.g., we do not know all possible scenarios) and we are aware (i.e., we know) that we do not know these things. This is also sometimes described as "known unknowns."
- Unrecognized ignorance: In the case of unrecognized ignorance, we do not know certain things but we are unaware of our ignorance. We might even believe that we know something while we actually do not. This category is also known as "unknown unknowns."
- Indeterminacy: Situations are indeterminate if the causal chains potentially leading to a certain outcome are open and depend on the actions of some relevant actor. (In some cases, it might be possible to predict or model human behavior reliably, so that despite indeterminacy, risks can be established.).
- Normative ambiguity: Refers to disagreement about the relevant moral values and their relative importance.

Dealing with uncertainty requires a deliberate and strategic decision on how to combine the four dimensions of responsible innovation (anticipation, inclusiveness, reflexivity, and responsiveness). In general, the higher the level of uncertainty (according to the above taxonomy), the more difficult it is to fully anticipate even possible futures, and thus the more important the responsiveness dimension of responsible innovation becomes. Moreover, particularly cases of normative ambiguity might require that attention be paid to inclusiveness, to ensure that different views on what is socially desirable are included.

(5) Public Scrutiny

What RRI strategy a company can and will develop will also depend on the level (and the kind of) public scrutiny. Perez-Batres, Doh, Miller, and Pisani [11] researched what type of voluntary

self-regulatory codes companies are likely to adopt, distinguishing between more symbolic and more substantive codes. They found that, for example, what codes companies adopt depends on stakeholder pressure and company resources: The larger the number of stakeholder appraisals, the more likely it is that a company will adopt a substantive rather than a merely symbolic code. In addition, the level of public scrutiny of a sector as a whole appears to have an effect. Companies are aware that they may, in the eyes of the public or stakeholders, be guilty by association with other firms in their sector. This in turn may trigger the adoption of substantive self-regulatory codes.

An example is Responsible Care, a voluntary self-regulatory code for the chemical industry [55–57] that has been adopted by an increasing number of chemical companies since the 1980s. Responsible Care is aimed at improving the environmental and safety performance of the chemical industry, also in innovation; it is therefore an early example of *de facto* RRI. One of the main reasons to develop Responsible Care was an awareness that the public image of individual chemical companies depends not on the performance of that company, but on the sector as a whole [57]. Responsible Care may thus be seen as an attempt to create a level playing field that improves the safety and environmental performance of the chemical industry as well as its public image. At the same time, it has been criticized as an attempt to postpone government regulation [56]. One of the lessons learned from Responsible Care is that it is important to have some form of external auditing to check whether companies indeed live up to voluntary self-regulatory codes [55,57].

The above suggests that high levels of public scrutiny trigger the adoption of substantive self-regulatory codes at the sector level. An interesting current example is synthetic biology, which has also come under intense public scrutiny. Like chemical companies at the end of last century, synthetic biology companies are likely to be judged also by the performance of other synthetic biology companies. Some of these companies have already embraced responsible innovation as a way to signal to the public that they take their responsibility seriously [58].

Company

The company characteristics are reflected in the resources, capabilities, and the stakes that companies have in technology. These are heterogeneous among companies and may be a reason why the strategies to implement RRI and the eventual outcomes of those strategies may differ from one company to another.

(1) Resources

The resources of a company are the various types of capital, for example financial, human, or social capital. The resources reflect all the assets that a company has to carry out the corporate activities. Some resources, such as knowledge and networks of partners and stakeholders, are more relevant in developing an RRI strategy. Also the extent to which these resources are available is important to the success of implementing an RRI strategy, because employing some of the RRI dimensions extensively might be quite resource-intensive. This seems particularly true for the RRI dimensions of anticipation and inclusiveness, while the RRI dimensions of reflexivity and responsiveness might require certain commitments from a company but might be less resource-intensive. With regards to RRI, the core values of a company, its stakeholder and public dialogues, and its code of conduct are some of the resources that are often mentioned.

(2) Dynamic Capabilities

While resources are the assets that a company has to carry out certain activities, the skills, knowledge, and processes of a company reflect the capabilities to integrate and combine these resources into activities and procedures. Dynamic capabilities are a specific subset of capabilities that enable a company to be responsive to new and sometimes unexpected developments. In the literature, concepts like “absorptive capacity” and “dynamic capabilities” have been proposed to describe the ability of companies to take in and act on new knowledge and information. Absorptive capacity, for example,

has been defined as the "ability to recognize the value of new information, assimilate it, and apply it . . . " [59] (p. 128), and dynamic capability as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments." [60] (p. 516). It has been argued that dynamic capabilities are particularly important for firms in environments that not only pose risks, but also involve uncertainty at higher levels or of other types [61]. The extent to which a company has developed dynamic capabilities, has an influence on how well it is equipped to act on the RRI dimensions of responsiveness and anticipation.

(3) Stakes

The stakes that companies have in a technology may be quite different. Large companies may have a large stake in an existing technology, and may have large sunk costs and investments, for example in terms of machinery, personnel with certain skills, market share, etc. In such cases, in which the stakes are high, anticipation will often be an attractive and worthwhile strategy for a company. However, in cases where the stakes are lower, anticipation may not be worth the costs, and responsiveness may be a better strategy to rely on.

3.2.2. Strategic Level

The strategic level is the primary level at which a company needs to make choices with respect to how it wants to achieve RRI. The choices will reflect the context in which the company operates, as we described above, but usually there is still ample room for the company management to make certain strategic choices given the context in which it operates. These choices will result in what we call an RRI strategy, the main elements of which we describe below.

RRI Strategy

The term RRI strategy refers to a company's aims and ambitions in relation to implementing RRI in all its activities, and the strategy it follows with respect to RRI. As we have stressed, one important aspect here is the degree to which the RRI strategy is integrated with the CSR strategy and the more general business strategy for achieving a competitive advantage.

Yaghmaei [62] distinguishes five successive stages of RRI implementation that can be used to characterize the level of ambition of a company's RRI strategy (see also [63], who distinguish somewhat different stages or (what they call) "maturity levels"). These five stages are:

- *Defensive*: The company only reacts if it is criticized on RRI aspects by its environment.
- *Compliance*: The company actively meets legal requirements with respect to RRI, but no more than that.
- *Managerial*: RRI has been taken up in several activities of the company.
- *Strategic*: RRI is a full and coherent part of the general business strategy of the company.
- *Civil*: The company itself becomes a change agent that promotes RRI principles also for other companies and actors.

In developing an RRI strategy, companies need to take into account the four process dimensions of RRI distinguished by Stilgoe et al. [3,30], namely anticipation, inclusiveness, reflexivity, and responsiveness. A full-blown RRI strategy will encompass at least these four dimensions. However, the exact mix of dimensions and which dimensions receive the most attention may be different for different technologies and different companies, as we have suggested above.

Another aspect in which RRI strategies may differ is whether they are aimed at achieving a competitive advantage over other companies, or at creating a level playing field that applies equally to all companies in a certain sector. In the first case, companies may use their RRI strategy to differentiate themselves from their competitors; they may, for example, differentiate themselves by being "green," "fair," or "sustainable." In the latter case, companies aim for certain minimal RRI standards that all companies and their products in a sector have to meet, so that companies cannot gain competitive

advantage by less responsible practices. As we have seen, the strategies that are most suitable and that companies are most likely to follow, will at least partly depend on such environmental variables as market structure and the degree of public scrutiny.

3.2.3. Operational Level

The operational level refers to the concrete RRI activities a company undertakes and the RRI tools it employs. This level has been the focus in most current RRI models, like the general RRI process model of Stilgoe et al. [3,30], which emphasizes the four process dimensions of anticipation, inclusiveness, reflexivity, and responsiveness, and the more recent model for RRI in industry of Lubberink et al. [7], which stresses the same four dimensions and also pays attention to knowledge management. Since this level has been extensively described in the existing literature, we limit ourselves here to a brief description and refer for further details to the relevant literature. More elaborate overviews of tools for RRI can be found in [3,7,30,64].

RRI Activities

Table 2 gives an overview of some of the relevant tools and approaches. Some of the tools below, however, can contribute to multiple RRI dimensions simultaneously.

Table 2. RRI tools.

RRI Dimension	Possible Tools
Anticipation	Scenario building Scenario workshops Foresight studies Technology assessment Life cycle assessment
Inclusiveness	Stakeholder mapping Stakeholder engagement strategies Stakeholder dialogues Public dialogues User-centered design
Reflexivity	Codes of conduct Core values Embedded ethicists
Responsiveness to values and needs	Value sensitive design Stage-gate approaches Sustainable design
Responsiveness to new developments	Monitoring Gradual scaling-up Adaptive risk management Living labs and social experimentation Flexible and adaptive design

For the RRI dimension of anticipation, companies can use tools like scenario building, technology foresight, and assessment. The dimension of inclusiveness deals with the dialogue a company has with stakeholders and end-users. In doing so, companies can rely on user-centered design techniques and user groups to learn the exact needs and concerns of users and stakeholders. Reflexivity represents the learning orientation of a company toward reflecting on a wider set of values and integrating them into the innovation process. The role of ethicists is key in this dimension to include various values and understand the impact these may have on the innovation outcome. The responsiveness is the extent to which the company has a systematic approach to identifying how users and stakeholders respond to the innovation process and collecting feedback from them in order to adapt the innovation to the changes

and new requirements. Continuous monitoring, value sensitive design, and the use of living labs are examples of methods and techniques that companies can adopt to implement this dimension of RRI.

3.2.4. RRI Outcomes

The RRI outcomes are probably best expressed in terms of social impact and the societal embedding of new products and services. However, these lie in the future, and even when they have materialized it may be difficult to causally attribute these to the RRI strategies of individual companies. We therefore take a different approach here and propose a set of RRI KPIs that company managers can monitor to assess RRI progress.

RRI Key Performance Indicators (KPIs)

Within the field of innovation management, we found literature that explicitly highlights KPIs for ongoing R&D processes, from a management/organizational perspective, from a practical/working floor perspective, and from the perspective of the outcomes of such processes, all from different fields of innovation, including empirical papers, theoretical studies, and literature reviews, see [65–69]. Within the field of RRI, key performance criteria are much less abundant in peer-reviewed, academic literature, but see [70]. We therefore resorted to reports on EU-funded projects and by policymakers [71–75].

From these papers and reports we distilled roughly 250 indicators. We reduced this number to 92 by removing redundancies and irrelevant indicators, and we grouped these indicators into categories (see Table 3). We then reformulated all these indicators into statements about R&D processes that people might agree or disagree with to a certain extent, in preparation for the later scoring of these elements on a 7-point Likert scale. An example of a statement under gender equality is "The integration of gender dimensions is actively integrated in research and innovation outcomes," and under public and ethical issues "We document best practices about ethical acceptability for this type of project during its development." We then clustered the remaining indicators into themes relating to organizational R&D aspects and specific RRI criteria, on both the product and the process level of innovation.

Table 3. Categories of RRI KPIs.

Organizational	
	Internal
	Technology
	Sales/marketing
	Planning/management.
	Resources
	Collaboration/communication
	External
	Market
	Customer/end-user
RRI	
	Diversity & Inclusion
	Gender equality
	Engagement
	Anticipation and reflection
	Legislative landscape
	Assessment
	Public and ethical issues
	Responsiveness and adaptive change
	Openness and transparency
	Intellectual property and confidentiality
	Open access
	Environmental Sustainability
	Social Sustainability

In order to help derive our organizational and RRI indicators for companies, companies identified relevant indicators within their projects from 49 organizational and 43 RRI indicators. Companies might show a variation in their selection of relevant indicators under organizational indicators and RRI counterparts. These variations probably reflect differences in the stage of implementation of RRI within companies.

Considering that not all our identified statements are relevant for each company, we developed a method to identify and select elements that play a role in the individual pilot projects. Table 4 provides an overview of how we envision this to work in practice.

Table 4. Methodological steps for developing RRI KPIs.

Step	Description	Use
1	Literature review	
1a	Review academic literature from innovation management	Find R&D-relevant innovation performance criteria
1b	Reports on RRI criteria	Find RRI criteria to add to performance criteria
1c	Develop RRI performance indicators and clusters	Integrate literature findings to compose general criteria list
2	Workshops for individual companies	
2a	Companies categorize relevant items (yes, maybe, no)	Determine which RRI and innovation elements are relevant
2b	Combine elements into clusters of indicators	Determine which integrated aspects matter to the companies
2c	Score relevance of individual items	Determine how important companies find the clusters
3	Tool development	
3a	Adapt digital tool in online environment	Enable companies to enter data in personalized digital tool
3b	Initial academic analysis of workshop results	Determine which elements were always/never selected, identify cluster relations between companies
4	Use tool in eight pilot organizations	
4a	First measurement of projects in companies	T-0 measurement: starting situation for companies
4b	Mid-term review(s)	T-1-n measurement: find out how projects developed
4c	Final measurement	T-n measurement: assess how projects turned out
5	Meta-analysis	
5a	Comparison within organizations	Determine whether RRI projects have similar or dissimilar development pattern vs. non-RRI projects
5b	Comparison between organizations	Investigate patterns of RRI performance development between organizations

The tool basically asks for indicators to be entered, clustered into key performance indicators, and given a score that determines the mathematical relative value of each of the clusters in relation to each other. We aim to determine initial similarities and differences between companies and between different projects within a company. The plan is to identify to what extent companies recognize the same individual indicators within these clusters. We also compare the clusters that the companies identify, to see whether they recognize the same clusters of indicators. Furthermore, the kinds of aspects that are considered important now, need not be relevant over time. Therefore, our approach can be repeated over time, to see whether some elements that were missed earlier can still be included, or whether items that are no longer relevant can be excluded for a certain company.

4. Conclusions

The implementation of responsible research and innovation (RRI) in industry is still in its infancy. Although some companies already undertake de facto RRI activities, this usually does not amount to a systematic integration of RRI in the company. What is needed is not just more tools for RRI, but a more integral view of RRI in a business context, and of what this can yield in terms of societal, environmental, and financial benefits. We have argued that this first of all requires a more comprehensive view in which RRI is connected to a company's business strategy and its corporate social responsibility (CSR) strategy and activities. This requires companies to think about where they can add value to society and to make deliberate choices rather than necessarily undertaking the full spectrum of RRI activities.

To this end, we have proposed a conceptual model for a company's RRI strategy. We believe that our model has a number of distinct advantages. First, it offers companies a framework to devise a strategy to implement RRI in a way that can do justice to the specific context in which the company

operates, by taking into account environmental and company variables. Second, it can be used as a descriptive tool to describe both successful and less successful examples of RRI strategies, and it may eventually develop into an explanatory framework that explains why companies adopt certain RRI strategies and the relative success of such strategies.

An important component of our conceptual model is the assessment of RRI outcomes through the definition of a number of RRI key performance indicators (KPIs). We are aware that assessing or even measuring RRI outcomes raises a number of issues that are beyond the scope of this paper. One issue is who is to do the assessment. Although it is good if companies apply tools for self-assessment, from a societal point of view, some form of independent assessment is required. This can be implemented in several ways, including external auditing, independent certification, or government oversight, each of which may have its advantages and drawbacks. Second, one should be aware that assessing or measuring RRI in a certain way will induce behavior changes. While this is not bad in itself, the consequence might be that there is too much focus on meeting some measurable performance criteria, rather than on addressing the underlying societal or environmental problems.

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